Risk factors for valgus subsidence in uncemented medial unicompartimental knee arthroplasty

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Aims

Valgus subsidence of uncemented tibial components following medial unicompartmental knee arthroplasty (UKA) poses a challenge in the early postoperative phase, necessitating a comprehensive understanding of its prevalence, risk factors, and impact on patient outcomes.

Methods

This prospective multicentre study analyzed 97 knees from 90 patients undergoing UKA across four participating hospitals. A standardized surgical technique was employed uniformly by all participating surgeons. Postoperative evaluations were conducted preoperatively, and one day, four weeks, three months, and one year postoperative, encompassing weightbearing radiographs, bone mineral density assessments, and clinical outcome reports using the Forgotten Joint Score and Oxford Knee Score. Statistical analyses, including non-parametric correlation analysis using the Kendall correlation coefficient and Mann-Whitney U test, were performed to explore associations between subsidence and various patient-related or radiological parameters.

Results

A total of eight patients showed more than 2° valgus subsidence (8.2%), higher than previously reported rates. There were significant correlations between subsidence and higher preoperative varus alignment of the tibia, larger adaptation of the preoperative varus to a postoperative neutral or valgus alignment, mediolateral undersizing of the tibial component, excessive lateral load of tibial component by more lateral position of femoral component relative to tibial component, a lower T-score, and female sex. Our study found no significant difference in pain scores between subsidence and non-subsidence groups at various postoperative milestones.

Conclusion

These findings corroborate earlier suggested risk factors based on biomechanical models. Further research might provide the opportunity to identify high-risk groups preoperatively and adapt treatment strategies for these patients.

Take home message

- Valgus subsidence of uncemented tibial components in medial unicompartmental knee arthroplasty might be more prevalent than previously reported.
- Significant risk factors include higher preoperative varus alignment, greater postoperative correction to neutral or valgus, mediolateral undersizing of the tibial component, increased lateral loading due to femoral component

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positioning, lower T-scores, and female sex.

Introduction

Medial unicompartmental knee arthroplasty (UKA) has received substantial acclaim for its potential to address isolated medial compartment osteoarthritis (OA) while preserving the native anatomy of the knee.[1-5] This surgical modality, considered a less invasive alternative to total knee arthroplasty, has demonstrated commendable success in restoring function and alleviating pain in appropriately selected patients.[1-5] Reported revision rates for cementless implants are only 0.37% (95% CI 0.26 to 0.52) per annum.[6] However, literature suggests that further research is needed into the mechanisms of failure because of the growing demands for joint arthroplasty.[6-9]

Valgus subsidence of uncemented tibial components (Figure 1), marked by the gradual descent of the implant within the bone, emerges as a challenging complication following medial UKA.[5,8,10-16] The term 'subsidence' usually refers to the tibial component descending into a relative valgus position (usually defined as more than 2° of relative valgus compared to immediate postoperative radiograph).[5,8,10-16] This is reported to be accompanied in most cases by a relative increase in slope, sometimes described as posterior subsidence.[16] The presence of subsidence introduces a nuanced layer to the postoperative care paradigm demanding a comprehensive understanding of its prevalence, risk factors, and management.

In clinical practice, subsidence seems to be an important factor contributing to higher initial pain scores and slower early rehab after cementless UKA.[10] The prevalence of subsidence, however, has been investigated by multiple authors and is reported to be low to very low, with most authors reporting a prevalence of less than 1% of uncemented UKAs.[5,8,11-16] Kamenaga et al[10] reported a markedly higher prevalence of 5% in a mostly Asian population.[10] They also reported a possible link between valgus subsidence and excessive external rotation or medial positioning of the tibial component.[10] Liddle et al[16] proposed a relative lateral position of the femoral component compared to the tibial component, and that excessively deep sagittal cut (especially in posterior cortex) might predispose a patient to subsidence.[16] Small et al[17] established a biomechanically based target alignment for the balance of the tibial loading. In this model, minimal resection and most lateral positioning, neutral rotation, and 3° of slope (from mechanical axis) of the tibial component exhibited the most balanced strain response to loading. There has, however, been no research linking this theoretical model to in vivo occurrence of subsidence.[17]

The goal of this study was to analyze the phenomenon of subsidence by evaluating both the prevalence of subsidence and its risk factors, and linking this to function and pain scores of the patients.

Methods

Patient recruitment

This study employed a prospective multicentric approach with four participating hospitals (Jan Yperman Hospital in Ypres; AZ Sint-Lucas and AZ Sint-Jan hospitals in Bruges; and the University Hospital in Ghent). Ethical committee approval was obtained from all participating institutions. Patients presenting with medial OA of the knee eligible for UKA were prospectively enrolled after providing informed consent. During enrolment, participating surgeons committed to placing only uncemented components to reduce the risk of selection bias. Nine patients eligible for inclusion refused to participate before enrolment. A total of 108 patients were initially enrolled, with 97 patients completing the study. Reasons for non-completion were patient choice (six patients) and incomplete data (five patients, often due to missing radiographs during follow-up).

A standardized surgical technique, in accordance with Zimmer Biomet (USA) recommendations for the Oxford implant,[18] was uniformly applied by all participating surgeons (FH, JV, PJV, CD, LB). All implants were cementless, and surgeries were conducted under a blood void with a tourniquet. A preoperative hiatus adductor block, coupled with local intraoperative analgesia of the posterior capsule, facilitated a rapid recovery protocol, enabling partial weightbearing at day zero or day one postoperative.

Patients underwent evaluations preoperatively, and one day, four weeks, three months, and one year postoperative. Each visit included a set of weightbearing radiographs with radio-opaque marker according to the Oxford Radiograph Protocol,[19] encompassing a full leg view, anteroposterior (AP) and condylar views of the knee, and a lateral view.[20] Additionally, at the three-month visit, bone mineral density assessments were conducted using dual energy x-ray absorptiometry (DXA).

Data

A group of 97 knees from 90 patients was enrolled in the study, comprising 52 right knees and 45 left knees. Among these participants, 68 were male and 29 were female. The mean age at inclusion was 64.4 years (42.8 to 81.2), with a mean BMI of 30.4 kg/m^2 (19.8 to 44.5). Demographic data, including age, sex, affected side, weight, height, and BMI, were collected preoperatively. Preoperative radiographs were evaluated for various parameters, such as Kellgren-Lawrence grade of OA, hip-knee-ankle (HKA) alignment, HKA without joint line deformity (arithmetic HKA), medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), posterior proximal tibial angle (PPTA), mediolateral width of the proximal tibia, AP width of the medial proximal tibia, and width of the medial femoral condyle.[21–23]

Postoperatively, tibial implant size, femoral implant size, and insert size were recorded. The tibial and femoral sizes were quantified numerically (with a tibial implant size AA recording as "0", A as "1" etc and a femoral implant size XS recording as "0", S as "1" etc). The difference between these sizes was calculated to indicate relative sizing (with a positive value signifying a relatively larger tibial size compared to the femoral component).

Parameters evaluated on day one postoperative radiographs included postoperative HKA (pHKA), valgus angle of the tibial component (defined as the angle between the tibial anatomical axis and a line drawn adjacent to the tibial side of the tibial component in the AP view), slope of the tibial component (defined as the angle between the line perpendicular to the anatomical tibial axis and a line drawn adjacent to the tibial side of the tibial component in the profile view), width of the tibia not covered by the tibial component on the

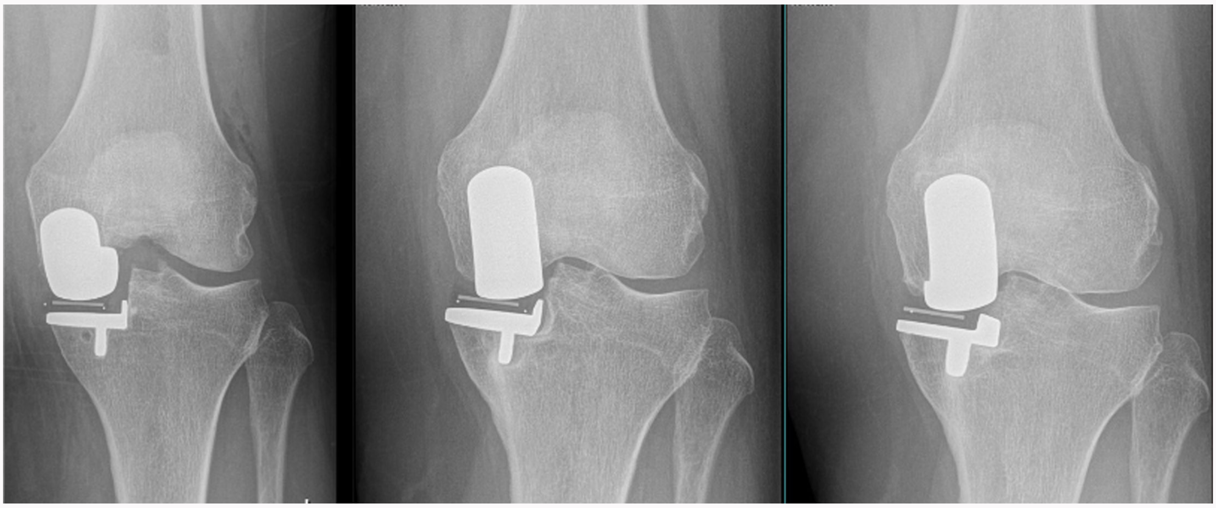

Fig. 1
Example of a 53-year-old female patient exhibiting valgus subsidence shown on an anteroposterior radiograph at one day, four weeks, and one year postoperative.

medial and anterior sides (in mm), distance from the lateral side of the tibial component to the centre of the tibial plateau, distance from the lateral side of the femoral component to the lateral side of the tibial component, and joint line lowering.[10,24] Figure 2 shows an overview of measurements not described in the literature.

The following parameters were calculated by comparing values of preoperative and postoperative radiographs: 1) the difference between the HKA and pHKA as well as the difference between the arithmetic HKA and pHKA; 2) the difference between the MPTA and the valgus angle of the tibial component; and 3) the difference between the PPTA and the postoperative slope of the tibial component.

Mean T-scores were extracted from the results of the DXA scan at three months. On the one- and three-month radiographs, the valgus angle of the tibial component was measured again, and the difference between the angles at these moments and the day one postoperative measurement was calculated. Subsidence was defined as a relative valgus increase of 2° or more of the valgus angle of the tibial component at four weeks or three months when compared to one day postoperative.[10,16,25]

Finally, each patient provided a clinical outcome report employing the Forgotten Joint Score (FJS)[26] and Oxford Knee Score (OKS)[27,28] questionnaires. These assessments were administered preoperatively and at the four-week, three-month, and one-year postoperative timepoints.

Statistical analysis

Normality testing using the Shapiro-Wilk test preceded non-parametric correlation analysis of the different parameters to subsidence, employing the Kendall correlation coefficient due to non-normal distribution results. Patient-reported outcome measures (PROMs) were compared between the subsidence and non-subsidence group by means of the Mann-Whitney U test or independent-samples *t*-test depending on the result of the Shapiro-Wilk test. Statistical significance was set at $p < 0.05$, and data analyses were conducted using the RStudio v.2021.09.1 software (Posit, USA).

Results

Subsidence

In terms of OA severity, four participants had Kellgren-Lawrence grade 2, 26 had grade 3, and 67 had grade 4. Evaluating the valgus angle of the tibial component, eight out of 97 cases (8.2%) displayed subsidence exceeding 2° (values ranging from 2.2° to 3.3° of valgus subsidence with one female outlier of 5.4°).

There was no statistically significant difference between the tibial valgus angle at four weeks and three months postoperative in either the subsidence or non-subsidence group (p = 0.657 and 0.372, respectively; Mann-Whitney U test). All our subsidence cases manifested in the first four weeks postoperative.

Between four weeks and three months postoperative, two patients experienced polyethylene dislocation (one in the subsidence group and one in the non-subsidence group). Both cases were successfully revised with a larger insert size and were able to resume rehabilitation without further issues. No other major complications were recorded, and no additional revision surgeries were performed at the final follow-up.

Correlations

Correlation analysis, conducted using the non-parametric Kendall correlation coefficient due to the result of the Shapiro-Wilk test, explored associations between valgus subsidence of the tibial component and various patient-related or radiological parameters. A detailed list of tested parameters is provided in Table I. Significantly correlated parameters with subsidence include: higher preoperative varus (lower MPTA value) (p = 0.029); larger difference between preoperative MPTA and postoperative valgus angle of the tibial component, indicating correlation of subsidence with a more substantial adaptation from preoperative varus to postoperative neutral or valgus alignment (p = 0.010); greater distance between the lateral side of the tibial component to the centre of the tibia ($p < 0.001$); relatively more lateral position of the femoral component compared to the tibial

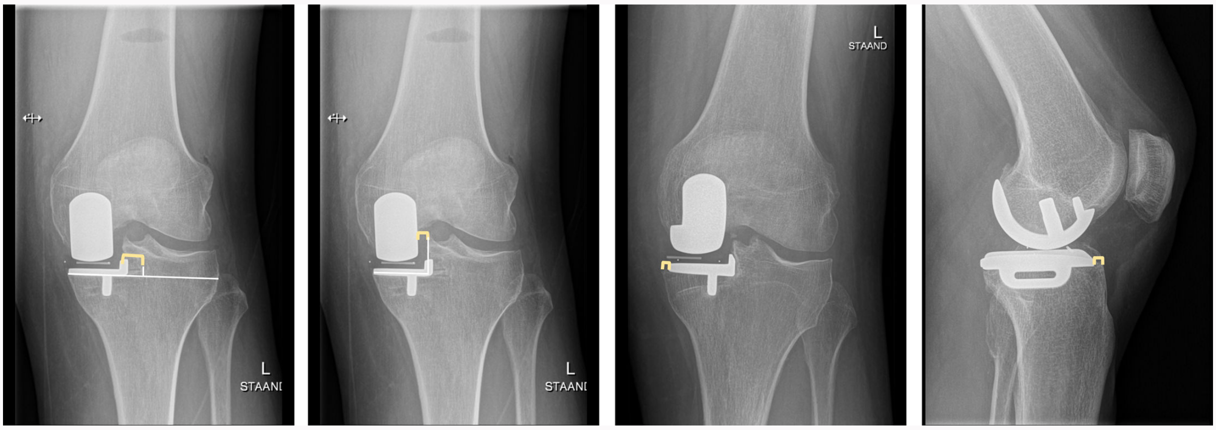

Fig. 2
An overview of measurements not described in literature: the first radiograph shows the mediolateral distance of the lateral side of the tibial component to the mediolateral centre of the tibial plateau, measured parallel to the line tangential to the under surface of the tibial component. The second radiograph shows the mediolateral distance between the lateral side of the femoral component and the lateral side of the tibial component, measured parallel to the line tangential to the under surface of the tibial component. The third radiograph shows the mediolateral distance between the medial side of the tibial component and the medial side of the native tibia (medial part of the tibia not covered by the tibial component). The fourth radiograph shows the anteroposterior distance between the anterior side of the tibial component and the anterior side of the native medial tibia (anterior part of the tibia not covered by the tibial component).

component ($p = 0.002$); lower average T-score ($p = 0.001$); and female sex ($p < 0.001$).

A relatively large femoral component compared to the tibial component showed a borderline correlation with subsidence, but did not reach the threshold for significance ($p = 0.054$, Kendall correlation coefficient).

The mean age of the male cases in the subsidence group was 75.1 years (SD 1.4), while the mean age of the female cases was 58.2 years (SD 7.7), a statistically significant difference ($p = 0.041$, Mann-Whitney U test).

The mean values of MPTA and postoperative valgus angle are shown for both the non-subsidence and subsidence groups in Table I. Six out of our eight subsidence cases ranged between 2.7° and 6.8° of varus measured by means of the MPTA, and were corrected to a postoperative valgus angle ranging between 0.4° of varus and 2.1° of valgus of their tibial component. Two cases did not exhibit a large adaptation in the coronal plane. They showed a MPTA value of 0.6° and 0.9° preoperative and a postoperative valgus angle of -0.3° and 0.2°, respectively.

Pain scores

There was a significant difference in OKS at the preoperative check, with the subsidence group scoring significantly better ($p = 0.048$, independent-samples *t*-test). There was no difference in FJS at this moment ($p = 0.229$, Mann-Whitney U test).

Pain scores in the subsidence and non-subsidence groups were not significantly different at the four-week, three-month, and one-year postoperative timepoints. The OKS showed p-values of 0.718 (independent-samples *t*-test), 0.711 (Mann-Whitney U test), and 0.203 (Mann-Whitney U test), while the FJS showed p-values of 0.665 (Mann-Whitney U test), 0.911 (Mann-Whitney U test), and 0.293 (independent-samples *t*-test), at four weeks, three months, and one year, respectively.

Discussion

This study identified eight cases of valgus subsidence exceeding 2° out of a cohort of 97 cases, equating to an 8.2% incidence. All instances manifested within the initial four weeks postoperative, with no notable increase in the valgus angle between four weeks and three months postoperative. This greatly exceeds the typically reported rates of subsidence in the literature, usually below 1%. Our incidence rate, in a Western European population, exceeded even the rate of the study of Kamenaga et al,[10] reporting 5% in a mostly Asian population.

Primary factors that correlated with this phenomenon in this study included a higher preoperative varus alignment of the tibia, substantial adaptation from preoperative varus to postoperative neutral or valgus alignment, mediolateral undersizing of the tibial component or a more medial position of the tibial component, excessive lateral load of the tibial component due to a more lateral position of femoral component relative to tibial component, a lower T-score, and female sex.

In the introduction, we highlighted three previous studies exploring factors associated with subsidence. Small et al[17] proposed a biomechanically based target alignment for the most balanced strain response to tibial loading. They reported minimal tibial resection and most lateral positioning, neutral rotation, and 3° of slope (from the mechanical axis) of tibial component as the optimal theoretical component position. Liddle et al[16] suggested a relative lateral position of the femoral component compared to the tibial component as a possible predisposing factor for subsidence. Kamenaga et al[10] reported a possible link between valgus subsidence and excessive external rotation or medial positioning of the tibial component.

Our findings align with almost all factors described above, excluding rotational analysis of the tibial component (due to radiological analysis constraints), the tibial component slope, and the tibial resection depth (measured as joint line lowering). In addition, our study introduces preoperative varus

Table I. Different tested demographic and radiological parameters.

Parameter	Non-subsidence group	Subsidence group	Kendall tau statistic	p-value
Demographic parameters				
Mean age, yrs (SD)	63.4 (8.1)	68.6 (11.5)	τ = -0.006	0.932
Sex (female/male), n	23/66	6/2	τ = 1.000	< 0.001
Mean weight, kg (SD)	91.5 (17.5)	84.3 (16.7)	τ = -0.082	0.260
Mean length, m (SD)	1.73 (0.01)	1.67 (0.06)	τ = -0.035	0.636
Mean BMI, kg/m^2 (SD)	30.4 (4.7)	30.2 (5.6)	τ = -0.076	0.295
Radiological parameters				
Preoperative				
Mean LDFA, ° (SD)	89.4 (1.96)	88.9 (2.34)	τ = -0.060	0.411
Mean MPTA, ° (SD)	87.3 (2.06)	84.4 (2.03)	τ = 0.153	0.034
Mean PPTA, ° (SD)	82.5 (2.05)	83.8 (1.14)	τ = 0.049	0.499
Mean HKA, ° (SD)	174.6 (2.70)	173.8 (2.45)	τ = 0.087	0.229
Mean aHKA, ° (SD)	176.3 (2.58)	175.4 (2.41)	τ = 0.100	0.166
Mean mediolateral width of the proximal tibia, mm (SD)	89.9 (9.04)	86.1 (9.45)	τ = -0.035	0.634
Mean AP width of the medial proximal tibia, mm (SD)	64.1 (5.64)	60.3 (6.76)	τ = -0.132	0.073
Mean mediolateral width of medial femur condyle, mm (SD)	30.4 (3.37)	28.3 (3.67)	τ = -0.061	0.412
Mean T-score (SD)	0.43 (1.32)	-0.58 (1.72)	τ = -0.222	0.002
Postoperative				
Mean femoral component size (SD)	3.1 (0.70)	2.8 (0.83)	τ = -0.038	0.645
Mean tibia component size (SD)	3.5 (1.26)	2.9 (1.36)	τ = -0.112	0.157
Mean insert size (SD)	3.6 (0.66)	3.4 (0.53)	τ = -0.056	0.515
Mean difference tibia-femur component size (SD)	0.4 (0.76)	0.1 (0.78)	τ = -0.162	0.051
Mean postoperative HKA, ° (SD)	177.2 (2.28)	177.3 (2.73)	τ = 0.108	0.135
Mean postoperative tibial valgus angle, ° (SD)	87.9 (2.13)	88.0 (1.77)	τ = 0.002	0.977
Mean postoperative slope, ° (SD)	85.4 (1.86)	84.9 (2.87)	τ = 0.033	0.645
Mean mediolateral width of the medial tibia not covered by a component, mm (SD)	0.5 (1.32)	2.2 (1.64)	τ = -0.127	0.116
Mean AP width of the anterior tibia not covered by a component, mm (SD)	1.6 (1.59)	1.9 (1.45)	τ = 0.043	0.581
Mean distance from the lateral side of the tibial component to the centre of the tibial plateau, mm (SD)	11.6 (2.39)	15.7 (2.06)	τ = 0.317	< 0.001
Mean distance from the lateral side of the femoral component to the lateral side of the tibial component, mm (SD)	7.8 (3.03)	4.5 (2.01)	τ = -0.242	0.001
Mean joint line lowering, mm (SD)	0.5 (0.82)	1.2 (1.08)	τ = -0.014	0.785
Mean difference in HKA, ° (SD)	2.7 (2.53)	1.9 (1.25)	τ = -0.031	0.664
Mean difference between MPTA and valgus angle, ° (SD)	1.0 (2.55)	3.4 (2.27)	τ = 0.188	0.010
Mean difference in slope, ° (SD)	0.7 (2.53)	0.6 (3.42)	τ = -0.001	0.990

aHKA, arithmetic HKA; AP, anteroposterior; HKA, hip-knee-ankle alignment; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; PPTA, posterior proximal tibial angle.

and its adaptation to a neutral or valgus alignment in the postoperative setting, and lower T-scores as additional factors correlated with subsidence. Female patients seem to be at risk at a significantly younger age, possibly due to earlier onset of osteopenia and osteoporosis in the female population.

The underlying biomechanical explanation for subsidence linked to relative lateral position of the femoral component, as proposed by Liddle et al,[16] suggests unequal loading of the mobile bearing with subluxation of the femoral component causing the bearing to tip. This results in heightened stresses on the lateral side of the tibial component, leading to subsidence. Due to the valgus subsidence, the congruence of the femoral component and the mobile bearing are restored, normalizing the load distribution on the tibial component.

This biomechanical pathway may also explain the contribution of the tibial rotation to subsidence. Non-neutral rotation of this component might force the mobile bearing into a similar position described above, either in extension (with excessive internal rotation of the tibial component) or in flexion (with excessive external rotation of the tibial component). It is important to note that the description of 'more lateral position of the femoral component' lacks completeness. Both our findings and the model proposed by Liddle et al[16] analyze the position of the femoral and tibial components in relation to each other, where a relative lateral position of the femoral component or a relative medial position of the tibial component correlates with subsidence. Rotation of the femoral component could likewise be of influence, but could not be analyzed given our imagining methods, and has, to our knowledge, not been described in literature. In conjunction with the finding of relative mediolateral undersizing of the tibial component in our study, and the finding of a medial tibial component position (as found by Kamenaga et al[10]) as correlated factors, this suggests that the absolute position of the tibial component is the most crucial factor in the tibiofemoral relation. While maximum mediolateral coverage of the tibia, and a sagittal cut of the tibia truly adjacent medial to the insertion of the ACL, are reaffirmed as most important, the absolute position of the femoral component might be of less significance.[29,30] We would like to underscore that all of these biomechanical pathways are possible interpretations of the data leading to hypotheses, but have not been confirmed by biomechanical studies, and thus they should be taken with caution.

While a relatively large femoral component compared to the tibial component might contribute via a similar biomechanical pathway described above, it does not reach the threshold for significance in this study.

The explanation for preoperative varus and the adaptation of this varus to a neutral or valgus alignment is challenging based on our study's findings. One hypothesis could be that, given the Oxford tibial guide mandates a neutral coronal cut on the tibia, a greater preoperative varus automatically leads to a more substantial difference between preoperative and postoperative coronal alignment of the tibia. This implies a deeper cut in the mediolateral centre of the tibia, causing the lateral side of the tibial component to rest on softer metaphyseal bone. The keel, serving a very similar purpose here to a keel in sailing to prevent tilting, may therefore fail in its purpose. The softer metaphyseal bone cannot withstand the pressure and yields. In the case shown in Figure 1, remodelling of the medial cortex of the tibia is also shown, with markedly more dense bone remodelling up to the base of the keel.

Foissey et al[24] elucidated that high residual varus and substantial joint line lowering are strongly associated with heightened susceptibility to early implant failure. Although our investigation did not corroborate the influence of joint line height, the possibility cannot be discounted, given the small sample size and power of this study. For instance, it could be hypothesized that similar biomechanical mechanisms, as discussed earlier, might come into play, with the component resting on less dense metaphyseal bone. Further research is warranted to thoroughly assess this aspect.

Earlier studies have highlighted subsidence as an important cause of slower early rehabilitation and lower patient-reported outcome measures (PROMs) in the early postoperative phase.[10] Most cases stabilize over time, demonstrating improvement in clinical findings and PROMs between three and six months postoperative, with similar long-term outcomes.[10] These observations are not corroborated in this study, with the subsidence group exhibiting similar pain scores than the non-subsidence group.

The large variation in pain scores and very small sample size of the subsidence group in this study are important limiting factors for evaluation of these parameters. Furthermore, the subsidence group scores significantly better in the OKS at the preoperative check. This might indicate our small subset of subsidence patients trending towards a lower subjective scoring of pain in general. This could possibly also contribute to their subsidence, since lower pain scores might lead to a more rapid early rehab and higher loading in the early postoperative phase.

This study has notable limitations, the most significant being the relatively small sample size of the subsidence group. Additionally, the analysis of the rotational alignment of the tibial component using CT was not included. There was also no radiostereometric analysis in this study.

In conclusion, the findings of this study should not be interpreted as an exhaustive list of risk factors for subsidence. The exact nature of the correlation between these factors and subsidence should be investigated further to determine whether they are truly predisposing factors. Future studies with larger sample sizes and a larger subsidence group might differentiate between these correlations and determine other factors related to subsidence. One suggested factor is joint line lowering or resection depth of tibia, a previously proposed factor not represented in our dataset. A relatively large femoral component compared to the tibial component might be another factor barely missing the threshold for significance in this study.

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Data sharing

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