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Comparison of ultra-congruent anterior-stabilized *vs.* a posterior cruciate substituting total knee arthroplasty for osteoarthritis with severe varus knee deformity: comparable 2 year outcomes with two design

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Abstract. – OBJECTIVE: In this retrospective study, we compared the functionality and clinical outcomes of patients with severe varus knees who underwent total knee arthroplasty (TKA) that used prostheses with either a posterior stabilized (PS) design or an ultra-congruent (UC) design.

PATIENTS AND METHODS: Primary TKA was performed in 161 patients; the UC device was used in 82 (51%) cases and the PS device in 79 (49%). Preoperatively and at the final follow-up examination, all patients were evaluated by orthoroentgenography. The mechanical axis angle and radiolucent lines were evaluated according to the Knee Society Roentgenographic Evaluation System on preoperative and 5-year follow-up radiographs. Total Knee Society Score (KSS) (knee score/function score) and Visual Analog Scale scores were obtained at the final follow-up examination. Demographic and surgical data and revision rates were evaluated for all patients.

RESULTS: Postoperative angle values were significantly decreased in both the UC and PS groups ($p<0.001$ and $p<0.001$, respectively). Postoperative flexion range of motion values were significantly increased in both the UC and PS groups ($p<0.001$ and $p<0.001$, respectively). The postoperative KSS function scores were not significantly different between the groups ($p=0.194$). The mean surgical time of the PS group (54.99±4.18 minutes) was significantly higher than that of the UC group (46.02±4.48 minutes) ($p<0.001$).

CONCLUSIONS: No notable differences were found between the UC and PS groups with respect to the clinical and functional parameters examined. Based on these results, UC TKA can be considered a safe alternative to PS TKA in severe varus knees.

Key Words:
Ultracongruent (UC) insert, Posterior stabilized (PS), Total knee arthroplasty (TKA), Posterior cruciate ligament (PCL), Mobile bearing.

Introduction

Although there are many studies[1,2] on substitutions of the posterior cruciate ligament (PCL) in severe varus knees, this remains controversial in the literature. Total knee arthroplasty (TKA) in severely varus knees is a more difficult technique than primary TKA in knees with neutral alignment. Posterior stabilized (PS) implants with a box and cam mechanism or ultra-congruent (UC) inserts with anterior-posterior lips are two options for the substitution of PCL. The UC insert was designed to ensure anterior-posterior stability in the absence of the PCL without using a post-cam mechanism, such as that seen in PS designs. Thus, the high anterior lip provides great compatibility. To prepare the box in the PS implant, further femoral bone resection is needed, thereby prolonging the operating time and increasing the risk of fracture[3]. Moreover, the additional cam mechanism can cause subluxation or dislocation, patellar clunk syndrome, and polyethylene wear[4,5].

As one of the primary stabilizers of the knee joint is the PCL[6] sacrificing the PCL can affect knee stability, kinematics, and deep proprioception and can decrease shear forces on the tibia.

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In cases where PCL is absent, inadequate, or resection is necessary, the substitution of PCL is required[3,7]. An ultra-congruent design was developed as an alternative to PCL substitution[8]. The UC device, which preserves the femur bone and probably reduces the operating time and blood loss, does not require additional bone preparation, which is required in the PS design[9]. By providing greater tibiofemoral compatibility, the deeper form of the geometry and the presence of symmetrical anterior and posterior lips allow anteroposterior stability and posterior femoral rollback, thereby preventing paradoxical femoral shift when the knee is in flexion[10].

Nevertheless, there are potential disadvantages to the UC design. Some studies[11,12] have shown that UC has a lower range of movement than the PS design[11], while others have found a similar ROM for both designs. Some concerns remain regarding reduced joint flexion and reduced axial rotation in this UC design[12]. In the literature, the results of the PS design and UC device in neutrally aligned knees were compared, but there are no new studies in the literature that have compared these two designs (PS, UC) in severe varus knees[11-25].

This retrospective study aimed to compare the ROM and clinical and radiographic results of patients with severe varus knees who underwent TKA with PS and UC. We hypothesized that the clinical and radiographic results would be similar in both groups.

Patients and Methods

A total of 1,194 TKA operations were performed at our institution between April 2017 and March 2023. From a scan of the hospital database, we identified 192 patients who underwent TKA for severe varus deformities. Thirty-one of these patients were excluded from the study because they were followed up for <2 years (n=22) or died within 2 years postoperatively (n=9). Thus, the study was completed with 161 patients, including 91 women and 70 men, with a mean age of 69±6.4 years (range, 50-80 years) and a mean follow-up of 24±86.76 months (range, 24-27 months). Primary TKA was performed in all patients, with the UC device used in 82 (51%) cases and the PS device in 79 (49%).

The inclusion criteria were an age of 50-80 years and the presence of severe varus deformity and primary osteoarthritis classified radiographically as Kellgren-Lawrence grade 3 or 4. The exclusion criteria were a history of corrective osteotomy on the affected extremity, arthritis following trauma, a history of knee arthroplasty, the presence of malignancy, knee deformity, follow-up of <2 years, body mass index (BMI) >40 kg/m^2, rheumatoid arthritis, chronic inflammatory joint disease, neuromuscular disorders, poliomyelitis, and a history of total hip arthroplasty.

The research protocol was approved by the Hitit University Ethics Committee (03.05.2023-05), and informed consent was obtained from all patients.

Clinical Evaluation

All patients were evaluated at 1, 3, and 6 months postoperatively, and 1 and 2 years postoperatively. Aseptic loosening was determined based on the postoperative evaluation of periprosthetic radiolucency. Preoperatively and at the final follow-up examination, all patients were evaluated by orthoroentgenography, and an analog goniometer was used to measure the mechanical tibiofemoral angle. The total Knee Society Score (KSS) (knee score/function score) and Visual Analog Scale (VAS) score for patient satisfaction from 0 (very dissatisfied) to 10 (very satisfied) were obtained at the final follow-up examination. Demographic and surgical data and revision rates were evaluated for all patients. The time of operation was calculated as the time from the first skin incision to wound closure. The two groups were comparable in terms of age, BMI, and primary diagnosis.

Radiological Evaluation

Knee alignment was defined as the mechanical angle between the femur and tibial axes on long-leg standing radiographs (Figure 1). The KSS criteria were grouped according to the severity of knee deformity as mild (≤5°), moderate (6-10°), significant (11-15°), or severe (≥15°). Thus, severe varus deformity was defined by a coronal angle of ≥15°. The mechanical axis angle and radiolucent lines were evaluated according to the Knee Society Roentgenographic Evaluation System on preoperative and 2-year follow-up radiographs. The presence of radiolucent lines was investigated on standing anterior, posterior, and mediolateral radiographs and on silhouette radiographs taken with the knee in 90° flexion. The methodology described by the American Knee Society was used to determine the radiolucent lines[26].

At the 2-year follow-up examination, no radiolucent lines thicker than 1 mm were detected in any of the patients. In three patients in the UC group, there were radiolucent lines ≤1 mm in

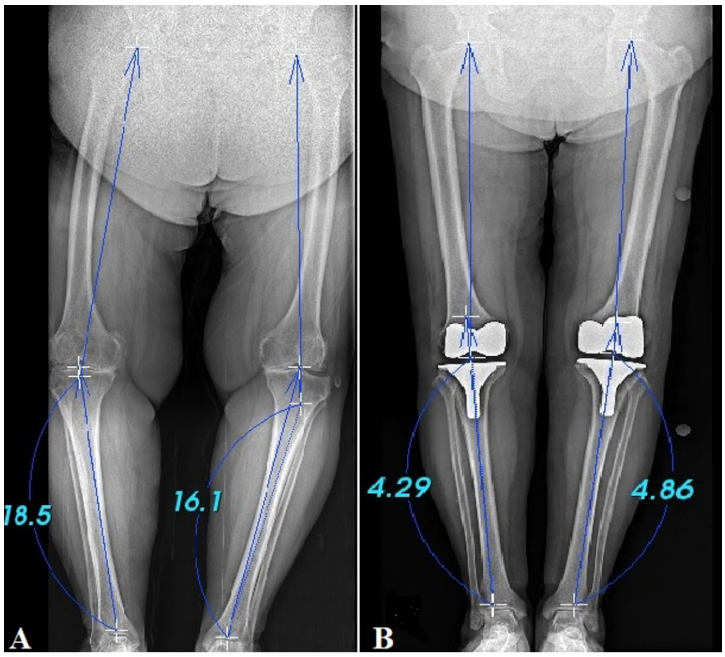

Figure 1. **A**, Preoperative ortho roentgenography showing right and left severe varus deformity of 18.1° and 16.1°, respectively, in a 66-year-old female. **B**, Postoperative Ortho roentgenography examination at the last follow-up visit showed right and left varus alignment of 4.26° and 4.86°, respectively.

thickness: one line in two patients (region 1, tibia, anteroposterior image) and two lines in one patient (region 2, femur, lateral image). In the PS group, radiolucent lines ≤1 m in thickness were observed in four patients: one line in two patients (region 2, tibia, anteroposterior image) and two lines in two patients (region 1, femur, anteroposterior image) (Figure 1).

Surgical Procedure

Senior arthroplasty surgeons who specialized in the use of both designs performed all operations. Cemented TKA (UC or PS) without patellar resurfacing was performed in all the patients. Resection of both cruciate ligaments was performed. Bone cuts to the tibia and femur were made using the space-balancing technique and mechanical alignment with conventional instrumentation. In cases in which the UC design (Figure 2) was used, a standard femoral component was implanted, and for the PS design, additional bone preparation was required for the box.

Statistical Analysis

Statistical data analysis was performed using SPSS software, version 22, [(IBM Corp., Armonk, NY, USA) Program license: Hitit University]. Descriptive statistics for categorical variables are presented as frequencies (n) and percentages (%). Depending on the sample size in the crosstab

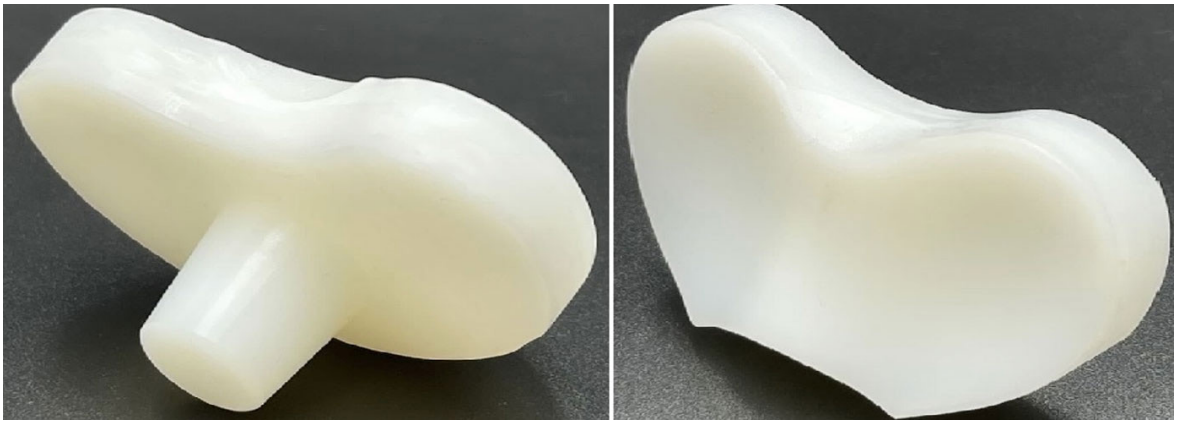

Figure 2. Photograph of the mobile ultracongruent insert.

cells, the Chi-square test or Fisher's exact test was used to examine relationships between categorical variables. Descriptive statistics for numerical data are presented as mean ± standard deviation (SD) or median (min-max) based on the assumption of normal distribution. The Kolmogorov-Smirnov test, Shapiro-Wilk test, and graphical approaches (Histogram, Q-Q plot) were used to test the assumption of a normal distribution of numerical data. Levene's test was used to test the hypothesis that variances were homogeneous. Student's *t*-test was used to compare the numerical data between the two independent groups when parametric test assumptions were met, and the Mann-Whitney U test was used when they were not met. The paired *t*-test was used to compare the related numerical data (pre-post) when the parametric test assumptions were met, and the Wilcoxon signed-rank test was used when they were not met. In all comparisons, $p<0.05$ was accepted as the statistical significance limit.

Results

Data on 161 patients, 82 (50.9%) in the UC group and 79 (49.1%) in the PS group, were statistically analyzed. The patients included 72 men (44.7%) and 89 women (55.3%), with a mean age of 67.29±7.27 (range, 50-80) and a mean BMI of 27.25±2.99 (range, 21-34). The mean surgery time was 50.42±6.23 (range 38-63) minutes.

Table I presents the comparison of the demographic and clinical characteristics between the research groups. The distribution of sex ratios between the study groups was statistically similar ($p=0.917$): in the UC group, 45.1% (n=37) of the patients were male and 54.9% (n=45) were female, and in the PS group, 44.3% (n=35) were male and 55.7% (n=44) were female. The mean BMI and mean age were not significantly different between the groups ($p=0.984$ and $p=0.309$, respectively). In the UC group, the mean age was 67.28±7.03 and the mean BMI was 27.01±2.85; in the PS group, the mean age was 67.3±7.55 and the mean BMI was 27.49±3.12. The follow-up time of patients did not differ significantly between the groups ($p=0.806$). The mean follow-up period of the UC group was 24.88±0.77 months, and the mean follow-up period of the PS group was 24.85±0.76 months. The mean surgical time of the PS group (54.99±4.18 minutes) was significantly higher than that of the UC group (46.02±4.48 minutes) ($p<0.001$).

Comparisons for angle, flexion ROM, KSS scores, and KS function scores within and between the groups are presented in Table II. Postoperative angle values were significantly decreased in both the UC and PS groups ($p<0.001$ and $p<0.001$, respectively). The preoperative angle values were not significantly different between the groups ($p=0.901$), nor were the postoperative angle values ($p=0.204$). A boxplot showing the distribution of the angle values is presented in Figures 3 and 4.

The postoperative KS scores were significantly higher in both the UC and PS groups ($p<0.001$ and $p<0.001$, respectively). Neither the preoperative KS scores nor the postoperative KS scores were significantly different between the groups ($p=0.119$ and $p=0.170$, respectively). The postoperative KS function scores were significantly higher in both the UC and PS groups ($p<0.001$ and $p<0.001$, respectively). Similar to the KS scores, the preoperative KS function scores and the postoperative KS function scores were not significantly different between the groups ($p=0.874$ and $p=0.194$, respectively). Box plots showing the

Table I. Statistical findings for the comparison of socio-demographic and clinical characteristics of the patients.

		Groups		*p*-values
		UC (n=82)	PS (n=79)	
Gender	Male	37 (45.1%)	35 (44.3%)	0.917[a]
	Female	45 (54.9%)	44 (55.7%)	
Age		67.28±7.03	67.3±7.55	0.984[b]
BMI		27.01±2.85	27.49±3.12	0.309[b]
Follow-up time		24.88±0.77	24.85±0.76	0.806[b]
Surgical time		46.02±4.48	54.99±4.18	**<0.001**[b]

[a]Chi-square test with n (%). [b]Student's *t*-test with mean±standard deviation (SD). UC: Ultracongrent Insert, PS: Posterior Stabilized Insert, BMI: Body Mass Index.

Table II. Statistical findings for the comparison of preoperative and postoperative Angle, Flexion ROM, KS score, and KS function parameters.

	Groups	Pre	Post (within)	*p*-values
Angle	**UC**	20.96±3.29	3.51±1.73	**<0.001**[d]
	PS	20.96±3.3	3.84±1.47	**<0.001**[d]
	***p*-values (between)**	0.901[b]	0.204[b]	
Flex ROM	**UC**	91.29±12.54 (97)	113.38±6.77 (112)	**<0.001**[e]
	PS	94.29±11.44 (97)	113.27±6.18 (112)	**<0.001**[e]
	***p*-values (between)**	0.237[c]	0.913[b]	
KS score	**UC**	41.24±7.97	88.77±7.17	**<0.001**[d]
	PS	43.19±7.77	86.86±10.18	**<0.001**[d]
	***p*-values (between)**	0.119[b]	0.170[b]	
KS function	**UC**	35.94±8.90	76.43±13.58	**<0.001**[d]
	PS	36.16±9.05	79.05±11.87	**<0.001**[d]
	***p*-values (between)**	0.874[b]	0.194[b]	

[b]Student's *t*-test with mean±standard deviation (SD). [c]Mann Whitney U test with mean±SD and median. [d]Paired *t*-test with mean±SD. [e]Wilcoxon signed rank test with mean±SD and median.

distribution of KS and KS function scores are shown in Figure 5.

The statistical findings for the comparison of changes in angle, flexion ROM, KS score, and KS function scores before and after the operation are presented in Table III. The changes in angle, flexion ROM, and KS function scores before and after the operation were not significantly different between the groups (p=0.474, p=0.269, p=0.357, respectively) (Table III). The change in KS scores before and after surgery in the UC group (47.52±9.90) was significantly higher than that in the PS group (43.67±11.93) (p=0.027), (Table III).

Discussion

The most significant finding of this study was that in the 2-year follow-up of patients with severe varus knees who received TKA, no significant differences were observed between the UC and PS groups with respect to the total KSS, ROM, and knee alignment. TKA can relieve the pains suffered by patients with severe varus gonarthrosis and improve the kinematics and functions of the knee joint[27].

The optimal management options for the PCL during primary TKA include cruciate retention (CR), PS, and UC designs. The debate surround-

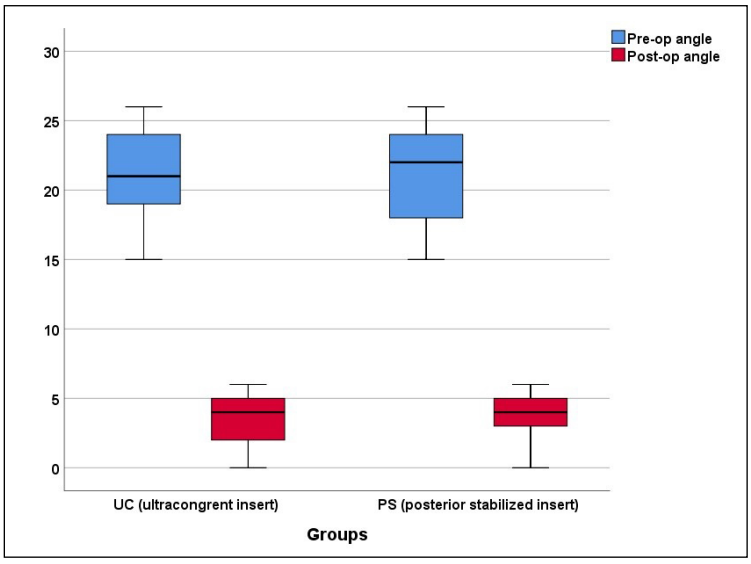

Figure 3. Boxplot with jitters showing preoperative and postoperative Angle values. Postoperative flex ROM values were significantly increased in both the UC and PS groups (p<0.001 and p<0.001, respectively). The preoperative flexion ROM values were not significantly different between the groups (p=0.237). Postoperative flexion ROM values were not significantly different between the groups (p=0.913). The boxplot showing the distribution of the Flexion ROM values is shown in Figure 4.

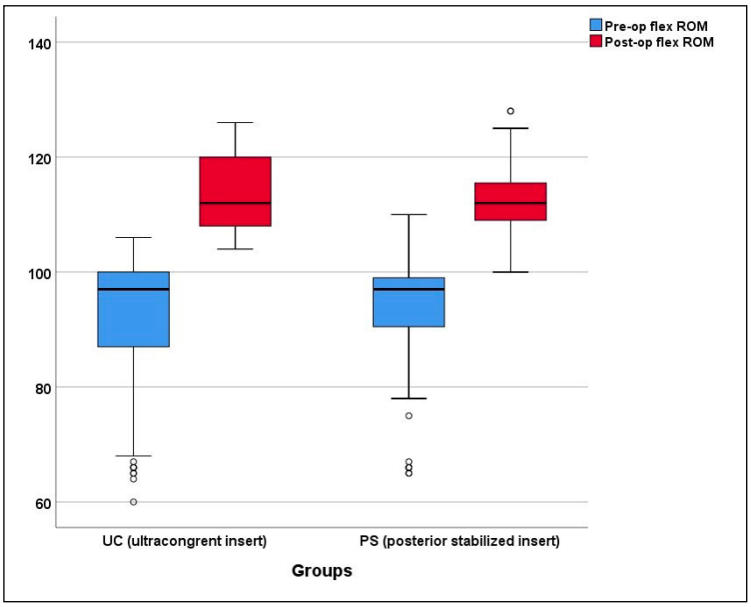

Figure 4. Boxplot with jitters showing preoperative and postoperative Flexion ROM values.

ing these designs is ongoing. From an analysis of a series of 920 patients who underwent CR TKA, Bae et al[6] reported that in 83 (9%) knees, conversion to a PS design was performed intraoperatively. The reported advantages of the anterior stabilized design include the ease of conversion from CR to PS, bone preservation, and reduced wear due to the potentially reduced contact surface forces because of the increased surface contact area[7,13,14].

Kinematic studies[15,16] have shown that, compared with UC TKA, the PS design provides improved ROM, less anteroposterior loosening, and greater posterior femoral rollback. However, the clinical and patient-reported results of both TKA approaches did not seem to be affected by these

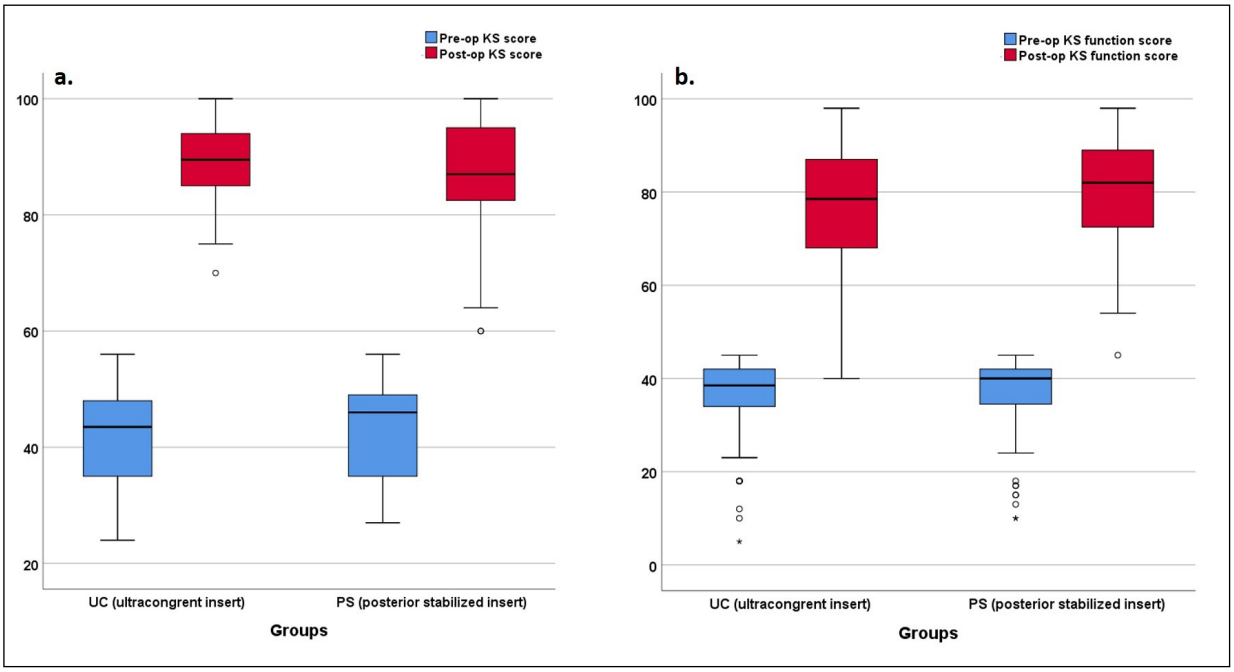

Figure 5. Boxplot with jitters showing preoperative and postoperative (**a**) KS scores and (**b**) KS function scores.

Table III. Statistical findings for the comparison of Angle, Flex ROM, KS score, and KS function changes (difference between pre and post operation) among research groups.

	Groups		*p*-values
	UC (n=82)	PS (n=79)	
Angle	17.45±3.26	17.06±3.59	0.474[b]
Flex ROM	22.08±14.28 (20)	18.97±13.38 (16)	0.269[c]
KS score	47.52±9.90	43.67±11.93	**0.027**[b]
KS function	40.49±16.76	42.89±16.17	0.357[b]

[b]Student's *t*-test with mean±standard deviation (SD). [c]Mann Whitney U test with mean±SD and median. UC: Ultracongrent Insert, PS: Posterior Stabilized Insert.

kinematic aspects. In a report[17] comparing UC and PS TKA in the same patient, Kim et al[17] stated that despite the kinematic advantages of the PS design, no differences were observed with respect to patient satisfaction and joint perception. Akti et al[18] also reported no difference between UC and PS TKA with respect to the isokinetic performance. Using a standard CR insert and UC insert in TKA, Lützner et al[19] compared intraoperative stability and ROM before and after PCL resection. Similar results were obtained for both inserts with respect to mediolateral and anteroposterior stability and ROM.

Although several studies[17-19] have compared the results of the PS and UC devices in neutrally aligned knees, the literature lacks studies that have compared the results of UC TKA and PS TKA in severe varus knees. A common belief that appears logical is that the PCL substitution design could show better performance in knees with severe deformity. The current study presents the results of patients with severe varus knees treated with UC-TKA and PS-TKA, and the results obtained with the UC design were equivalent to those obtained with the PS design. However, the use of the UC design eliminated the disadvantages of prolonged surgical time, additional bone cuts, and increased bleeding.

Various studies[20-22], have reported the clinical results of different TKA designs for varus knees. Mullaji et al[20] used PCL substitution implants in 173 knees of 117 patients with severe varus knee deformity >20°. The average postoperative KS score was reported to be 91.1±22.8, and the KS function score was 72.1±18.7. Similar results have been reported in other studies[21,22] verifying that PCL-stabilizing prostheses can be successfully used for the treatment of severe varus deformities. Overall, the results of the current study are similar to those of the literature.

Retrospective studies[23,24] that have compared UC-TKA and PS-TKA in terms of many variables (implant survival, ROM, clinical scores, knee score, radiological results, patient satisfaction score, revision rates, and complication rates) have also shown similar results for both UC and PS designs, with no significant differences between the two groups. In the current study, no statistically significant differences were found between the groups in terms of postoperative complications and aseptic loosening.

One of the most commonly used parameters to evaluate arthroplasty results is survival rate. In a study[25] in which 8,117 TKA patients were reviewed, the survival rate for PS TKA in varus knees >15° was found to be 77%. Similarly, in the current study, aseptic failure requiring revision surgery was diagnosed in only one UC-TKA and one PS-TKA.

Limitations

This study had some limitations, including its retrospective design, relatively low number of patients, and patient selection method (>15° varus). As nine patients died before the completion of 2 years of follow-up, not all suitable patients could be included, so there could have been a risk of selection bias. A specific mobile-bearing TKA design was used in this study, which precludes the applicability of these results to other TKA designs. Nevertheless, this study is the first to analyze and compare the results of UC and PS TKA in severe varus knees in detail.

Conclusions

The results obtained in this study demonstrated no statistically significant differences between the UC and PS groups with respect to the clinical and functional parameters examined. These results

suggest that UC TKA can be a safe alternative to PS TKA in severe varus knees. This could be an advantage for surgeons who do not always apply PCL substitution. In addition, as UC TKA does not require additional bone preparation, it reduces the possibility of fracture in osteoporotic cases. Although the UC design could be a good alternative to standard PS implants in severe varus knees, the literature offers no clear evidence regarding the radiological and clinical results. Therefore, further randomized clinical studies and advancement of knowledge in the biomechanical and kinematic areas will enable a better understanding of the results of UC total knee prostheses used in knees with severe varus deformities.

Authors' Contributions
Conceptualization, A.D; methodology, A.D. Ş.K; software, A.D. D.İ.; validation, A.D. and Ş.K. D.İ.; formal analysis, Ş.K. D.İ.; investigation, A.D.; resources; data curation, A.D.; writing-original draft preparation, A.D.; writing-review and editing, A.D.; visualization, Ş.K.; supervision, A.D. D.İ.; project administration, A.D. D.İ.; funding acquisition, Ş.K. All authors have read and agreed to the published version of the manuscript.

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Informed Consent
Informed consent was obtained by the participants.

Data Availability
The data supporting this study's findings are available from the corresponding author, [A.D], upon reasonable request.

Conflicts of Interest
The authors declare no conflict of interest.

Ethical Approval
The research protocol was approved by the Hitit University Ethics Committee (No.: 03.05.2023-05).

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