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ORIGINAL ARTICLE

Does sagittal alignment of the femoral component have an impact on radiological loosening and functional results in revision knee arthroplasty?

Osman Çimen, MD, Muhammed Mert, MD, Abdurrahim Navat, MD, Alper Köksal, MD, Ali Öner, MD, Ferdi Dırvar, MD, Deniz Kargın, MD

Department of Orthopedics and Traumatology, Istanbul Metin Sabancı Baltalimani Bone Diseases Training and Research Hospital, Istanbul, Türkiye

ABSTRACT

Objectives: In this study, we aimed to investigate the effect of sagittal alignment of the femoral component on both radiological loosening and functional results in revision total knee arthroplasty (rTKA), as well as the anterior condylar offset (ACO) and posterior condylar offset (PCO).

Patients and methods: Between December 2005 and November 2020, a total of 47 patients (12 males, 35 females; mean age: of 67.1±8.4 years; range, 52 to 90 years) who underwent rTKA due to aseptic prosthesis failure were retrospectively analyzed. Demographic data including age, sex, body mass index (BMI), and clinical outcomes of the patients were recorded. Early postoperative sagittal alignment of the femoral component, ACO, and PCO were measured. Radiological loosening of patients was evaluated using the modified Knee Society Score, while the functional outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS).

Results: The mean follow-up was 55.4±28.0 (range, 24 to 142) months. While there was a moderate and inverse correlation between the sagittal alignment of the femoral component and ACO (p=0.002), there was no significant correlation between the sagittal alignment of the femoral component and PCO (p=0.980). There was a weak and inverse correlation between BMI and KOOS (p=0.024). There was no significant relationship between the sagittal alignment of the femoral component, ACO, PCO, age, and sex with radiological loosening (p=0.241) or KOOS (p=0.894).

Conclusion: In rTKA, sagittal alignment of the femoral component does not affect radiological loosening and functional results. The sagittal alignment of the femoral component exhibits a moderate and inverse correlation with ACO, while it has no significant correlation with PCO.

Keywords: Alignment, knee, prosthesis failure, revision, sagittal.

Due to the aging population and the rapid increase in the number of primary total knee arthroplasties (TKA), revision total knee arthroplasty (rTKA) surgery rates have increased and are expected to continue to rise in the future.[1] It is known that improper prosthesis placement and positioning would affect clinical outcomes by causing aseptic prosthesis failure, instability, and premature wear of polyethylene.[2] In rTKA, the components are placed perpendicular to the mechanical axis in the coronal plane; however, the ideal component positioning in the sagittal plane has not been clearly defined yet.[3] Numerous studies in the literature have investigated the effects of femoral component placement on joint functions and knee kinematics.[4-8] Extension of the femoral component delays post-cam engagement, alters postoperative kinematics,[5] and may result in abnormal patellofemoral biomechanics with increased anterior condylar offset (ACO) and

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Correspondence: Osman Çimen, MD. İstanbul Metin Sabancı Baltalimanı Kemik Hastalıkları Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, 34470 Sarıyer, İstanbul, Türkiye.

E-mail: osmancimen44@gmail.com

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overstuffing of the anterior compartment.[6] Placing the femoral component in hyperflexion may lead to anterior impingement of the components.[8] Increasing the flexion of the femoral component has also been used to increase the posterior condylar offset (PCO).[7] Restoring PCO is important in terms of providing flexion stability and potentially increasing the range of motion (ROM) in rTKA.[4] A decreased PCO may cause flexion instability and decreased ROM.[3]

Abnormal knee kinematics is associated with postoperative patient dissatisfaction and decreased implant survival.[3] In the present study, we hypothesized that the sagittal alignment of the femoral component could affect both radiological loosening and functional results in rTKA, as well as the ACO and PCO. We, therefore, aimed to investigate the effect of sagittal alignment of the femoral component on both radiological loosening and functional results in rTKA.

PATIENTS AND METHODS

Patient information

This single-center, retrospective study was conducted at Istanbul Metin Sabancı Baltalimani Bone Diseases Training and Research Hospital, Department of Orthopedics and Traumatology between December 2005 and November 2020. Radiological and clinical data of 167 patients who underwent revision knee replacement surgery due to aseptic prosthesis failure were reviewed. Patients who had minor, that is, type 1 or type 2a defect according to the Anderson Orthopaedic Research Institute (AORI) classification, underwent rTKA with the hybrid cementation technique for the first time, and who had at least two years of follow-up were included in the study. Patients who developed complications that may affect radiological loosening, such as periprosthetic fracture or periprosthetic joint infection after rTKA surgery, were excluded from the study. Finally, 47 knees of 47 patients (12 males, 35 females; mean age: of 67.1±8.4 years; range, 52 to 90 years) who met the study criteria and attended the final follow-up visit were included (Figure 1).

The occurrence of complications was recorded. Additionally, demographic data such as age, sex, body mass index (BMI) and clinical outcomes were noted. Sagittal alignment of the femoral component, ACO, PCO, the number and width of radiolucent lines (RLLs) around the revision knee prosthesis and stem were measured using the postoperative radiographs.

Operative data

Surgeries were performed by the surgeons from the Joint Reconstruction Department using one of the Vanguard Constrained Condylar Knee System (Zimmer-Biomet Inc., Warsaw, IN, USA), NexGen Legacy Constrained Condylar Knee (Zimmer-Biomet Inc., Warsaw, IN, USA), LEGION Total Knee System (Smith & Nephew Inc., Memphis, TN, USA) or PFC SIGMA (DePuy Synthes, Warsaw, IN, USA) rTKA implants. The medial parapatellar arthrotomy approach by entering through the previous skin incision was used. None of the patients required quadriceps snip, V-Y quadriceps turndown, or tibial tubercle osteotomy. Wide synovectomy was performed. The femoral and tibial components were carefully removed to preserve the maximum bone stock. The integrity of the medial and lateral collateral ligaments was checked. The PCO of the femoral component was restored intraoperatively using appropriate distal and posterior augments. The femoral component stem thickness and length were selected according to the degree of bone loss in the distal femur. Revision TKA was placed using the hybrid cementation technique. Patellar resurfacing was performed only in patients with preoperative patellofemoral symptoms.

A standard rehabilitation protocol was followed for all patients. Passive ROM and quadriceps strengthening exercises were started on the first postoperative day. Two weeks after the operation, the patients were called for removal of the sutures and wound control. Routine follow-ups were performed at six weeks, six months, and 12 months and ROM, quadriceps strength, presence of any contracture, or possible signs of infection were assessed. After the first postoperative year, outpatient controls were performed annually.

Outcome assessment

The sagittal alignment of the femoral component was determined by measuring the angle between the sagittal femoral anatomical axis (SFAA) and the femoral stem, as defined by Ettinger et al.[9] (Figure 2). Postoperative PCO was determined by measuring the thickness of the posterior condyle, which protrudes to the posterior of the line drawn tangent to the posterior cortex of the femoral shaft on the true lateral radiograph, as defined by Bellemans et al.[4] (Figure 3). The ACO was determined by measuring the thickness of the anterior condylar prominence, which protrudes to the anterior of the line drawn tangent to the anterior cortex of the femoral shaft on the true lateral radiograph (Figure 3).[10]

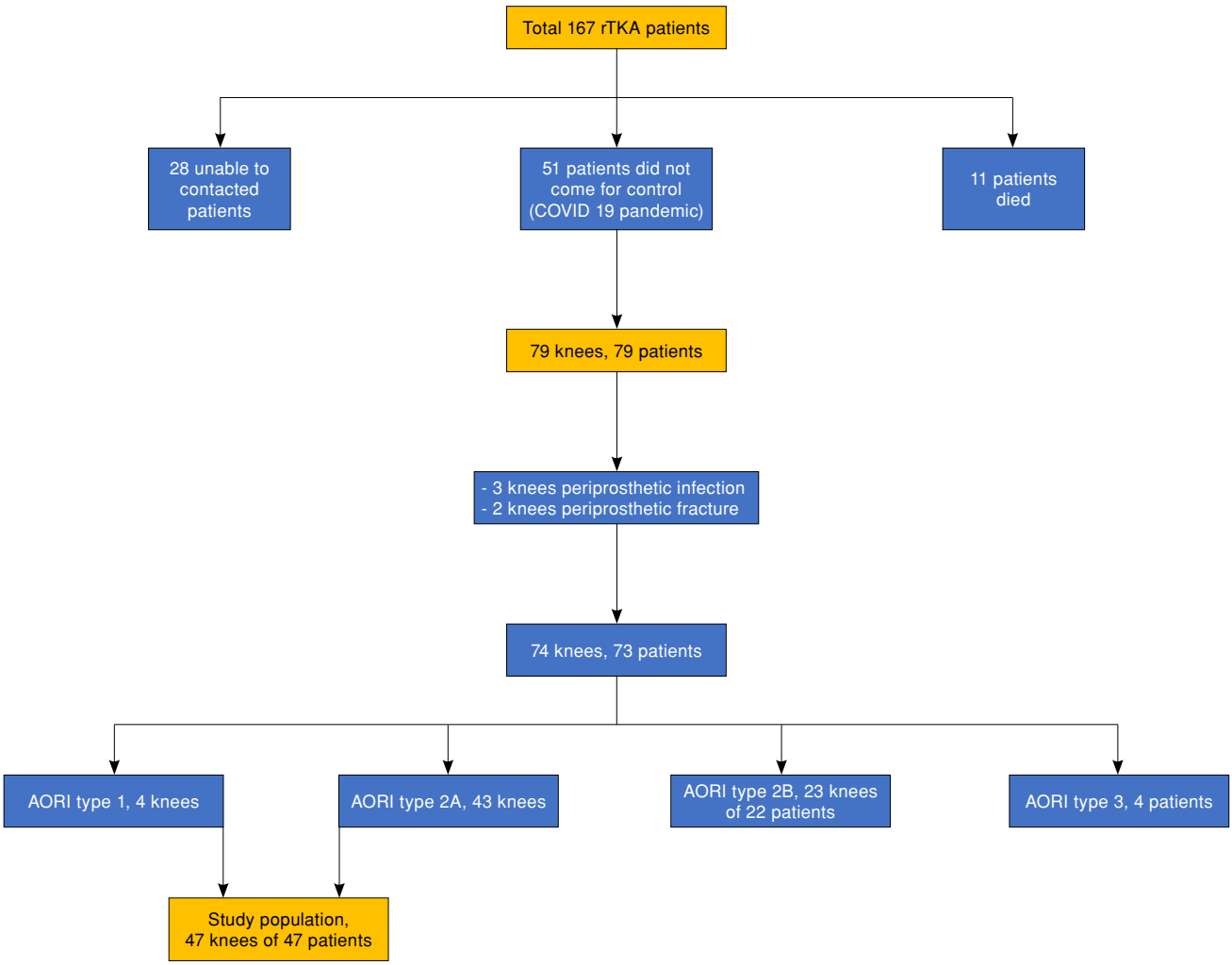

FIGURE 1. Study flowchart.

In rTKA, tibial component malposition, and femoral and tibial component alignment may affect prosthesis failure. Since component alignment may affect the results of the study, these parameters of the patients were also evaluated. Due to the unavailability of pre- and postoperative full-length standing radiographs for all patients, the coronal alignment of the femoral component and the coronal and sagittal alignment of the tibial component were assessed using Meneghini et al.'s[11] method, which allows anatomical axis measurement from direct radiographs (Figures 4a and b). Radiographic measurements of the patients were carried out using the ExtremePacs software (ExtremePacs, Ankara, Türkiye).

The stability of the rTKA was determined by using the modified Knee Society radiographic scoring system. This score is calculated by measuring and summing the thickness of the RLLs in mm in each area surrounding the prosthesis (Figure 5).[12] Scores ≥9 were accepted radiological loosening of the femoral component.[13]

All radiographic measurements were repeated by a senior author of the article, and the intraclass correlation coefficient (ICC) was calculated.

The Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to evaluate the functional outcome of the knee joint that underwent rTKA. In this scoring system, the knee joint is scored between 0 and 100. A score of 0 indicates very serious problems in the knee joint, while a score of 100 indicates there is no problem with the joint. The KOOS is a patient-reported outcome measures (PROM) used to evaluate both short-term and long-term functional outcomes of the knee. This

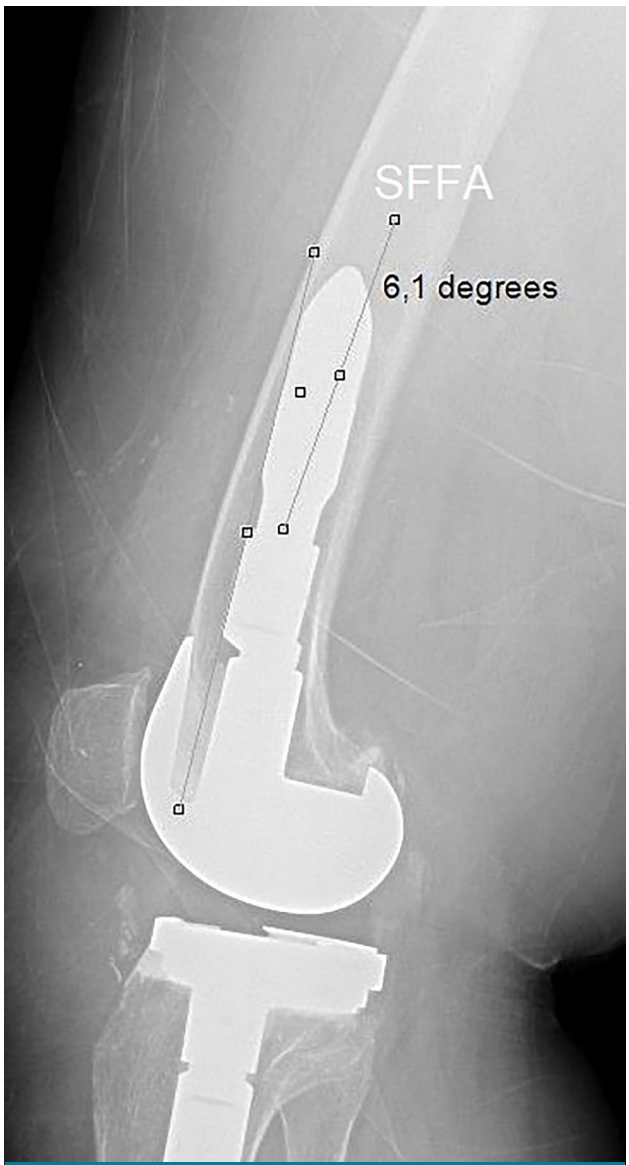

FIGURE 2. Measurement of the sagittal femoral component alignment using sagittal femoral anatomical axis (SFFA).

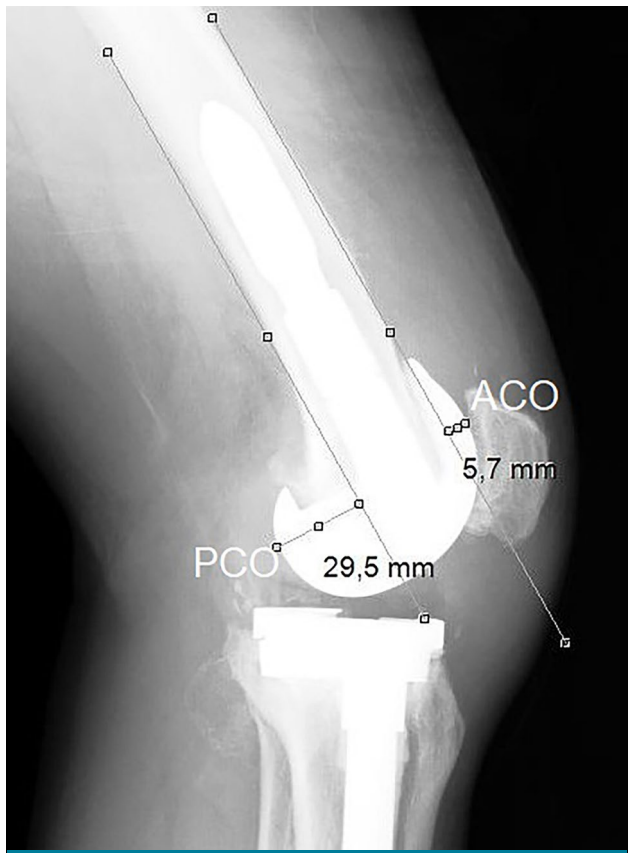

FIGURE 3. Measurement of the anterior condylar offset (ACO) and posterior condylar offset (PCO).

scoring system includes 42 items in five subscales that are scored separately.[14]

Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The reproducibility of the radiologic measurements was determined by calculating the ICC; where values between 0.75 and 0.90 indicated good reliability and values greater than 0.90 excellent reliability. The Spearman correlation coefficient test was performed for the correlation analysis between variables such as patient demographics, ACO, PCO, postoperative coronal and sagittal alignment of the tibial and femoral components, BMI, clinical outcomes, and the total score of RLLs. A p value of <0.05 was considered statistically significant.

RESULTS

Demographics, radiological characteristics, and clinical results of the patients are presented in Table I. The mean follow-up was 55.4±28.0 (range, 24 to 142) months. According to the AORI classification, four patients (8.5%) had type 1 and 43 (91.5%) had type 2a metaphyseal defects in the distal femur.

Complications including patellar tendinitis in one patient and deep vein thrombosis (DVT) in another patient developed. The patient who developed DVT recovered with medical treatment, while the patient with patellar tendinitis recovered with combined medical and physical therapy.

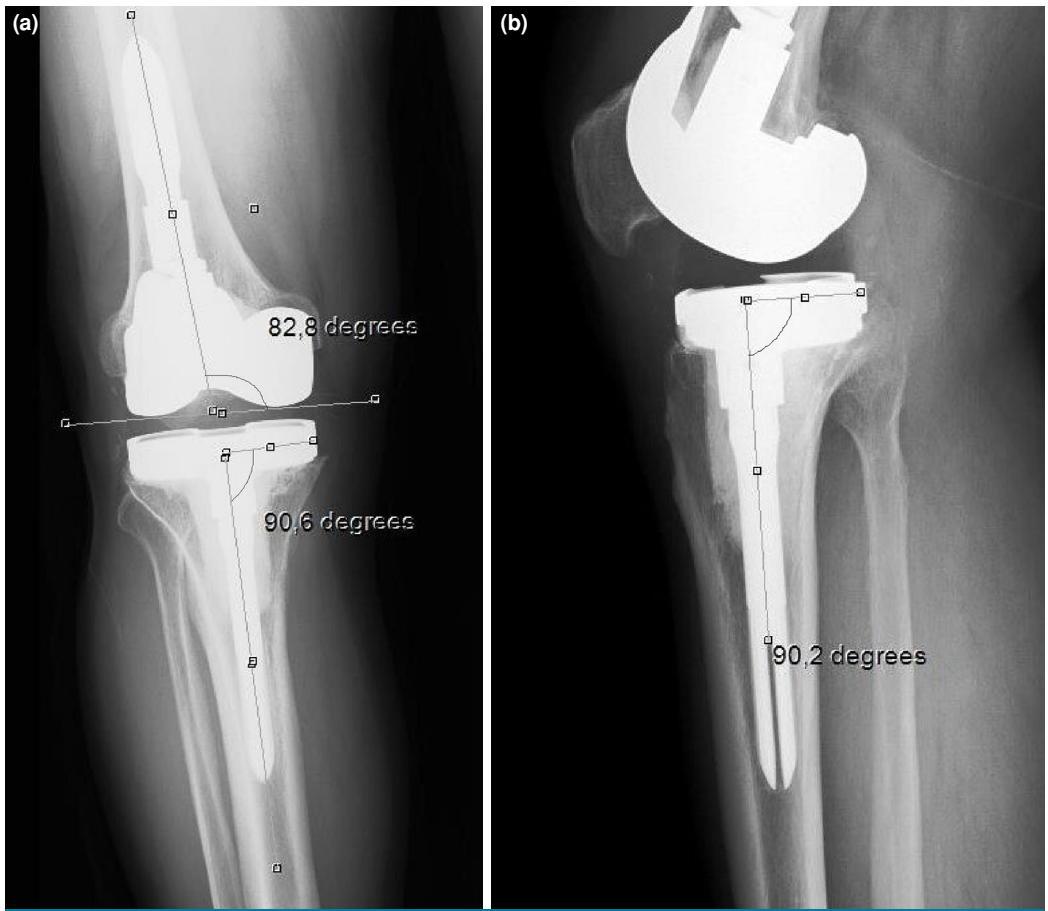

FIGURE 4. (a) Coronal alignment of the tibial and femoral components according to Meneghini's measurement method. **(b)** Sagittal alignment of the tibial component according to Meneghini's measurement method.

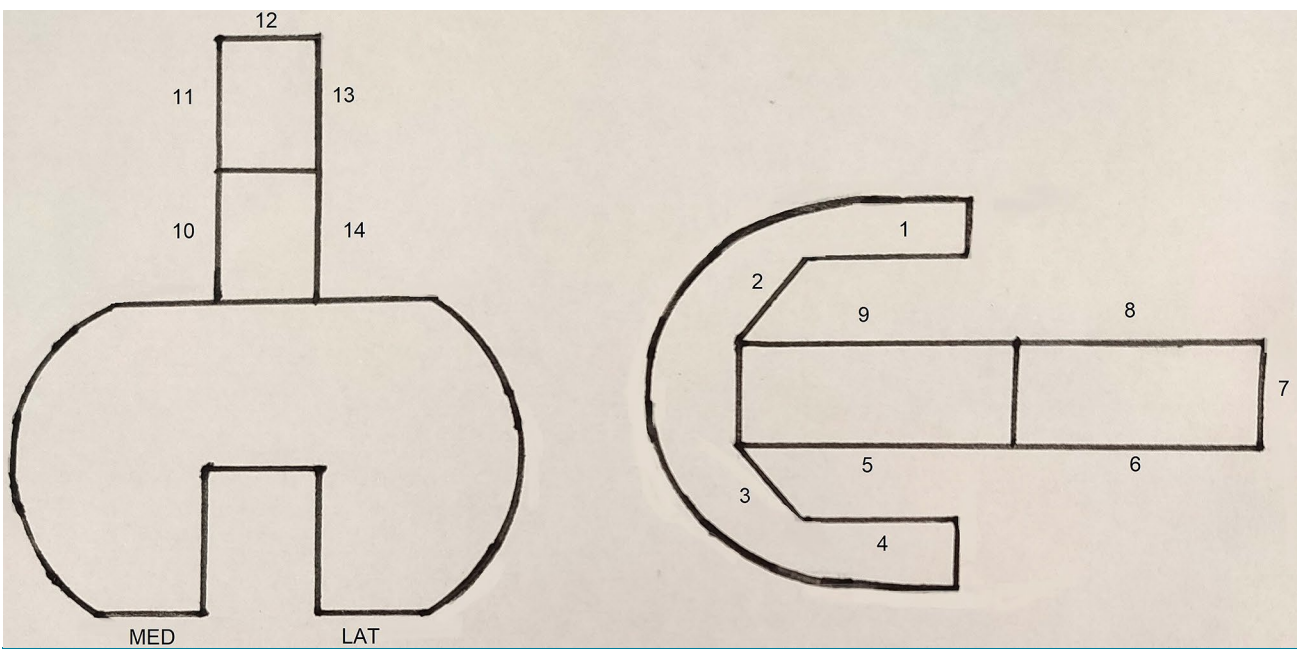

FIGURE 5. Measurement of the thickness of the radiolucent lines (RLLs) in the femoral component of the revision knee prosthesis according to the modified Knee Society radiographic scoring system.

TABLE I
Demographics, radiological features, and clinical outcomes of the patients

	Mean±SD	Range
Demographic data		
Age (year)	67.09±8.36	52-90
Body mass index	35.13±5.57	22-49.9
Follow-up time (month)	55.4±27.97	24-142
Radiological features		
Sagittal alignment of the femoral component (degrees)	1.98±1.91	-4.3-6.1
ACO (mm)	7.83±2.74	0.1-14.6
PCO (mm)	31.45±3.88	22.3-38.6
RLLs	6.49±4.12	1.4-25.4
Functional scoring		
Symptoms-stiffness	74.68±18.9	21-100
Pain	70.7±17.68	33-100
Function in daily life	73.92±17.55	31-100
Function in sports	29.89±20.97	0-90
Quality of life	55.7±25.73	0-100
KOOS	60.94±17	21-98

ACO: Anterior condylar offset; PCO: Posterior condylar offset; RLLs: Radiolucent lines; KOOS: Knee Injury and Osteoarthritis Outcome Score.

The ICC calculated for the measurement of the reproducibility of radiological measurements was 0.9 for the measurement of the sagittal alignment of the femoral component, 0.88 for the measurement of ACO, 0.91 for the measurement of PCO, and 0.89 for the measurement of the RLLs.

There were only two patients (4.3%) who had their femoral component placed in extension on the sagittal plane. According to the correlation analysis, the sagittal alignment of the femoral component did not have a significant effect on radiological loosening (p=0.241) and functional outcomes evaluated by KOOS (p=0.894). In the entire cohort, only nine patients (19.1%) exhibited radiological loosening of the femoral component as indicated by the modified Knee Society Score. The amount of radiological loosening detected using the modified Knee Society Score also did not have a statistically significant effect on the KOOS of the patients (p=0.621).

According to the correlation analysis, there was a moderate and inverse correlation between the sagittal alignment of the femoral component and ACO (r= −0.444, p=0.002). As the flexion of the component increased, ACO decreased. Also, the sagittal alignment of the femoral component did not have a significant effect on PCO (p=0.980). In addition, ACO and PCO did not have a significant effect on KOOS (p=0.699 and p=0.707, respectively) and radiological loosening (p=0.486 and p=0.725, respectively).

The correlation analysis also revealed that the coronal alignment of the femoral component (p=0.966) and the coronal (p=0.779) and sagittal alignment (p=0.763) of the tibial component did not have a significant effect on the radiological loosening of the femoral component (RLLs).

The effect of age, sex, and BMI on RLLs and KOOS is presented in Table II. There was a weak and inverse correlation between BMI and KOOS (r= −0.329, p=0.024), KOOS symptoms-stiffness

TABLE II
The effect of age, sex and BMI on RLLs and KOOS according to Spearman correlation coefficient test

	RLLs	KOOS
	p value	*p* value
Age	0.218	0.336
Sex	0.226	0.321
Body mass index	0.224	0.024

BMI: Body mass index; RLLs: Radiolucent lines; KOOS: Knee Injury and Osteoarthritis Outcome Score.

(r= –0.351, p=0.015), and function in daily life (r= –0.323, p=0.027) subscale scores.

DISCUSSION

There are few studies investigating the role of sagittal component alignment in rTKA in the literature. However, to the best of our knowledge, there is no study evaluating the effect of femoral component sagittal alignment on radiological loosening and PROMs in rTKA. The primary objective of the current study was to evaluate the effects of sagittal alignment of the femoral component on radiological loosening and functional outcomes. Our study results showed that the sagittal alignment of the femoral component had no significant effect on radiological loosening and functional outcomes.

Although there is no study evaluating the relationship between the sagittal alignment of the femoral component and implant loosening in rTKA, there are few studies showing sagittal alignment of the femoral component affects implant survival in primary TKA.[15] It has been shown that placing the femoral component in more than 3° of flexion in TKA is a risk factor for prosthesis failure, and the femoral component should be placed in a sagittal alignment between 0-3° to increase the survival of the knee prosthesis.[16] Nishitani et al.[17] showed that flexion of the femoral component greater than 8.5° in the sagittal plane, in the patients operated with cruciate-retaining (CR) TKA, yielded very poor functional outcomes. In the current study, the femoral component of 10 patients (21.3%) was placed in more than 3° of flexion, while only one patient (2.1%) had the femoral component placed in more than 1° of extension. The relatively low rate of patients with sagittal femoral malalignment and the absence of any patients with severe sagittal malalignment (maximum: 6.1°) may have affected the establishment of a statistically significant relationship between sagittal alignment and radiological loosening.

Although there is no study in the literature evaluating the effect of sagittal alignment of the femoral component on functional outcomes in rTKA, Kazarian et al.[15] reported that there was not enough evidence to prove implant placement (including sagittal alignment) affected PROMs in primary TKA. The authors also concluded that malalignment did not seem to be an important driver for the high rates of patient dissatisfaction. In addition, Huijbregts et al.[18] showed that neither mechanical axis nor component alignment (including sagittal alignment) affected patient satisfaction outcomes one year after TKA. Nishitani et al.[17] associated the placement of the femoral component with slight flexion (approximately 3° to 4°) with the best reported patient satisfaction and functions in CR TKAs. The relatively low rate of patients with sagittal femoral malalignment and the fact that we did not have any patient with severe sagittal malalignment may have affected the establishment of a significant relationship between sagittal alignment and functional outcomes.

In the current study, we showed that radiological loosening according to the modified Knee Society Score did not have a statistically significant effect on the KOOS of the patients. In our literature search, there is no study evaluating PROMs in patients with radiological loosening after rTKA. Indeed, the presence of RLLs does not necessarily indicate the failure of the implant, unless it is progressive. The majority of patients (80.9%) in the current study did not have prosthesis failure and the symptoms in some of the patients with radiological loosening were not advanced. This may be the reason why no statistically significant correlation was found between radiological loosening and KOOS of the patients. Taken together, evaluating the symptoms and making a decision with clinical follow-up is more valuable in deciding prosthesis failure.

The secondary objective of the current study was to evaluate the effect of the sagittal alignment of the femoral component on ACO and PCO. Abnormal knee kinematics has been associated with postoperative patient dissatisfaction and impaired implant survival.[3] Therefore, while evaluating the prosthesis failure and PROMs in revision knee prosthesis, parameters such as ACO and PCO, which may be affected by the sagittal alignment of the femoral component and are expected to affect the knee kinematics, should be considered. In the present study, there was a moderate and inverse correlation between the sagittal alignment of the femoral component and ACO. However, we observed no correlation between the sagittal alignment of the femoral component and PCO. In a study, Ng et al.[10] showed that there was a statistically significant positive correlation between the sagittal alignment of the femoral component and PCO and a negative correlation with ACO in rTKA. In other words, when the flexion of the femoral component increases, PCO increases and ACO decreases. Indeed, ACO and PCO are affected not only by the sagittal alignment of the femoral component, but also affected by the chosen component size. This may be a critical factor in our inability to detect a correlation between the sagittal alignment of the femoral component and PCO.

Increased ACO increases the patellofemoral pressure and causes anterior knee pain.[6] In addition, increased ACO may result in the formation of an overstuffed patellofemoral joint due to the anterior overhang of the femoral component. Although several studies on primary TKAs have reported that overstuffing of the patellofemoral joint had no significant effect on clinical outcomes, this is still an ongoing debate.[19] It is accepted that adequate restoration of PCO is important in rTKA to provide stability in midflexion and to limit posterior tibiofemoral impingement in deep flexion.[4] It has been well documented that increased quadriceps performance and reduction in pain are key elements in almost all functional outcome scoring systems in TKA.[20] Therefore, it is expected that ACO and PCO restoration would have a positive effect on PROMs. Although there are studies in the literature showing that PCO has positive effects on PROMs, some authors have reported that changes in PCO do not affect PROMs.[20] Clement et al.[7] reported that PCO in rTKA patients was an independent predictor of patient satisfaction, while a reduced ACO was associated with better PROMs in rTKAs. On the other hand, Wang et al.[21] reported that PCO did not affect PROMs, particularly in patients who underwent posterior-stabilized (PS) TKA. In the current study, we could not demonstrate that ACO and PCO had a significant effect on functional outcomes. A possible reason for this may be that there was not a significant difference between the PCOs of the patients enough to reveal statistical significance. In many studies performed in patients operated with PS primary knee prosthesis, which is similar to rTKA in terms of stabilization mechanism, there were no significant relationship reported between PCO and PROMs, as in the current study.

Malalignment in the prosthesis can lead to excessive stress on the implanted components and, consequently, higher wear rates. This leads to poor results and high failure rates.[22] Although there are studies in the literature examining the effect of sagittal alignment of the femoral component on loosening in primary TKA,[16,18] there is no study showing the effect of ACO and PCO on radiological loosening in primary or revision TKAs. In the current study, we could not demonstrate that ACO and PCO had a significant effect on radiological loosening. However, the number of patients included in the current study and the rate of patients with radiological loosening were not sufficient enough for an accurate statistical analysis. To evaluate the effect of these parameters, it would be more appropriate to compare data groups containing a large number of patients with normal and abnormal ACO and PCO values.

As a result of the statistical analysis in the current study, age and sex did not affect the radiological loosening of the femoral component (RLL measurement) and the functional outcomes. Studies on the effects of age and sex on implant failure in rTKA have produced conflicting results in the literature.[23-26] Meehan et al.[24] found that the rates of medium and long-term implant failure were higher in young patients (<50 years) undergoing TKA than that in elderly patients. Rosso et al.[25] found no significant relationship between sex and advanced age (>75 years) and the development of RLLs in rTKA. Similarly, some studies have shown that younger patients have lower PROMs in rTKA,[26] whereas others have suggested that there is no relationship between age and PROMs.[25,27] In addition, although there were studies reporting lower PROMs in female patients in rTKA, some studies reported that sex did not affect PROMs.[26,27]

In the present study, BMI did not have a significant effect on radiological loosening (RLL measurement) of the femoral component; however, there was a weak and inverse correlation between BMI and KOOS, KOOS symptoms-stiffness, and function in daily life subscale scores. In the literature, different results have been reached in the studies evaluating the effect of BMI on radiological loosening and PROMs. In a recent study, the authors found that the development of RLLs increased in patients with obesity who underwent rTKA.[26] Conversely, Rosso et al.[25] found that there was no relationship between increased BMI (>30 kg/m^2) and the development of RLLs in rTKA. Additionally, Özcan et al.[28] reported that PROMs were higher in patients with lower BMIs, whereas Kasmire et al.[29] reported lower PROMs in patients with higher BMIs.

Nonetheless, there are some limitations to our study. First, we had a small number of patients, particularly those with radiological loosening. Second, although surgeries were performed following the same surgical steps, they were performed by more than one surgeon. Third, factors such as patient age, physical condition, and bone quality differred among patients; these factors may have affected radiological loosening and functional outcomes. Fourth, different implant designs were used in the patients and implant design may have affected PROMs. The fact that the collateral ligament was not evaluated in the study can be considered as another limitation, since collateral ligament integrity and flexibility may affect the stress

loadings on the prosthesis-bone and cement-bone interface and, thus, prosthesis failure. In addition, retrospective nature of the study is another limiting factor.

In conclusion, our study results showed that sagittal alignment of the femoral component in patients with rTKA did not affect radiological loosening and functional results. Nevertheless, minimal sagittal malalignment in our patient cohort may have affected the establishment of a significant relationship between the sagittal alignment of the femoral component and functional outcomes. While there was a moderate and inverse correlation between the sagittal alignment of the femoral component and ACO in patients who underwent rTKA, there was no statistically significant relationship with PCO. Based on these findings, it can be assumed that changes in the sagittal alignment of the femoral component in revision knee replacement have no effect on prosthesis survival or functional outcomes.

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Ethics Committee Approval: The study protocol was approved by the Metin Sabanci Baltalimani Bone Diseases Training and Research Hospital Medical Specialty Education Board (date: 26.11.2020, no: 65/447). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Study design, writing the article: O.Ç.; Radiological measurement and functional scoring: M.M.; Radiological measurement: A.N.; Clinical evaluations of patients: A.K.; Study desing and evaluating patients: A.O.; Study design and last control: F.D.; Last control: D.K.

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