ORIGINAL ARTICLE

Posterior Condylar Offset Ratio and Anterior Femoral Cut between Anterior and Posterior Referencing Systems in Total Knee Arthroplasty

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Background: The postoperative posterior condylar offset ratio (PCOR) and the anterior femoral cut (AFC) after total knee arthroplasty in the anterior referencing system (ARS) and posterior referencing system (PRS) are controversial.

Objective: To compare PCOR and AFC in both referencing systems.

Materials and Methods: The present study was a retrospective study that included 331 patients with 443 knees that underwent primary PS-TKA. The patients were divided into two groups according to the referencing system. One hundred four knees were selected for the ARS and 104 knees were selected for the PRS by using the systematic sampling method. Preoperative PCOR, postoperative PCOR, and AFC were measured and compared in each group and between groups.

Results: Preoperative PCOR and postoperative PCOR in the ARS and PRS were 0.47 (SD 0.04). Postoperative PCOR in the ARS and PRS were not significantly different (p=0.43). The gaps between the tip of the anterior flange of the femoral component and anterior femoral cortex were 24.04% in the ARS and 28.85% in the PRS, with no statistically significant difference (p=0.43). Anterior femoral notching was not found in either group.

Conclusion: Both ARS and PRS could preserve the PCOR and showed no statistically significant difference in the AFC after total knee arthroplasty.

Keywords: Posterior condylar offset ratio; Anterior referencing system; Posterior referencing system; Anterior femoral cut; Total knee arthroplasty

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The goals of total knee arthroplasty (TKA) are pain relief, deformities correction, good function, good stability, and longevity of the knee prosthesis. The posterior condylar offset (PCO), including tibial slope and joint line, affects knee flexion stability. Alteration of the PCO after TKA causes knee instability. Therefore, preservation of the PCO after TKA should be performed[1-4].

PCO after TKA depends on the level of the posterior condylar cut and the size of the femoral component. The posterior referencing system (PRS) provides a constant level of the posterior condylar cut even if the femoral component is upsized or downsized. In contrast, the anterior femoral system (ARS) provides constant level of the anterior femoral cut (AFC) even if the femoral component is upsized or downsized, but not in the level of the posterior condylar cut.

In situations where distal femoral measurements are in-between size, choosing the large size of the femoral component increases the postoperative PCO while choosing the small size causes reduction the postoperative PCO in the ARS. In the PRS, choosing the large size of the femoral component increases the gap between the tip of the anterior flange of the femoral component and the anterior femoral cortex, while choosing the small size causes anterior femoral notching.

Furthermore, position of the femoral component in the anterior-posterior direction will also affect PCO or AFC as well. Theoretical, anterior positioning of the femoral component causes reduction of PCO while posterior positioning of the femoral component causes anterior femoral notching.

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However, many studies have shown that both the ARS and the PRS are controversial regarding the outcomes of PCO[5-7]. Although measurement of the PCO is inaccurate with different magnifications of the radiograph, the posterior condylar offset ratio (PCOR) is constant even if the measurement is performed at different radiograph magnifications[8]. The present study was designed to compare not only the PCO but also the AFC in both referencing systems. The authors hypothesized that the postoperative PCO and PCOR would be preserved in both the ARS and the PRS. The authors also hypothesized that the AFC problems such as gap or notching, would occur in the PRS more than the ARS.

Materials and Methods

The present study data were collected after obtaining permission from the BUU Ethics Committee for Human Research of Burapha University (Certificate Number 186/2019).

The present study was a retrospective study conducted at the Faculty of Medicine of Burapha University. The data were collected after obtaining permission from the Human Research Ethics Committee (Certificate Number 186/2019). Then, 331 patients with 443 knees that underwent primary posterior-stabilized total knee arthroplasty (PS-TKA) between January 2015 and December 2020 were included in the present study. One knee with valgus osteoarthritis (OA), one knee with posttraumatic OA, three knees with severe knee deformities, three knees with inflammatory polyarthritis, and 142 knees with inadequate radiographs were excluded. Patients were divided into two groups according to the referencing system with 128 knees in the ARS and 155 knees in the PRS. In each group, 104 knees were selected using the systematic sampling method for statistical calculation and analysis (Figure 1). The systematic sampling method was used for the selection of the 104 knees in each group. The sampling interval in the ARS was 128/104 equaled 1.23, which rounded to 1. So, the samplings in the ARS were the knees ordered 1, 2, 3, ..., 104. The sampling interval in the PRS was 155/104 equaled 1.49, which rounded to 1. Thus, the samplings in the PRS were the knees ordered 1, 2, 3, ..., 104.

Surgical technique

All patients undergoing primary TKA were cemented, posterior-stabilized, and received fixed-bearing prostheses. Two surgeons performed the same surgical technique. A pneumatic tourniquet

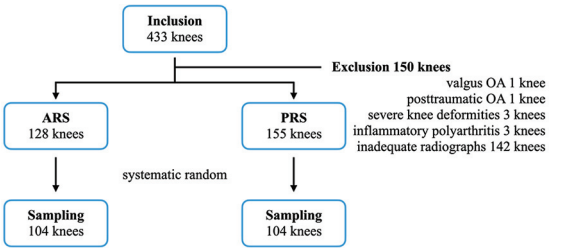

Figure 1. Sample selection and grouping procedures.

was used in all operations, as well as the medial parapatellar approach, and then an intramedullary guide was inserted through the intramedullary canal of the femur and the distal femoral cut was made at a valgus angle, which was 5 degrees, with the cutting block. For the proximal tibial cut, the proximal tibia was cut perpendicular to its anatomical axis with the cutting block oriented by an extramedullary cutting guide, with 3 degrees of posterior slope.

The next step included distal femoral size measurement and posterior condylar cut, and insertion of the measured sizing and rotation guide. It was rotated externally 3 degrees compared with the posterior condylar axis, then the anterior femur and posterior femoral condyle were cut according to the measured size. In case of the measurement was in the in-between size. The large size was chosen if the flexion gap was wider than the extension gap by 2 millimeters in the ARS. The small size was chosen if the flexion gap was not wider than the extension gap by 2 millimeters or if the overhang of the femoral component was more than 3 millimeters medial-lateral. In case of the PRS, the large size was chosen for prevention of anterior femoral notching. The small size was chosen if the overstuff on the patellofemoral joint or overhang of the femoral component was more than 3 millimeters medial-lateral. The cutting block was shifted anteriorly to prevent anterior femoral notching. Then, the anterior femur and posterior femoral condyle were cut.

Patients who underwent TKA in the present study used a different femoral component. The ARS group had four femoral components, Attune® (DePuy, Loughbeg, Ringaskiddy Co. Cork, Ireland) for 49 knees, P.F.C.® Sigma® (DePuy, Warsaw, IN, USA) for 21 knees, NexGen® (Zimmer, Warsaw, IN, USA) for 30 knees, and Persona® (Zimmer, Warsaw, IN, USA) for four knees. The PRS group had two femoral components, Genesis II® (Smith&Nephew, Memphis, TN USA) for 95

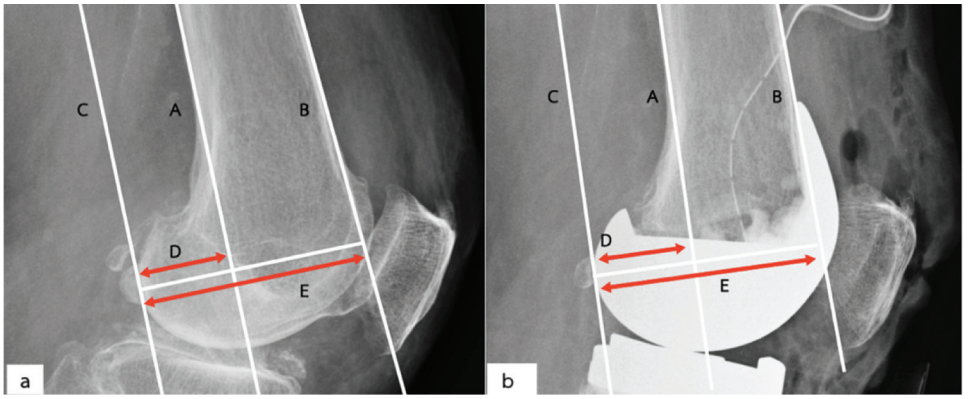

Figure 2. Preoperative (a) and postoperative (b) radiographs show PCO=distance of D and PCOR=ratio of D and E.

PCO, posterior condylar offset; PCOR, posterior condylar offset ratio; A, axis of the posterior femoral shaft cortex; B, axis of the anterior femoral shaft cortex; C, axis that touched the posterior femoral condyle and was parallel to the axis of A; D, distance between the posterior femoral condyle and the axis of A; E, distance between the posterior femoral condyle and the axis of B.

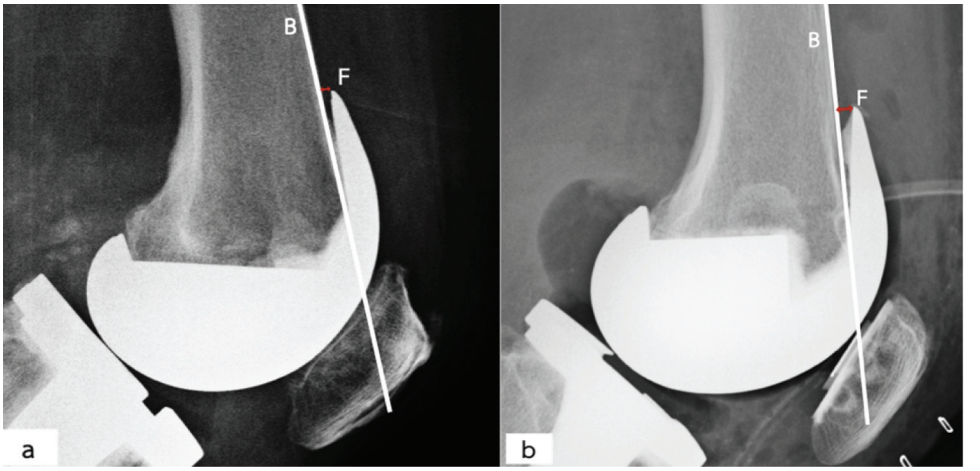

Figure 3. Postoperative radiographs of total knee arthroplasty with the anterior referencing system (a) and posterior referencing system (b) show the gap (F) between the tip of the anterior flange of the femoral component and the anterior femoral cortex.

knees, and Vanguard® (Biomet, Warsaw, IN, USA) for nine knees.

Radiographic measurement

True lateral radiographs of the knee were included in the present study. The "INFINITT PACS" software, version 3.0.11, was used for measurement of the PCO and calculation of the PCOR. The AFC, describing the gap between the tip of the anterior flange and anterior femoral cortex or notching, was measured in a postoperative radiograph (Figure 2). The width of the gap and the depth of notching of more than 1 millimeter were collected and analyzed (Figure 3). The measurements of PCO, PCOR, gap, and notching were collected and analyzed by a single observer. Intrarater reliability, assessed using SPSS version 22 (ICC 3, 1) two-way mixed effects, consistency, and single rater/measurement, was ICC=0.90.

Statistical analysis

Qualitative data such as gender, side of surgery, amount of gap or notching, and amount of PCOR change were presented by distribution of frequency, percentage, and comparative analysis between groups using Pearson's chi-square test.

Quantitative data such as age, PCO, PCOR, gap width, and notching depth were presented as the mean and standard deviation, and comparative analysis within groups or between groups was performed using independent samples t-test by IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk,

NY, USA). A p-value less than 0.05 was considered statistically significant.

Results

The demographic data of both the ARS and PRS groups showed no significant differences in age, gender, or side of surgery. For the PCO, the mean preoperative PCO in the ARS was 27.22 (3.28) mm while PRS was 27.70 (3.05) mm. There was no significant difference. Not only the mean preoperative PCO but also the mean postoperative PCO was not statistically different. The mean postoperative PCO in the ARS was 27.75 (2.68) mm, while in the PRS was 27.59 (2.82) mm.

The mean preoperative PCOR in the ARS and PRS groups was 0.47 (0.04), with no significant difference. This also occurred with the mean of postoperative PCOR in the ARS and PRS groups. The postoperative gaps between the tip of the anterior flange of the femoral component and anterior femoral cortex were 24.04% in the ARS group and 28.85% in the PRS group. There was no postoperative anterior femoral notching in either group (Table 1).

The postoperative PCOR changes were divided into three groups, postoperative PCOR changes less than 0.03 were in the decreased PCOR group, those with 0.03 were in the preserved PCOR group, and those greater than 0.03 were in the increased PCOR group. Most of both the ARS and PRS groups had preserved postoperative PCOR (Table 2).

Table 1. Comparisons of demographic data and radiographic measurements between the ARS and PRS groups

	ARS (n=104)	PRS (n=104)	p-value
Age (year); mean (SD)	67.30 (7.91)	68.91 (6.74)	0.11[a]
Sex (female/male)	91/13	96/8	0.25[b]
Side (right/left)	58/46	54/50	0.58[b]
PCO; mean (SD)			
Preop	27.22 (3.28)	27.70 (3.05)	0.28[a]
Postop	27.75 (2.68)	27.59 (2.82)	0.69[a]
PCOR; mean (SD)			
Preop	0.47 (0.04)	0.47 (0.04)	0.58[a]
Postop	0.47 (0.04)	0.47 (0.04)	0.43[a]
Gap			
Number of samples	25	30	0.43[b]
Mean (SD)	1.6 (0.41)	2.11 (0.80)	<0.05[a]
Amount of anterior femoral notching	0	0	N/A

ARS=anterior referencing system; PRS=posterior referencing system; preop=preoperative; postop=postoperative; PCO=posterior condylar offset; PCOR=posterior condylar offset ratio; SD=standard deviation; gap=distance between the tip of the anterior flange of the femoral component and the anterior femoral cortex; N/A=not applicable

[a] Independent samples t-test, [b] Pearson's chi-square test

Statistical significance was set at $p<0.05$

Table 2. Comparison of postoperative PCOR changes between the ARS and PRS groups

	ARS (n=104); n (%)	PRS (n=104); n (%)
Decreased PCOR	21 (20.2)	25 (24.0)
Preserved PCOR	56 (53.8)	57 (54.8)
Increased PCOR	27 (26.0)	22 (21.2)

ARS=anterior referencing system; PRS=posterior referencing system; PCOR=posterior condylar offset ratio

Discussion

The purpose of the present study was to compare the postoperative PCOR and the AFC of PS-TKA between the ARS and PRS groups. Both groups had no statistically significant differences in postoperative PCOR or AFC with a gap between the tip of the anterior flange of the femoral component and the anterior femoral cortex. No anterior femoral notching was observed in either group.

The postoperative PCOR should be restored or as close as possible before surgery. However, in practice, sometimes the prosthetic size cannot be measured properly. This made it possible to choose a femoral component either with a larger size or a smaller size than the measured size. For ARS prosthetic sizing in the present study, the surgeon selected the large femoral component in the event of an in-between size measurable event to prevent flexion instability, where the posterior cruciate ligament was cut, and the flexion gap was wider than the extension gap[9-11]. However, a smaller femoral component was chosen if the larger femoral component was found to exceed the distal femur by more than 3 millimeters in the medial-lateral direction to prevent overhang[12]. Ordinarily, if a large femoral component was selected, the PCOR was increased. On the other hand, selection of the smaller femoral component also decreased the PCOR. Therefore, in the present study, the PCOR changes were maintained at 53.8%, an increase of 26.0%, and a decrease of 20.2%. Then, the mean PCOR before and after surgery was found to be not significantly different. Previous studies with differing results were found due to different choices of femoral component. Bellemans et al. studied 150 patients undergoing CR-TKA. If the measurement indicated the in-between size, a small femoral component was selected. The preoperative PCO was 25.8 (SD 2.9) mm, and the postoperative PCO was reduced to 23.6 (SD 3.8) mm[1]. However, Wang et al. studied 89 patients undergoing PS-TKA.

If the measurement was between sizes, a large prosthesis was chosen. If the femoral component was larger than 2 to 3 mm, measured medial-laterally, the surgeon would choose a small prosthesis. Thus, after surgery, there were 31 knee reductions in the PCO and 58 knee augmentations in the PCO[2].

In PRS prosthetic sizing, the level of the posterior condylar cut was always fixed and, even if there was an in-between size, a small prosthesis was selected, which resulted in an increased AFC. On the other hand, if a larger prosthesis was selected, the AFC decreased, which did not affect the PCOR changes. However, in the present study, the PCOR increased and decreased in the PRS group because the surgeon used the technique of shifting the position of the femoral component during surgery. In cases of in-between size, the surgeon selected a larger femoral component. If there was an overstuff of the patellofemoral joint, the surgeon shifted the femoral component backward to reduce its impact, thus resulting in an increase in PCOR. At that time, if the selected large femoral component exceeded the medial-lateral distal femur by 3 millimeters, the surgeon selected a smaller femoral component. Then, the surgeon used the technique of sliding the femoral component forward to prevent anterior femoral notching. Consequently, the results of the present study revealed that the postoperative PCOR was restored at 54.8%, an increase of 21.2% and a decrease of 24.0%, resulting in no significant difference in the mean values of the PCOR before and after surgery.

As a result, the study comparing the PCOR between the ARS and the PRS was not statistically significant. Consistent with a study by Chang et al., a retrospective study of PS-TKA patients in South Korea compared the PCOR between 93 knees in the ARS and 91 knees in the PRS[13]. The postoperative PCOR was not significantly different between the two groups. In the study, it was found that in the case of in-between size measurements, a larger implant size was chosen in both the ARS and PRS groups. However, in the PRS group, if there was a tendency to overstuff, a small substitute would be considered, which was in line with the present study.

Additionally, a retrospective study by Almeida and Vilaça compared the PCOR in 66 patients with ARS and 91 patients with PRS TKA in Portugal[7]. There was no statistically significant difference in the postoperative PCOR of either group. It was found that the femoral component shift technique was used in the case of in-between size.

Nojiri et al. conducted a prospective study in Japan to compare the PCO between the ARS and PRS groups[14]. Seventeen patients received one-day bilateral TKA with in-between size prosthetic measurements. ARS was used on one side and PRS on the other. In the ARS, a smaller femoral component was selected, whereas in the PRS, a larger femoral component was selected. There were no significant differences in postoperative PCO between groups.

Degen et al. performed a retrospective study of 970 PS-TKA patients with both ARS and PRS[15]. Most of the postoperative PCOs were maintained at 59.6%. There was a 25.3% decrease and a 15.1% increase. However, the study did not compare the changes in PCO between the ARS and PRS groups, so the details of each group were unknown. The majority (59.6%) maintained PCO, consistent with Chang et al.[13], and consistent with the present study, the majority of postoperative PCOR values remained restored.

However, the authors found a previous study that yielded different results from those obtained in the present study. Lee et al. compared prospective studies in South Korea of patients undergoing PS-TKA between the ARS and PRS groups(5). The postoperative PCOR was significantly higher in the PRS group than in the ARS group at 0.54 (SD 0.03) and 0.52 (SD 0.04), respectively. It was found that, with in-between size measurements, the smaller femoral component was chosen in the ARS group, but the larger femoral component was chosen in the PRS group. It was also found in the study by Nojiri et al. that in the in-between size group, postoperative PCO in the PRS was statistical significantly greater than in the ARS at 31.2 (SD 2.9) mm. and 28.7 (SD 3.3) mm, respectively. In the ARS, a small femoral component was selected, but in the PRS, a larger femoral component was selected[14]. In addition, there were more studies with postoperative PCO in the ARS than in the PRS. Han et al. conducted a prospective study in 20 patients with bilateral PS-TKA in South Korea[6]. A randomized controlled trial in one knee was performed as an ARS, and as a PRS in the other knee. The PCO was measured using computed tomography. There was more postoperative PCO than before surgery in both the ARS and PRS groups, but the postoperative PCO in the ARS group was significantly higher than that in the PRS group. It was found that in the surgical procedure, if the prosthesis was in-between size, the ARS group was determined by the difference between the flexion gap and the extension gap. If the flexion gap was wider

than the extension gap by more than 2 millimeters, a larger prosthesis was used. In the PRS group, a large prosthesis was always used. Therefore, the postoperative PCO was higher in the ARS group than in the PRS group.

The present study found that there were gaps between the tip of the anterior flange of the femoral component and the anterior femoral cortex in the ARS with 24.04% and in the PRS with 28.85%. The average gap width in the PRS, at 2.1 (SD 0.8) millimeters, was wider than that in the ARS at 1.6 (SD 0.4) millimeters. Unlike the study by Lee et al., the incidence of gaps in the ARS (48.1%) was higher than that in the PRS (13.1%)[5]. These gaps could be described. In the ARS, due to the placement of the prosthesis, the femoral component had a greater flexion angle than the angle of the anterior flange. In the PRS, if a large femoral component was selected as in-between size, there was a chance of a gap after surgery as well.

Anterior femoral notching, if there was a depth of 3 millimeters or more was one of the risk factors for a supracondylar periprosthetic fracture[16-18]. The present study found no anterior femoral notching in either group, which was consistent with the theory of ARS. For the PRS, if a smaller femoral component was selected, the surgeon shifted the position of the femoral component forward to avoid this problem.

The limitation of the present study was that six different femoral components were used. They included different posterior condylar thicknesses such as P.F.C.® Sigma® 7.6 millimeters thick, NexGen®, and 10 millimeters thick. There was a difference in width between adjacent prosthesis sizes such as Persona® has a width between sizes of 2 millimeters, and Genesis II® has a width between sizes of 4 millimeters. They had different anterior flange angles of the prosthesis such as Genesis II® has a 3-degree angle and Attune® has a 5-degree angle. In addition, the equipment used in surgery was different. However, the present study used a measured resection technique in which the posterior condylar cut was equal to the thickness of the posterior condyle of the replaced femoral component. The angle of the AFC was equal to the angle of the anterior flange of the prosthesis. Therefore, if the distal femoral size measurement was equal to the size of the femoral component, the PCOR and the AFC were not different. However, in the in-between size measurement group, different size selections and placement of the femoral components would have different effects on the PCOR or the AFC, as discussed above.

Conclusion

TKA by ARS and PRS resulted in preservation of postoperative PCOR, which was not significantly different. There were no statistically significant differences in the gap between the anterior femoral component and the anterior femoral cortex in either group at 24.04% in the ARS group and 28.85% in the PRS group. No anterior femoral notching was found in either group.

What is already known on this topic?

Different femoral component size selection resulted in different postoperative PCO or PCOR in the ARS but resulted in different postoperative AFC in the PRS.

What this study adds?

This study shows the outcome comparing between ARS and PRS in postoperative PCO or PCOR and postoperative gap between the tip of the anterior flange of the femoral component and the anterior femoral cortex, or anterior femoral notching. This study only focuses on radiographic findings but not on clinical outcomes.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

AP analyzed and interpreted the patient data regarding the outcomes of PCOR and AFC and was a major contributor in writing the manuscript. TY performed the data collection. All authors read and approved the final manuscript.

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Conflicts of interest

The authors declare that they have no competing interests.

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