

Effect of Femoral Resection on Coronal Overall Alignment after Conventional Total Knee Arthroplasty

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Abstract

Background: A good postoperative alignment in total knee arthroplasty (TKA) is the key to achieving satisfactory results. We assessed the effect of femoral and tibial resection on the overall alignment after conventional TKA.

Methods: We conducted a retrospective analysis of 212 primary TKAs in 188 patients. Intramedullary (IM)-guided resection was applied on the femoral side while extramedullary (EM)-guided resection was used on the tibial side. Using full-length X-ray, the preoperative femoral valgus angle and lower extremity alignment, as well as 2-week postoperative femoral and tibial prosthetic coronal alignment and overall lower extremity alignment, were measured.

Results: Postoperatively, good prosthetic alignment was achieved in 191 cases (90.1%) on the tibial side and in 144 cases (67.9%) on the femoral side ($\chi^2 = 5.441$, $P = 0.02$). Multiple linear regression analysis was used to assess the effect of different alignment sides on the overall alignment in the coronal plane. Data were divided into five subgroups based on the valgus or varus status of the prostheses. The standardized regression coefficients of the femoral and tibial prosthetic alignment on the overall alignment were 0.666 and 0.414, respectively; in varus on both sides were 0.658 and 0.377, respectively; in valgus, 0.555 and 0.030; femoral side varus and tibial side valgus, 0.702 and 0.211; femoral side valgus and tibial side varus, -0.416 and 0.287. The study showed that the overall low extremity alignment was statistically influenced by the prosthetic alignment, except for the tibial prosthetic alignment when femoral prosthesis was in valgus ($P = 0.153$).

Conclusions: In conventional TKA, tibial side EM-guided resection may offer satisfactory postoperative alignment, and femoral resection relying on IM guide may lead to more undesirable results. Postoperative coronal alignment is mainly affected by the femoral resection. Therefore, femoral side operation should receive adequate attention from the surgeons.

Key words: Accuracy; Conventional Resection; Extramedullary Guide; Intramedullary Guide; Prosthetic Coronal Alignment; Total Knee Arthroplasty

INTRODUCTION

Total knee arthroplasty (TKA) is a successful treatment applied worldwide for end-stage osteoarthritis. A good postoperative alignment is the foundation of achieving satisfactory treatment results and longevity of the prostheses.^[1,2] In conventional TKA, bone cutting is guided by an intramedullary (IM) system on the femoral side and an extramedullary (EM) system on the tibial side. In general, IM guide is more precise compared to EM guide placed on the same site.^[3] Lower extremity coronal alignment after conventional TKA is often considered to be affected by tibial side more than the femoral side. However, this conception has not yet been supported by definitive data. In this study,

we conducted a retrospective analysis of imaging data of TKA finished by the same surgical team, and compared the effect of IM-guided resection for femoral side and EM-guided resection for tibial side on postoperative coronal alignment. In addition, we examined the rate of satisfactory postoperative alignment for the two different types of cutting guide system.

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METHODS

General information

This was a retrospective cohort study. We included patients with end-stage degenerative osteoarthritis treated with primary TKA. We excluded patients with external joint deformity, including prior trauma or osteotomy history of lower extremity, abnormal condition resulted from other diseases (such as Blount's, Paget's, tertiary syphilis, or rickets). Moreover, patients with limited motion of hip or ankle before surgery or contraction of knee extension 2 weeks after surgery, which would affect the quality full-length leg X-ray imaging, were also excluded. The selected images in our study were demand in high quality. Especially, the full-length X-ray should be finished in neutral position without knee flexion or rotation of lower extremity, which indicates that the anterior edge of tibial plateau could cover the posterior edge, and the proximity of tibia and fibula head should be overlapped a little, and the patella is in the middle or slightly lateral position of trochlea groove in the film.

Surgical method and postoperative management

A midline incision was made anterior to the knee in all patients, and the joint capsule was entered through an incision medial to the patella. A pneumatic tourniquet inflated at 300–320 mmHg (1 mmHg = 0.133 kPa) was used in the standard manner for hemostasis before making the incision and maintained until the end of the surgery. It was released only once after bone cutting, before the placement of prosthesis. Femoral resection was guided using an IM system. The IM entry point was chosen to be on the Whiteside's line (femoral anteroposterior axis), 1 cm above the terminal end of the medial border of the posterior cruciate ligament. The valgus angle of the IM rod was determined based on preoperative measurements. Tibial resection was achieved using an EM guide system. The proximal pin was placed on the connecting lines between the medial edge of the lateral intercondylar spine and the medial third of the tibial tuberosity. As reference, anatomical landmarks were used the medial third of the tibial tuberosity, the proximal tibial spine, and the anterior tibial tendon. We chose an open intercondylar designed prosthesis (Genesis II, Smith and Nephew, Memphis, USA). No patient received patellar replacement, and all surgeries were finished by the same surgical team. The main attending surgeon had a caseload >200 TKAs per year for 10 consecutive years.

Measurements

The coronal mechanical axis alignment and femoral valgus angle were measured on preoperative, full-length radiographs [Figure 1]. Two weeks after surgery, the femoral prosthesis was measured on full-length radiographs. The alignment was defined by the angle formed by the connecting line between the medial and lateral condyle and the perpendicular line to the mechanical axis of the lower limb. Likewise, the angle

formed by the tibial prosthetic platform and the vertical mechanical axial line of the tibia was measured to define the tibial prosthetic alignment [Figure 2]. A varus angle was defined as positive (+) and a valgus angle was defined as negative (–). TKAs with alignments within the limit of $\pm 3^\circ$ were considered satisfactory.

Statistical analysis

The statistical analysis was achieved by the SPSS 19.0 statistical software (IBM Corp., Armonk, NY, USA). We chose the mean and standard deviation (SD) to describe normally distributed measurement data, as well as median, along with minimum and maximum values for describing measurement data that were not normally distributed. Number of cases and percentage were used to describe counted data. The angles of alignment were presented in absolute values. The hypothesis of counted data was analyzed by Chi-square test. Multiple linear regression analysis was applied to analyze factors related to the overall alignment of the lower extremity. Two-tailed $P < 0.05$ was considered statistically significant.

RESULTS

Data were collected continuously between June 2014 and December 2014, from 195 patients who underwent primary TKA at Peking University Third Hospital. Seven patients were excluded due to low quality full-length lower extremity radiographs 2 weeks after surgery; therefore, 188 cases were included in the study. Among 188 patients included in the study, 22 were male and 166 were female. The average age was 65.8 years (range 49–85 years). A total of 212 TKAs were completed. Left- and right-sided procedures were equally represented. In the study group, 196 cases had varus knee preoperatively, with the varus angle (mean \pm SD) $11.78 \pm 5.54^\circ$, and 16 cases had valgus knee, with the valgus angle $10.28 \pm 8.36^\circ$ [Table 1].



Figure 1: Preoperative full-length leg X-ray, the femoral mechanical axis was showed as Line A, and Line B indicated the tibial mechanical axis, the angle between Line A and B was the angle of lower extremity mechanical axis.

Radiographs of all 212 TKAs were measured. Coronal alignment was within the range of $\pm 3^\circ$ in 144 cases with femoral side prostheses alignment and 191 cases with tibial side prostheses alignment. Satisfactory rates were 67.9% and 90.1%, respectively. The paired Chi-square test on the satisfactory rate of the two groups showed that the difference was statistically significant ($P = 0.02$) [Table 2].

Multiple linear regression analysis was applied, where dependent variables were determined by postoperative coronal alignment of the lower extremities, and independent variables were set as the coronal prosthetic alignment on the femoral and tibial sides. Results showed that femoral side prosthesis alignment had greater effect on overall lower extremity alignment than the tibial side. The standardized regression coefficient for femoral side was 0.666 and for tibial side was 0.414 ($P < 0.001$). Subgroup analysis was conducted based on the varus or valgus status of the prostheses. In case of both femoral and tibial side varus, the standardized regression coefficients were as follows: femoral side = 0.658 ($P < 0.001$) and tibial side = 0.377 ($P < 0.001$). In case of both femoral and tibial side valgus, the standardized regression coefficients were as follows: femoral side = 0.555 ($P = 0.010$) and tibial side = 0.030 ($P = 0.880$). In case of the femoral side varus and the tibial side valgus, the standardized regression coefficients were as follows: femoral

side = 0.702 ($P < 0.001$) and tibial side = 0.211 ($P = 0.034$). Finally, in case of the femoral side valgus and the tibial side varus, the standardized regression coefficients were as follows: femoral side = 0.416 ($P = 0.043$) and tibial side = 0.287 ($P = 0.153$). Analysis of each subgroup showed that femoral side alignment had greater effect on the postoperative coronal alignment of the lower extremity [Table 3].

DISCUSSION

A good prosthesis alignment after TKA is an important factor to ensure postoperative function, patient satisfaction, and prosthesis longevity.^[2,4,5] Precise bone cutting is the prerequisite for achieving good prosthetic alignment. Conventional TKA techniques rely on IM guide system on femoral side and EM guide system on tibial side. To the best of our knowledge, no studies comparing the effects of these two different methods on postoperative lower extremity coronal alignment exist.

Using the medial third of tibial tuberosity and the anterior tibial tendon as the proximal and distal reference marks is a common method used currently for tibial EM resection. A good postoperative alignment been reported in literature using this method. Chiu *et al.* defined satisfactory alignment as within the range of $\pm 3^\circ$, and the rate of satisfactory alignment was 78.7%.^[6] Among scholars who defined satisfactory alignment as within the range of $\pm 4^\circ$, Ishii *et al.* reported a rate of satisfactory alignment in 88% of cases,^[7] Teter *et al.* in 92% of cases,^[8] and Maestro *et al.* in 84% of cases.^[9] We defined satisfactory coronal alignment as within $\pm 3^\circ$, and we had 90.1% of patients with satisfactory postoperative alignment, which was consistent with previous literature reports.

It is generally believed that IM guide has higher accuracy compared with EM system at the same site. Reed *et al.* found in their analysis of 100 cases of TKA radiographs that tibial side IM-guided resection had an accuracy rate of 85%, but EM-guided resection had an accuracy rate of 65%.^[10] Cashman *et al.* also showed that tibial IM-guided resection had significantly more accurate postoperative coronal alignment compared with the EM.^[3] However, comparison between femoral side IM guide and tibial side EM guide failed to show the expected superior rate of satisfactory



Figure 2: Postoperative full-length leg X-ray, the bottom line of the tibial prosthetic platform was presented as Line c, and the vertical line of line c was named Line d, which crossed Line B forming the angle to evaluate the prosthetic coronal position. The femoral prosthetic alignment was defined by the angle formed by the connecting line between the medial and lateral condyle Line e and the perpendicular line to the mechanical axis of the lower limb Line A (Line f).

Table 1: General information of patients

Variables	Results
TKA (n)	212
Number of patients (n)	188
Gender (male:female)	22:166
Age (years)	65.8 (range 49–85)
Side (left:right)	1:1
Preoperative varus:valgus	196:16
Preoperative varus (degrees \pm SD)	11.78 \pm 5.54
Preoperative valgus (degrees \pm SD)	10.28 \pm 8.36

SD: Standard deviation; TKA: Total knee arthroplasty.

Table 2: Satisfactory postoperative alignment of femoral and tibial prosthesis (number of cases)

Items	Tibial side		Total	χ^2	P
	Satisfactory alignment	Unsatisfactory alignment			
Femoral side satisfactory alignment	125	19	144		
Femoral side unsatisfactory alignment	66	2	68	5.441	0.02
Total	191	21	212		

Table 3: Multivariate regression analysis of the effect of tibial side and femoral side prosthesis alignment on overall alignment

Prosthesis	Regression coefficient <i>r</i> (correlation)	Standardized regression coefficient β (effect size)	<i>t</i>	<i>P</i>
Total				
Femur	0.867	0.666	16.066	<0.001
Tibia	0.838	0.414	9.983	<0.001
Both varus				
Femur	0.962	0.658	10.869	<0.001
Tibia	0.946	0.377	6.224	<0.001
Both valgus				
Femur	1.104	0.555	2.867	0.010
Tibia	0.101	0.030	0.153	0.880
Femur varus	1.068	0.702	7.248	0.000
Tibia valgus	0.616	0.211	2.180	0.034
Femur valgus	-0.777	-0.416	-2.156	0.043
Tibia varus	0.709	0.287	1.486	0.153

postoperative alignment. Moon *et al.* reported that in their study of 154 surgical cases, in which IM guide was used, 34 cases had unsatisfactory femoral side postoperative alignment, and the rate of satisfactory alignment was 77%.^[11] Although Laskin *et al.* reported that 96% of patients with IM-guided resection had satisfactory femoral side alignment, this rate decreased to 72% in obese patients or patients with large medullary cavities.^[12] Our rate of satisfactory postoperative coronal alignment was 67.9%, which was significantly inferior to the results of the tibial side.

Previous studies investigated the causes of unsatisfactory femoral side alignment. Teter *et al.* reported that the curve in the distal third of the femur could cause inaccuracies in IM-guided resection.^[8] The study by Yau *et al.* supports this conclusion.^[13] They also noted a higher incidence of this type of coronal femoral curve in Chinese patients with end-stage osteoarthritis. This may be a possible cause for the unsatisfactory femoral prosthetic alignment in our study. Locating the femoral medullary entry point can also cause errors in bone cutting, leading to unsatisfactory postoperative alignment.^[8] By measuring 40 lower extremity radiographs, Reed *et al.* noted that 6.6 mm medial to the trochlear notch is the ideal medullary entry point in line with the coronal anatomical axis.^[14] The studies from Mihalko *et al.* on cadavers showed that only the sagittal alignment of the prosthesis was affected in case of three different medullar

entry points on the same femoral anteroposterior axis. The coronal alignments, on the other hand, did not show any statistical difference.^[15] Novotny *et al.* conducted studies on 45 cadavers and pointed out that the ideal coronal medullary entry point is where the ratio of the distance between the entry point and the distal lateral femoral cortex, and the overall diameter equals 0.53.^[16] In addition, effects of sex and lower extremity alignment on orientation of knee have been discussed in previous study,^[17] which indicated that the entry point of femur might be different between men and women. We selected a fixed position based on the clinical experience of surgeon as an entry point of femur, which might be a potential reason causing the error of bone cutting. Measuring the femoral morphology in the front view of X-ray to adjust the position of entry point is a method worth considering; more studies need to be done to confirm this assumption in further time. The diameter and length of the IM rods are other factors that can affect the accuracy of femoral coronal alignment.^[18] In Novotny *et al.*'s study, an increase in the diameter of the IM rod from 8 mm to 9 mm and length from 101.6 mm to 228.6 mm can decrease the coronal alignment maximum potential error from 5.78° to 0.66°.^[16] Thus, many factors can affect the accuracy of femoral IM-guided resection.

The results of this study showed that whether it is the overall alignment or various scenarios of the subgroups, postoperative coronal alignment is mainly affected by femoral side IM-guided resection. Noteworthy study results showed that when femoral prostheses had valgus placement, tibial side alignment had no effect on lower extremity postoperative coronal alignment ($P > 0.05$, clearly no statistical significance). Insufficient sample size after subdividing may have affected the results. Therefore, this conclusion will need to be confirmed by further studies with a larger sample size.

The significance of this retrospective, observational study is that it analyzed, for the first time, the effect of femoral and tibial side bone cutting on postoperative alignment, and noted that postoperative coronal alignment is mainly affected by femoral side IM-guided resection. In addition, our preliminary results suggest that the incidence of unsatisfactory postoperative femoral side alignment may be higher. Different factors, such as the distal curve of the femur, wrong medullary entry point, and inappropriate IM rod diameter and length, may all contribute to unsatisfactory femoral side alignment. Given that femoral side IM guide procedure is affected by so many factors, surgeons

should pay closer attention. The X-ray films in this study were affected by the rotation of lower extremity and the preoperative contraction of knee extension. Although we controlled the quality of our radiographs, as a retrospective study, we were unable to completely eliminate this effect on our results. Therefore, this study has certain limitations. In future, the results with a larger sample size should be analyzed by the difference valgus angle of femoral cutting guide and the preoperative contraction of knee extension in subdivided groups, to avoid the improper conclusion caused by the deviation data.

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Conflicts of interest

There are no conflicts of interest.

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