

# Coronal Alignment in Total Knee Arthroplasty

## Just How Important is it?

David M. Fang, MD,\* Merrill A. Ritter, MD,† and Kenneth E. Davis, MS†

**Abstract:** A recent study has challenged the premise that well-aligned total knee arthroplasties (TKAs) have better survival than outliers. This study examines the importance of overall coronal alignment as a predictor for revision. Patients with primary TKAs were stratified into neutral, varus, and valgus alignment groups based on the postoperative tibiofemoral angle. In 6070 knees (3992 patients), there were 51 failures (0.84%): 21 (0.5%) in the neutral group, 18 (1.8%) in the varus group, and 12 (1.5%) in the valgus group. The best survival was for overall alignment between 2.4° and 7.2° of valgus. Varus knees failed primarily by medial tibia collapse, whereas valgus knees failed from ligament instability. Outliers in overall alignment have a higher rate of revision than well-aligned knees. The goal of TKA should be to restore alignment within 2.4° to 7.2° of valgus.

**Keywords:** coronal alignment, total knee arthroplasty, revision.

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There is surprisingly little evidence to support the widely held assumption that restoring the coronal alignment in total knee arthroplasty (TKA) leads to improved function and longevity. Moreover, most of the supporting literature is based on historic prosthesis designs. Lotke and Ecker [1] showed that good clinical results were correlated with a well positioned geometric TKA. Moreland [2] believed that prosthesis malalignment was a major cause of component loosening and instability. Bargren et al [3] found that the Freeman Swanson (ICLH) knee failed at lower compressive loads and had a higher rate of clinical failure when aligned in varus. Ritter showed that the posterior cruciate condylar TKA should be aligned in neutral or slight valgus for improved survival [4]. Jeffrey et al [5] demonstrated that restoring the mechanical axis of the lower extremity through the center of the knee resulted in a more durable implant (Denham knee).

A recent study by Parratte et al [6] examining three modern knee designs has challenged the premise that restoring the coronal alignment improves implant durability. Although there was no statistical difference between outliers in mechanical alignment and well

aligned knees, the trend was towards fewer revisions in the outliers (94% vs 96% at 15 years).

The current study is an extension of the study by Berend et al [7], which found that varus positioning of the tibia was associated with an increase in failure by medial tibial collapse. This study differs in that it contains six years of additional patients and follow-up to the original study and examines all mechanical failures and not only tibial sided failures. The purpose of this retrospective study was to determine, in a large series of patients with long term follow-up, if correcting the normal coronal alignment is necessary with modern implants.

### Materials and Methods

Between 1983 and 2006, six thousand seventy (6070) consecutive primary TKAs in 3992 patients were performed. Intraoperative alignment was achieved as previously described [8]. The femoral component was aligned to 5° of valgus using an intramedullary femoral guide. The proximal tibial cut was made perpendicular to the mechanical axis of the tibia using an extramedullary guide. Final intraoperative confirmation of overall tibial alignment was verified using a long rod through the center of the tibial insert. All patients who had a minimum of 2 years of follow-up, and adequate radiographs were included in the study. The sample demographics are shown in Table 1. Preoperative and postoperative radiographs were obtained at 2 months, 6 months, 1 year, and every 2 to 3 years thereafter, with all measurements made by the attending surgeon using a handheld goniometer. The overall anatomic tibiofemoral angle and the femoral and tibial component position were measured on standard length, standing

From the \*Department of Orthopaedic Surgery, Indiana University School of Medicine, Indianapolis, Indiana; and †Center for Hip and Knee Surgery, Mooresville, Indiana.

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Reprint requests: David Fang, MD, 541 Clinical Drive, Suite 600, Indianapolis, IN 46202-5111.

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**Table 1.** Sample Demographics

	Mean ( $\pm$ SD)	Range
Age	70.1 years ( $\pm$ 8.6)	21-93
Female	2,436 (61.0%)	
Male	1,556 (39.0%)	
Body mass index	30.0 ( $\pm$ 5.5)	16.5-64.3
Diagnosis		
Osteoarthritis	5,803 (95.6%)	
Rheumatoid	187 (3.1%)	
Osteonecrosis	65 (2.1%)	
Other	15 (0.3%)	
Prosthesis		
Anatomically Graduated Components	100%	

anteroposterior knee radiographs measuring 14  $\times$  17 in. A cemented cruciate-retaining, metal-backed, nonmodular tibial implant with compression-molded polyethylene Anatomically Graduated Components (Biomet, Warsaw, Ind) was used in all cases.

Patients were stratified into three groups based on the postoperative tibiofemoral angle: a normal alignment group within 1 SD of the mean anatomical tibiofemoral angle, a varus group less than 1 SD, and a valgus group more than 1 SD above the mean angle. Patients were similarly stratified based on tibial component position into neutral, varus, and valgus groups. Failure was defined as any revision surgery not related to infection, including medial tibial collapse, progressive radiolucency, and functional instability. Postoperative radiographs and operative notes were reviewed for all revision cases to determine the mechanism of failure.

All statistical analysis was performed using SAS (SAS Institute, Cary, NC). Survival probabilities were given by

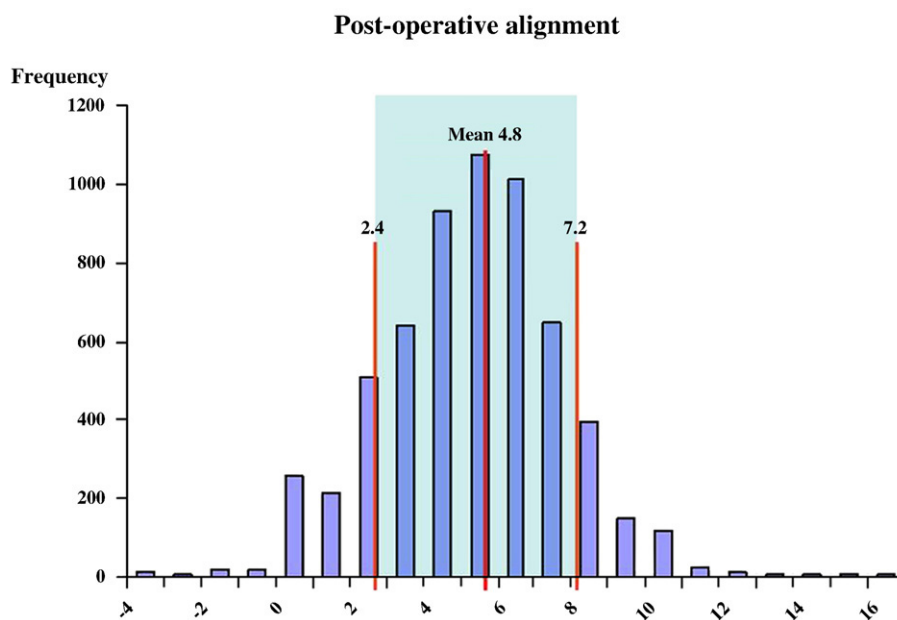
Kaplan-Meier survivor analysis, with mechanical failure requiring revision as the end point. Cox regression with forward, backward, and stepwise selection procedure was performed on age, sex, body mass index, overall anatomical alignment angle, and tibial component position. Odds ratios were reported with corresponding *P* values and a significance level of .05.

## Results

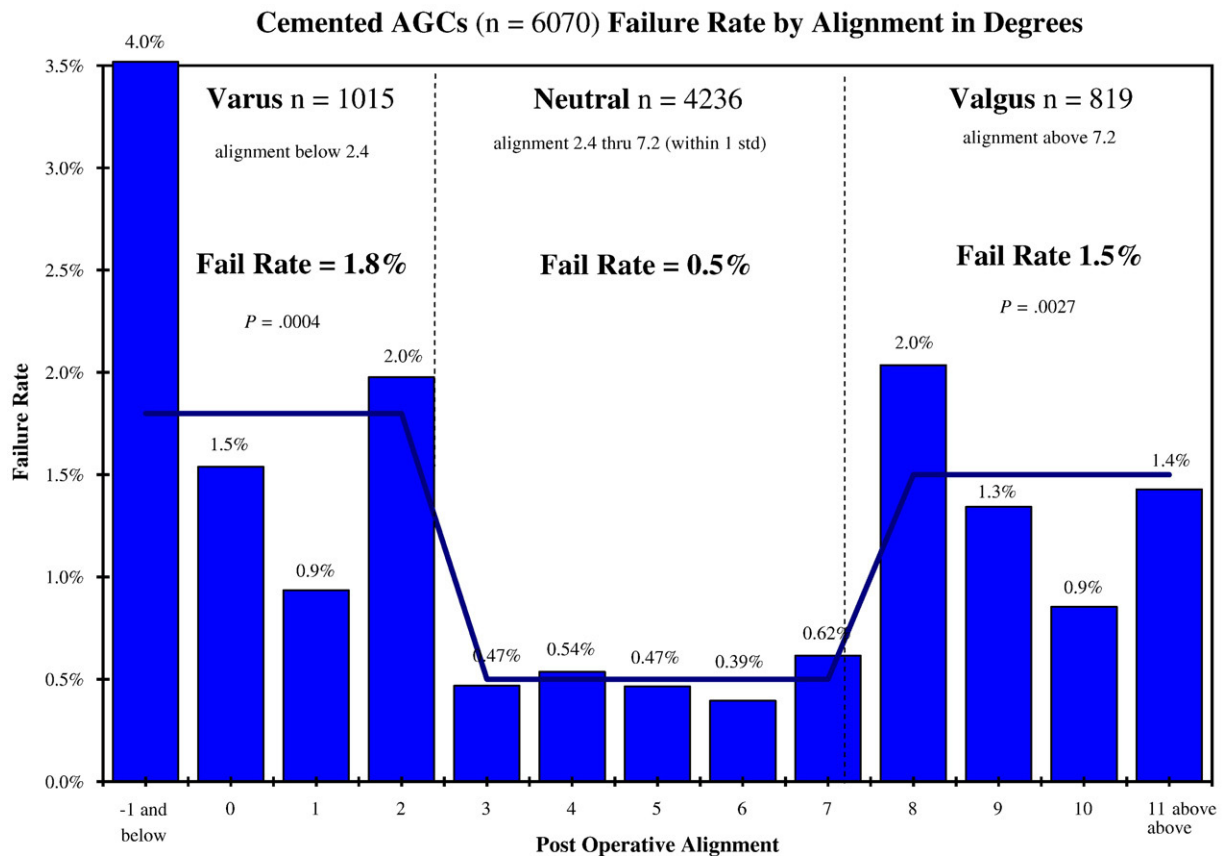
The average follow up was  $6.6 \pm 3.5$  years (range, 2-22.5 years). During the study, 1118 (28.0%) patients died. The mean preoperative alignment was  $0.1^\circ$  varus ( $\pm 7.7^\circ$ ) (range,  $25^\circ$  varus to  $35^\circ$  valgus); however, there was no difference in survival based on preoperative varus, valgus, or neutral alignment. The mean postoperative tibiofemoral angle was  $4.8^\circ$  ( $\pm 2.5^\circ$ ) valgus. There were 4236 patients (69%) in the normal alignment group within 1 SD of the mean tibiofemoral angle ( $2.4^\circ$ - $7.2^\circ$  valgus) (see Fig. 1). The mean tibial component position was  $90.4^\circ$  ( $\pm 2.1^\circ$ ).

There were 51 (0.84%) failures in the 6070 knees. Of these revisions, 40 (78%) were on the tibia side only, 7 (14%) were on the femoral side only, and 4 (8%) were due to failures on both the tibia and femoral side. The average time to failure was  $5.5 (\pm 3.7)$  years (range, 0.6-14.0 years).

The revision rate for the neutral alignment group was significantly lower at 0.5% (21/4029), compared to 1.8% (18/1222) for the varus group ( $P = .0017$ ) and 1.5% (12/819) for the valgus group ( $P = .0028$ ). The failure rate was equally low for each degree within the neutral alignment group, which includes a range of approximately  $5^\circ$  (Fig. 2). At 20 years, the survival rate was 99%, compared to 95% for the varus group and



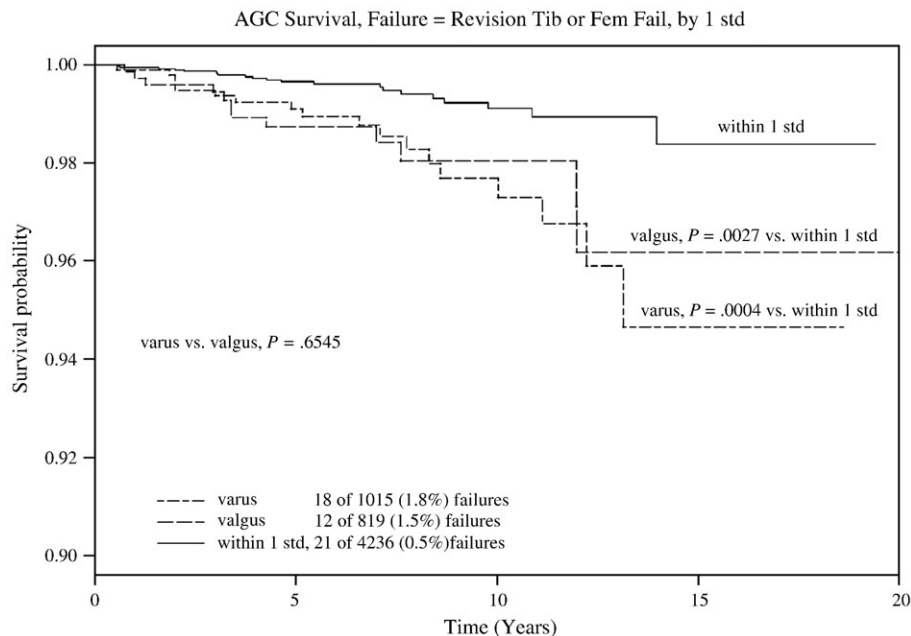
**Fig. 1.** Postoperative alignment followed an normal distribution, with 4236 patients (69%) in the normal alignment group within one standard deviation of the mean tibiofemoral angle.



**Fig. 2.** There was a significantly lower rate of revision for TKAs for all degrees between 3° and 7° of valgus of overall coronal alignment.

97% for the valgus group during the same period (Fig. 3). Thirteen of the eighteen of the varus side failures (72%) were due to medial tibial collapse. This

corresponded to a 6.9 times increased risk of failure by medial tibial collapse in varus knees compared to those that were properly aligned ( $P < .0001$ ). Of the twelve



**Fig. 3.** This Kaplan-Meier survival curve shows that well aligned TKAs had a statistically better survival than knees aligned in varus or valgus.

valgus-sided failures, five were attributed to instability (42%), with a 3.7 times increased risk compared to normal aligned knees ( $P = .02$ ). Older age was also a significant factor for improved prosthesis survival ( $P < .0001$ ). Sex and body mass index were not associated with revision surgery.

Using Cox regression analysis with forward, backward, and stepwise selection, varus tibial component position was not a stronger or more significant predictor for tibial collapse than overall varus alignment. Varus tibial alignment was found to be only associated with a 2.8 times increased risk of failure by medial tibial collapse (odds ratio, 3.0;  $P = .04$ ), compared to a 6.9 times risk for tibial collapse based on overall varus alignment ( $P < .0001$ ). The backward elimination  $P$  values for varus tibial alignment in favor of overall varus alignment were  $P = .3410$  for tibial collapse,  $P = 0.7054$  for any tibial failure, and  $P = .3118$  for tibial or femoral failure. Although the association between tibial collapse and varus tibial alignment observed by Berend et al [7] was confirmed in this study, varus tibial alignment alone did not explain any additional failure beyond that of overall alignment.

## Discussion

The function and durability of total knee replacement is determined by a combination of patient-, implant-, and surgeon-related factors. One of the important variables controlled by the surgeon is proper positioning of the individual components and the resulting overall alignment of the lower extremity. Preoperative alignment did not have an impact on implant survival. Rather, postoperative alignment was the chief predictor of failure and revision surgery, regardless of the preoperative alignment in varus, valgus, or neutral. The results from this study reaffirm the fundamental principle that a well aligned TKA has better longevity than one placed in varus or valgus.

There is no consensus whether the anatomic or mechanical axis should be used to describe overall coronal alignment. The "normal" alignment of the knee is generally considered to be an anatomic tibiofemoral angle of 7° to 9° of valgus or a mechanical axis that falls through the middle third of the knee. Nevertheless, Insall [9] believed that the mechanical axis should lie lateral to the center of the knee in valgus, whereas Townley [10] believed that the mechanical axis should lie medial to the center of the knee in varus. Standing full-length lower extremity radiographs have been the gold standard for assessing overall limb alignment, but they are not necessary or routinely obtained because of the added cost and technical difficulty of obtaining accurate films. Previous studies have shown that the anatomic and mechanical axes are directly correlated, and there is no significant difference between measurements from standard knee and hip to ankle films [11,12]. This

result was validated at our institution in a subset of 188 patients who received both long leg and standard length films postoperatively, and the manuscript has been submitted for publication. The correlation coefficient between the tibiofemoral angle and mechanical axis was 0.9 [13] ( $P < .01$ ). Therefore, overall alignment can be accurately evaluated using standard length knee films.

This study included approximately six additional years of data and twice the number of patients to the data presented in the Berend et al [7] study. During this time, there were three additional tibial failures. The correlation between tibial collapse and varus alignment was also observed in the present study; however, overall tibiofemoral alignment was a stronger predictor of failure than tibial component position alone. Berend et al reported that the negative effect of a varus tibia on survival may be partially compensated for by increasing the femoral component valgus [7]. This finding supports the relative importance of overall coronal alignment over tibial component position. The effect of femoral component alignment is currently being investigated and appears to be a significant independent predictor of survival; however, further investigation is needed to determine the relative importance of femoral, tibial, and overall coronal alignment. The importance of femoral component position is beyond the scope of this study but will be addressed in future research and publications.

The conclusion that a poorly aligned knee is more durable cannot be drawn from the recent study by Parratte et al [6]. Although their study examined 399 knees with 35 mechanical failures, the results did not reach statistical significance and were potentially underpowered. This study included a much larger series of patients and found that there was a statistically and clinically significant difference in survival based on overall alignment. The power of this study should also overcome potential confounding variables and differences in study design, such as those between surgeons and implants, as well as measuring the anatomic vs the mechanical axis.

Postoperative alignment is the most important surgeon-controlled factor in determining the durability of TKA. Although the difference in revision rate between well-aligned and poorly aligned knees may seem small, 99.5% compared to 98.5%, respectively, given the number of TKAs performed each year, this would translate into many potentially avoidable revision surgeries. The results of this study show that there is not a single ideal target degree for coronal alignment, but rather, a wide range of approximately 5° that can be achieved without the need for computer navigation. However, the decision to use navigation ultimately requires individual scrutiny of postoperative alignment and clinical outcomes to consistently reproduce the ideal coronal alignment

2.4° to 7.2° of valgus and the best survival of total knee implants.

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