Neutral Mechanical Alignment: A Requirement for Successful TKA: Affirms

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abstract

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Restoration of an overall neutral mechanical axis has been a long-held tenet in total knee arthroplasty (TKA). Numerous biomechanical, finite element, and clinical studies have demonstrated that coronal malalignment, particularly varus, is associated with increased strain, higher failure rates, and, in some cases, poorer outcomes. With advances in computer-assisted navigation, 3-dimensional imaging, and patient-specific positioning guides, the potential for greater precision in bone resection and component positioning has rekindled interest in this important issue. Several recently published studies demonstrating no difference in survivorship for malaligned TKAs have challenged the concept of an alignment safe zone. Some surgeons have discussed a paradigm shift in defining optimal alignment. While we agree that compared to several decades ago, there is greater understanding of TKA kinematics and that broad targets for alignment may not impart significant benefit as a dichotomous variable, there are multiple reasons why neutral alignment and classic bone cuts remain valid and important in delivering a successful TKA. In comparison to the preponderance of evidence advocating a neutral mechanical axis and approximately 5° to 7° valgus anatomic alignment, there is insufficient support for reasonably choosing any other target. Although technology has improved surgical precision, it has not eliminated the human factor, and aiming for neutral provides the safest margin for error. The foremost objective of TKA is a durable and well-functioning joint, not necessarily one that replicates normal or the patient’s native condition. While the latter goal is certainly desirable, the priority of the former should never be overlooked.

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Figure: The surgical technique for TKA aims to restore an overall neutral mechanical axis (right knee), which extends from the center of the femoral head to the center of the ankle and passes through the anatomic center of the knee, and achieve approximately 5° to 7° valgus tibiofemoral anatomic alignment (left knee).
Restoring an overall neutral mechanical axis that extends from the center of the femoral head to the center of the ankle and passes through the anatomic center of the knee, as well as achieving approximately 5° to 7° valgus tibiofemoral anatomic alignment have been long-held tenets in total knee arthroplasty (TKA) (Figure). Recent advances in computer-assisted navigation, 3-dimensional imaging, and patient-specific positioning guides have provided surgeons greater precision in bone resection and component positioning. While conventional instrumentation with intramedullary guides have performed adequately over the past 4 decades, the potential for achieving accurate alignment and reducing outliers has never been better than it is now.

However, several recently published studies demonstrating no significant difference in survivorship for malaligned TKAs have challenged the concept of a generic safe zone, traditionally ±3° from neutral.\textsuperscript{1,2} Additionally, some surgeons have discussed a paradigm shift in defining optimal coronal alignment and component position.\textsuperscript{3,4} Undoubtedly, compared to several decades ago, the current understanding of native and artificial knee kinematics is far greater, but we believe that there are multiple reasons why neutral alignment and classic bone cuts remain valid and important in delivering a successful TKA to our patients.

There is prodigious evidence supporting the concept of neutral coronal alignment and numerous contemporary biomechanical,\textsuperscript{5} finite element,\textsuperscript{6} and clinical studies\textsuperscript{7-9} have demonstrated that malalignment, particularly varus, is associated with increased strain, higher failure rates, and, in many cases, poorer outcomes. Green et al\textsuperscript{5} revealed a posteromedial hot spot of concentrated strain in the proximal tibia associated with 5° of tibial component varus. Neutral alignment was thought to have a protective effect by more even distribution of strain. These findings were corroborated by a finite element analysis\textsuperscript{6} demonstrating the greatest increase in maximum von Mises and contact stress for varus tibial tilt compared to other malalignment conditions. Clinically, this was evinced in a study of 3152 TKAs that found medial bone collapse as the predominant mode of tibial component failure and that significant risk factors included, in order of importance, varus tibial alignment >3° from neutral, body mass index (BMI) >33.7, and overall postoperative varus limb alignment.\textsuperscript{7} An extension of the same study, including 6070 TKAs, demonstrated significantly higher rates of revision in patients with >1 standard deviation varus or valgus malalignment. Of note, while varus knees failed by medial tibial collapse, valgus knees primarily failed from ligamentous instability.\textsuperscript{7} In a series of 1030 patients, Mahoney\textsuperscript{8} reported that for each degree of mechanical varus, the risk of failure rose 4.6-fold, and for >3° outliers, the odds ratio was at least 69. An additional study, using postoperative computed tomography, supported superior function and more rapid rehabilitation in patients with better individual component alignment.\textsuperscript{8}

The basis for challenging the fundamental premise of a coronal safe zone rests predominately on 2 recent studies. Parratte et al\textsuperscript{2} examined the 15-year survival rate of 398 TKAs and found that mechanical alignment in 292 cases did not confer a significant advantage in clinical outcomes compared to malalignment (±3°) in 106 cases. Outliers, however, whether varus or valgus, were grouped together, and the relative failure rate was not reported.\textsuperscript{10} Similar to Parratte et al,\textsuperscript{2} we recognize that while assessment of alignment as a dichotomous variable (aligned vs malaligned) is limited and may only serve as a general guideline, “one cannot and should not infer from or extrapolate from these findings to uniformly state that alignment is not important after TKA.”\textsuperscript{11} In a smaller study, Matziolis et al\textsuperscript{12} found no difference in implant survival or patient outcome between aligned TKA and a subset of varus outliers. Only 30 malaligned cases were examined, and there were no revisions in either group. Likewise, the authors emphasized that “correct component alignment should be intended in every case.”\textsuperscript{12} Indeed, the determination of ultimate TKA performance is multifactorial of which coronal alignment is only one, albeit important, aspect.
Critics of older studies and historical support for a coronal safe zone often cite the limitations of standard short-film knee radiographs. Nevertheless, no consensus exists on whether normal alignment of the knee should be described using tibiofemoral anatomic or mechanical axes or the relationship between the overall mechanical axis and the center of the knee. Studies have found that there is high correlation between all 3 of these parameters. Furthermore, the mechanical axes can, remarkably, be successfully approximated using knee radiographs.

The reproducibility of bone resection and component positioning is an important practical consideration. Although technology has significantly mitigated human error, 9% tibiofemoral, 4.9% femoral component, and 4% tibial component mechanical outliers remain even with computer-assisted navigation. To aim for and achieve a “slight degree” of overall varus, one would have to account for compounding or compensatory deviation of both the proximal tibia and distal femur, not to mention the ligamentous balancing and rotational effects. The margin for error would be decreased as well; a 3° to 4° varus error combined with a 3° varus target would likely be more problematic than if a neutral target had been chosen. Additionally, there is no substantial evidence that any alignment other than neutral confers a significant advantage.

The foremost objective of TKA is a durable and well-functioning joint, not necessarily one that replicates normal or the patient’s native condition. While the latter goal is desirable, the priority of the former should never be overlooked. The observation that there is variation in normal alignment is not new, and it is well recognized that achieving optimum biomechanical conditions for the prosthesis may require ligamentous balancing. Because the anterior cruciate ligament and menisci are excised, a TKA may never feel completely normal to patients, but this does not preclude success. The so-called “conflict” with healthy, noncontracted medial soft tissues induced by correcting a mildly varus patient to neutral with a TKA should not be resolved by leaving the patient in varus with a TKA. These patients are often candidates for a unicompartmental knee arthroplasty. Alternatively, if a TKA is chosen, small degrees of varus are typically corrected without medial release. Patients with significant preoperative varus deformities cannot be left in such alignment after TKA and release of contracted medial structures is unavoidable.

Restoration of a neutral mechanical axis is a requirement for successful TKA. It alone will not guarantee excellent outcomes, but a preponderance of historical and contemporary data demonstrate the detrimental effects of malalignment. As recent and emerging technology continues to refine our surgical precision, we can continue to refine our understanding of native and artificial knee kinematics in all planes. However, neutral coronal alignment is currently the gold standard, and selecting a different target without a compelling reason and conclusive evidence may prove to be a step backward in surgical evolution.

REFERENCES


