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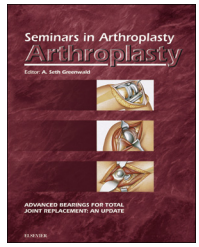

Neutral mechanical alignment: Stickin' with the one that brung ya—Opposes

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ABSTRACT

Total knee arthroplasty is a safe and reproducible procedure for the treatment of arthritis. Despite increased use and modern techniques, there remains up to a 20% rate of patient dissatisfaction for reasons unexplained in the literature. One hypothesis is that universally targeting a neutral, mechanical alignment rather than taking a more individualized approach to patient alignment may contribute to patient dissatisfaction. Constitutional varus and kinematic alignment techniques aim to match patient anatomy more closely in total knee arthroplasty and are discussed in detail in this review.

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1. Introduction

Total knee arthroplasty (TKA) is a safe and reproducible procedure for the treatment of pain and dysfunction secondary to knee arthritis. TKA is estimated to increase by more 600% by the year 2030 to over three million procedures yearly [1]. Despite the advent of advanced materials, improvements in implant design and surgical technique, 20–30% of patients who undergo total knee arthroplasty report some degree of dissatisfaction with their result [2,3]. Although most would argue that a total knee replacement is an effective treatment for end stage arthritis, it is important to continue to challenge currently practiced techniques and aim to improve patient satisfaction [4]. This article examines the currently held principle that total knee arthroplasty should be performed with an aim toward component placement perpendicular to the mechanical axis of the lower extremity with an overall hip-knee-ankle alignment within $0 \pm 3^{\circ}$ (a "neutral" mechanical alignment).

1.1. *Mechanical alignment: questioning the status quo*

The long-held principle that a neutral mechanical alignment of the lower extremity leads to increased implant survival, increased restoration of function and patient satisfaction has recently been questioned [5–8]. Recent studies have demonstrated dissatisfaction to persist even in accurately aligned prostheses as compared to those that fall outside a neutral, mechanical alignment [9]. Furthermore, a 2010 study by Paratte et al. demonstrated no difference between "well-aligned" and "outlier" TKAs for aseptic mechanical loosening and component survivorship at 15-year follow-up [10].

New technologies such as robotic assisted, patient specific, and navigated surgery present an opportunity to accurately attain alignment targets [9]. However, increased accuracy in achieving a neutral, mechanical alignment has not consistently led to improved survivorship or clinical outcomes. In a prospective, randomized controlled trial of 520 patients who underwent a computer-navigated TKA for one knee and a conventional TKA for the other, Kim et al. found no difference in component survivorship, knee function, pain, or Western Ontario and McMaster Universities Osteoarthritis Index at 10 years postoperatively [9]. Thus, in light of continued inconsistent satisfaction in TKA despite techniques that increase the accuracy of achieving a neutral, mechanical alignment, one must ask whether our targets in TKA are correct.

Achieving a neutral, mechanical alignment and joint line perpendicular to the mechanical axis usually involves a shift

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from the patient's anatomic alignment. This method omits patient specific factors such as preoperative alignment, gait, patient habitus and joint axis and aims at one homogeneous target for all-comers.

It stands to reason, that if patients present with variable mechanical axes prior to surgery, that perhaps a more individualized approach to alignment merits investigation. In a study of young asymptomatic adults, Bellemans et al. showed that 32% of included male patients and 17% of female patients demonstrated three or more degrees of genu varum at skeletal maturity [8]. Similarly, Nam et al. in an evaluation of 200 asymptomatic adults using 3-dimensional, weight-bearing images corrected for rotation found 19.5% of patients to have a varus and 10.5% to have a valgus overall HKA alignment [11]. Such studies suggest that targeting a neutral, mechanical alignment in all patients often alters the natural kinematics of the knee and, thus, may not be desirable. To this end, "constitutional varus" and the concept of kinematic alignment have gained popularity.

1.2. *Constitutional varus*

"Constitutional varus" as coined by Bellamans, and kinematic alignment, first referenced in 2008, are similar as both include anatomic considerations when balancing the knee rather than a strict emphasis on a neutral, mechanical alignment [8]. Constitutional varus as a surgical technique, refers to the maintenance of the preoperative anatomic axis by under-correction of hip-knee-ankle alignment thereby leaving a preoperative varus knee in its natural alignment [8].

In a study of 132 patients with preoperative varus alignment with a mean follow-up of 7 years, Calomel et. al demonstrate superior clinical outcomes in patients with a slight undercorrection of native varus (3°–6°) [12]. Although only a mid-term study, they did not show a difference in survivorship based on mild varus. Meneghini et al. refuted this conclusion in a recent study. They found no difference in postoperative outcomes at 1-year follow-up between mechanically aligned knees and those left in mild varus. It is important to note, however, that this study did not assess lower extremity alignment with hip-knee ankle films but with short knee radiographs [13]. As they appropriately reference in their discussion, there can be up to 33% error in this method of assessment [14]. In a recent investigation using full-length hip-knee-ankle radiographs in a series of 256 patients undergoing TKA with a preoperative varus deformity, Rames et al. found no difference in postoperative clinical outcomes based on the postoperative alignment category (severe varus, mild varus, neutral, or valgus) or category of joint line obliquity [15]. Although not yet well studied in its own right, the idea of constitutional varus suggests that we are not aiming for the right target in total knee arthroplasty and that closer adherence to native anatomy and, as will be discussed, native kinematics, may hold merit.

1.3. *Kinematic alignment: Restoring native anatomy*

Kinematic alignment aims to restore the native femoral axis and kinematics of the knee [16–18]. Specifically, kinematic alignment aims to restore the three kinematic axes of the knee. These include the transverse axis of the femur about which the tibia flexes and extends, the transverse axis of the femur about which the patella flexes and extends, and finally, the longitudinal axis about which the tibia internally and externally rotates about the femur. Each of these axes lies either perpendicular or parallel to the native joint line throughout arc of motion [6,16,19].

A mechanically aligned knee aims to align the femur and tibia perpendicular to the mechanical axis of the knee thus necessitating a change in the angle of the joint line [20]. This angle change may cause a change in the tension of the collateral ligaments, cruciates and capsule that leads to abnormal kinematics. Eckhoff and Howell independently show that abnormal kinematics may lead to instability, motion loss, and uneven load sharing between compartments. Arthroplasty that targets the native joint line minimizes the consequences of a change in kinematics about the knee [6,17,18].

1.4. *Brief technique of kinematic alignment*

In order to restore the transverse axis of the tibia and patella about the femur as well as the longitudinal axis of the knee retaining the native angle of the joint line, the following three assumptions are made. First, normal cartilage thickness is 2 mm; second, there is not significant bony wear; and finally, there are no fixed ligament contractures. These assumptions pertain to kinematic alignment in its purest form although many surgeons will modify the procedure on a case by case basis should these assumptions not be met [21].

Both the distal and posterior femoral cuts are performed with an aim to have the thickness of the femoral resections match the thickness of the femoral implant after accounting for cartilage wear and kerf of the saw blade. After the femoral cuts are complete, the tibial cut is performed to match the femur to achieve an overall kinematic balance.

As compared to traditional mechanical alignment, kinematic alignment results in femoral component valgus and internal rotation, tibial component varus, and a mean, overall hip knee ankle alignment that often remains neutral [22]. As compared to the native femoral axes, results of kinematic total knee arthroplasty demonstrate near congruence with preoperatively measured posterior condylar axis and approximately four degrees of internal rotation relative to the transepicondylar axis of the knee [14]. Internal rotation of four degrees relative to the transepicondylar axis is significant in that this is the difference between the TEA and the cylindrical axis found by Eckhoff et al. and suggests that kinematic technique may better estimate the native axis of the knee [18].

1.5. *History and results of kinematic alignment*

Kinematic knee replacement was first employed in the setting of knee resurfacing with the porous coated anatomic knee system approved for use in 1984 [23]. In this, first, experience with kinematic alignment, the Porous Coated Anatomic Knee showed early failures due to medial tibial subsidence [24]. However, several outliers with regard to alignment were reported in this patient cohort and thus