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Does standing limb alignment after total knee arthroplasty predict dynamic alignment and knee loading during gait?

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ABSTRACT

Background: A principle of TKA is to achieve a neutral standing coronal alignment of the limb (HKA angle) to reduce risks of implant loosening, reduce polyethylene wear, and optimize patellar tracking. Several long-term studies have questioned this because the relationship between alignment and implant survivorship is weaker than previously reported. We hypothesize that standing HKA poorly predicts implant failure because it does not predict dynamic HKA, dynamic adduction moment, and loading of the knee during gait. Therefore, the aim of our study is to assess the relationship between the standing and the dynamic (gait activity) HKAs.
Methods: A prospective study on a cohort of 35 patients treated with a posterior-stabilized TKA for primary osteoarthritis. Three months after surgery each patient had a long-leg radiograph and the limb was classified as neutrally aligned (17 patients), varus aligned (nine patients), or valgus aligned (four patients). Patients then performed a gait analysis for level walking.
Results: Standing HKA has a moderate correlation with the peak dynamic varus ($r = 0.318$, $p = 0.001$) and the mean and peak adduction moments ($r = 0.31$ and $r = -0.352$ respectively). No significant correlation between standing HKA and the mean dynamic coronal alignment ($r = 0.14$, $p = 0.449$). No differences were found for dynamic frontal parameters (dynamic HKA and adduction moment) between patients defined as neutrally or varus aligned.
Conclusions: The standing HKA after TKA was of little value to predict dynamic behaviour of the limb during gait, this may explain why standing coronal alignment after TKA may have limited influence on long-term implant fixation and wear.

1. Introduction

Total knee arthroplasty (TKA) aims to correct varus–valgus deformity via tibio-femoral realignment and alleviate pain via joint resurfacing. The rational for tibio-femoral realignment to neutral standing coronal alignment (0° ± 3°) is to reduce the adduction moment that could improve long-term survivorship of the implant, reduce polyethylene wear and optimize patellar tracking [1]. This belief came from basic biomechanical analysis of the knee in the standing position and also from extrapolation of results from gait analysis studies done on patients with knee OA that showed a strong correlation between standing coronal alignment and dynamic coronal alignment and the adduction moment [2]. Recent literature found little or no evidence to confirm superiority in long-term survivorship of neutrally aligned TKA (0° ± 3°) compared to other alignment groups [3,4]. These results concur

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with another observation that outlier-aligned TKAs are found in up to 30% of the TKA cohort [5–8] whereas long-term loosening rate in published studies and registers remains very low. In contrast, Ritter et al. found an increased rate of failure when femoral component is in >8° of anatomical valgus and when the tibial component is in varus [9], and Collier et al. reported significantly greater polyethylene wear in the medial compartment when the limb was aligned in >5° of varus [10]. These contrasting observations highlight the fact that standing (or static) coronal alignment of TKA alone may not be a reliable predictor of long-term survival rate as previously expected.

Dynamic assessment of TKA with the use of gait analysis has shown that TKA reduces varus deformity and adduction moments during level walking tasks [11]. While there is evidence that knee adduction torque is highly correlated with medial compartment loading [12], many publications have raised questions relating to the pertinence of the post-operative standing coronal alignment (obtained by double leg, weight bearing, long leg radiographs) in predicting the dynamic adduction moment [13–16]. Orishimo et al. [13] did not find any correlation between standing or dynamic (walking task) coronal alignment of TKA with peak adduction moments; even when a standing neutral alignment was restored, a high knee adduction moment still remained. Similarly there is controversy about the hypothesis that the standing coronal alignment can predict the dynamic load distribution on the tibial plateau during gait. On the one hand, Halder et al. [14] found on five patients with instrumented TKAs that 70% of the load was transmitted to the medial compartment for level walking tasks; there was a significant linear correlation between medial tibial plateau loading and standing coronal alignment with a deviation of one degree varus (from neutral alignment) increasing the medial load by five percent. In contrast to this, Miller et al. [16] found, using a computational model of 15 well functioning TKAs, that neutral alignment produced balanced loading between the tibial plateaus in the standing position but not during walking tasks; also they found no significant correlation between standing coronal alignment and mean dynamic medial plateau loading. Therefore, it seems that standing frontal alignment alone is not a sufficient explanation of dynamic loading patterns because there are dynamic phenomena as well (compensatory gait adaptations), which probably play a major role. Indeed, dynamic loading may be also affected by limb position, muscle contraction, soft-tissue stability, and walking speed. It is therefore possible that standing coronal alignment does not predict the dynamic alignment of the limb and the dynamic adduction moment at the knee, and this would explain why the standing coronal alignment of the limb poorly predicts implant failure in the long-term.

Accordingly, the present study aims to determine whether: 1) Does standing coronal alignment of a "mechanically aligned TKA" predict dynamic coronal alignment during stance phase?, 2) Does standing coronal alignment of a "mechanically aligned TKA" predict the adduction moment during stance phase?, and 3) Are "dynamic frontal parameters during the stance phase" (Hip Knee Ankle (HKA) angle & adduction moment) different between patients defined as inliers or outliers for standing coronal alignment?

2. Material and method

We performed a prospective non-comparative study, commencing in August 2012. Patients receiving a TKA had their standing coronal limb alignment assessed on a long leg plain radiograph and their dynamic coronal limb alignment and adduction moment assessed in a gait laboratory. Data were collected and analysed by an independent observer. The study protocol and consent forms were approved by the Institutional Review Board and the local research ethics committee (identification number 2011-015714-21) and, before participation, all subjects provided informed consent.

2.1. Participants

All patients scheduled between August and December 2012 to undergo unilateral primary TKA for primary OA were asked to participate in the study. Patients were excluded if they had a previous knee or other lower limb joint replacement, vascular or neurological disease. Thirty-five patients were finally included in this study. All had satisfactory results after TKA and were able to walk without assistive devices and without pain when the gait analysis was performed. After last follow-up at three months post-operatively, the mean flexion was 120° (min 110, max 130, standard deviation (SD) = 8) and the mean fixed flexion deformity was two degrees (min 0°, max 10°, SD 4.2) with five patients having <5° fixed flexion deformity (FFD) and three patients having five to 10° FFD. The demographics data, the pre- and post-operative HKA angles for every patient, and the flow-chart of patients are respectively displayed in Table 1 and Figures 1, and 2.

Table 1
Demographic characteristics of postoperative alignment groups.

	Overall	Neutrally-aligned group	Varus-aligned group	Valgus-aligned group
Number of subjects	35	22	9	4
Male gender	18	12	5	1
Age (SD—min/max)	71 (8—35/84)	74 (7—62/84)	65 (7.8—55/79)	57 (15.4—35/69)
BMI (SD)	29 (4.5)	29 (4.7)	31 (4)	27 (4)
Side (right/left)	17/18	8/14	5/4	4/0
Mean preoperative static HKA (SD—min/max)	174 (7.1—160/192)	175 (6—160/187)	171 (5.2—164/178)	189 (2.5—186/192)
Mean postoperative static HKA (SD—min/max)	179 (4.6—171/190)	179 (1.6—177/182)	174 (1.7—171/176)	187 (3.4—184/190)