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Mechanical vs Arithmetic Definitions of Coronal Plane Alignment of the Knee (CPAK) Measures Have Different Distributions: An Assessment of 3947 Cases

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Abstract

The Coronal Plane Alignment of the Knee (CPAK) classification has been used to describe healthy and arthritic knee alignment as well as to predict phenotypes which could benefit from kinematic alignment using soft tissue balancing during TKA. At our institution, we have access to a large database of navigated TKA procedures including intra and postoperative mechanical hip-knee-ankle angle (mHKA) measurements, which are defined differently than the aHKA. It has been previously recognized that these alternative, but related, measures of coronal alignment may have different distributions. The primary aim of this study was therefore to determine if the CPAK classification frequencies described in the original publication by MacDessi et al. for the aHKA are similar to frequencies acquired using the mHKA. A secondary aim was to categorise postoperative TKA alignment at our institution utilising the mHKA-based CPAK classification.

We analysed data from 3947 total knee arthroplasty procedures undertaken using surgical navigation at our institution between March 2007 and October 2022. The mHKA was measured directly during the registration process while JLO was calculated using the mHKA and LDFA (JLO = HKA + 2xLDFA). This was completed twice for each case using the pre and postoperative mHKA and LDFA. Each case was then categorized as one of the nine CPAK phenotypes.

The pre-operative mean mHKA was 2.0º varus using surgical navigation (compared to 0.8º varus reported by Macdessi et al. using the aHKA). The pre-operative mean JLO

was 175º (versus 174º). Using the mHKA as opposed to the aHKA resulted in more knees being categorized as Class I (34.0% vs 19.4%) or Class IV (17.5% vs 19.8%) and fewer in Class II (19.0% vs 32.2%) and Class V (6.3% vs 14.6%). All other differences in class frequencies were within 4%. For postoperative CPAK classification, a large majority of knees (72.7%) were categorized as Class V.

Our study using mHKA determined during navigated TKA showed that the majority of preoperative arthritic knees were Class I, II, and IV in contrast to the original CPAK publication where most preoperative knees were Class I, II, and III. For TKAs at our institution, the goal was to mechanically align knees to neutral mHKA and JLO. This reflects in our postoperative results in that 73% of all postoperative TKAs were categorized as Class V.

1 Introduction

The Coronal Plane Alignment of the Knee (CPAK) classification [1] has been used to describe healthy and arthritic knee alignment as well as to predict phenotypes which could benefit from kinematic alignment using soft tissue balancing during TKA. The original CPAK classification was based on long-leg radiograph analyses of 500 healthy and 500 arthritic knees. It described nine basic phenotypes depending on the arithmetic hip-knee-ankle angle (aHKA) and joint line obliquity (JLO). At our institution, we have access to a large database of navigated TKA procedures including intra and postoperative mechanical hip-knee-ankle angle (mHKA) measurements, which are defined differently than the aHKA. It has been previously recognized that these alternative, but related, measures of coronal alignment may have different distributions [1,3]. The primary aim of this study was therefore to determine if the CPAK classification frequencies described in the original publication by MacDessi et al. for the aHKA are similar to frequencies acquired using the mHKA. A secondary aim was to categorise postoperative TKA alignment at our institution utilising the mHKA-based CPAK classification.

2 Methods

We analysed data from 3947 total knee arthroplasty procedures undertaken using surgical navigation at our institution between March 2007 and October 2022. CPAK boundaries were determined to be as follows: a neutral mHKA as 0° ± 2° and a neutral JLO as 180° ± 3°. To determine the CPAK class for each knee, mHKA was measured directly during the registration process while JLO was calculated using the mHKA and lateral distal femoral angle (LDFA): JLO = HKA + 2xLDFA. This was completed twice for each case using the pre- and postoperative mHKA and LDFA. Each case was then categorized as one of the nine CPAK phenotypes according to its pre- and postoperative mHKA and JLO. Descriptive statistics were then calculated and compared to those previously reported [1] for arthritic knees.

3 Results

The pre-operative mean mHKA was 2.0º varus using surgical navigation (compared to 0.8º varus reported by Macdessi et al. using the aHKA) (Figure 1). The pre-operative mean JLO was 175º (versus 174º). Using the mHKA as opposed to the aHKA resulted in more knees being categorized as Class I (34.0% vs 19.4% in [1]) or Class IV (17.5% vs 9.8%) and fewer in Class II (19.0% vs 32.2%) and Class

V (6.3% vs 14.6%). All other differences in class frequencies were within 4%. As we used the mHKA to determine the CPAK class, which includes the effect of joint angle changes due to degeneration of cartilage, we observed a larger variance in HKA (5.0º versus 2.8º) and JLO (4.9º versus 2.7º) compared to those reported in [1]. We also found that 69% of preoperative knees were in varus alignment ([1] does not directly report this value, but ~30% were in the three varus categories vs ~24% in the three valgus categories). For postoperative CPAK classification, a large majority of knees (72.7%) were categorized as Class V (within ±2º mHKA and between 177º and 183º JLO) (Figure 2).

4 Discussion

Using the mHKA values determined during navigated TKA showed that the majority of preoperative arthritic knees were Class I, II, and IV in contrast to the original CPAK publication [1] where most preoperative knees were Class I, II, and III. The higher frequency of varus knees (69%) in the preoperative population was expected, as the mHKA is affected by angulation changes due to loss of cartilage in the knee whereas the aHKA is not.

One limitation of our study is that we did not have direct measurements of the medial proximal tibial angle (MPTA), and therefore calculated the JLO using mHKA and LDFA instead. This likely contributed to the increased variance in JLO observed (Figure 1). In [1], CPAK boundaries were determined based on the measured standard deviations of aHKA and JLO in their patient population. When using the mHKA, it would perhaps be beneficial to redefine these boundaries using the standard deviations associated with this measurement technique.

For TKAs at our institution, the goal was to mechanically align knees to neutral mHKA and JLO. This is reflected in our postoperative results in that 73% of all postoperative TKAs were categorized as Class V (neutral alignment). However, some TKAs were outside of this classification, perhaps reflecting individual surgeon decisions to align knees anatomically (Class II) or kinematically (cases where the CPAK classification remained the same postoperatively), or cases where bringing the knee into neutral alignment may have been difficult while maintaining a balanced and stable knee [5]. Work is currently underway at our institution to compare CPAK class pre- and postoperatively with clinical outcomes such as the Oxford Knee Score, Patient Satisfaction Scores, range of motion and long-term implant survival.

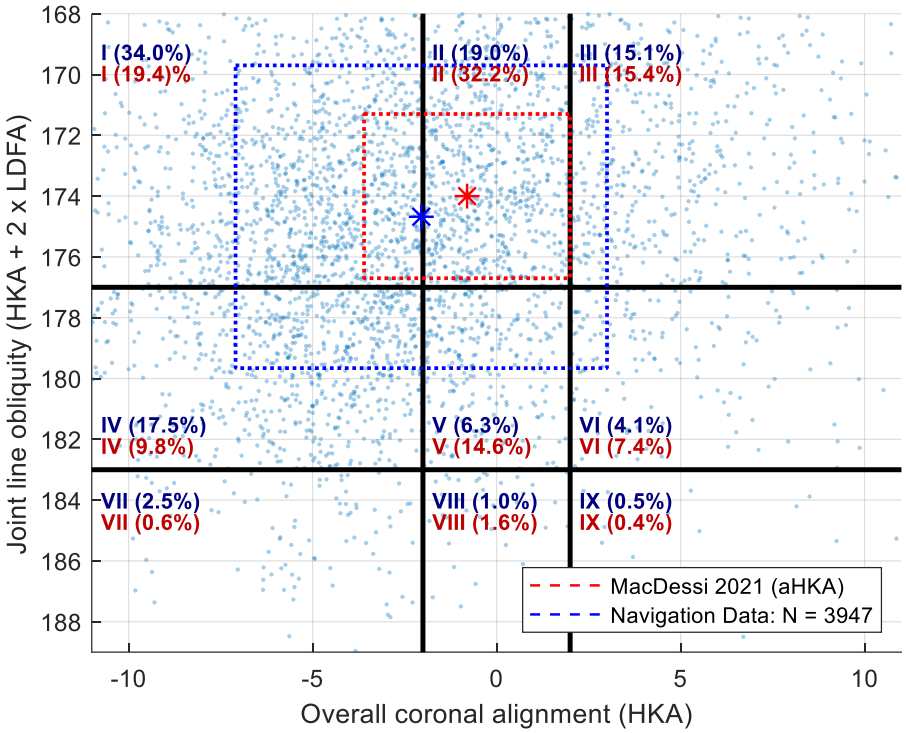

Figure 1: Preoperative Coronal Plane of the Knee (CPAK) classifications for cases at our institution (blue scatter) measured with mechanical hip-knee-ankle (mHKA) angle compared to those measured in [1] using arithmetic hip-knee-ankle (aHKA). The dotted lines represent ± one standard deviation from the mean (*). The proportion of cases in each class is reported as a percentage.

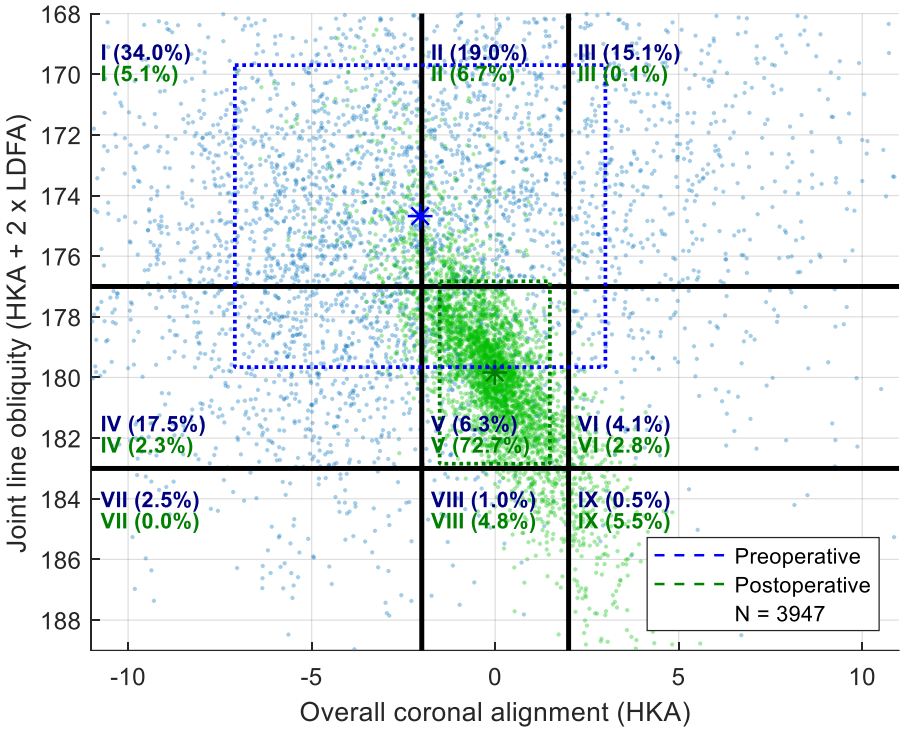

Figure 2: Comparison of pre (blue) and postoperative (green) Coronal Plane of the Knee (CPAK) classifications for cases at our institution (blue scatter) measured with mechanical hip-knee-ankle (mHKA). The dotted lines represent ± one standard deviation from the mean (*). The proportion of cases in each class is reported as a percentage.

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