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Authors’ reply:

Sir,

We are very appreciative of the deep consideration Drs Huang and Hsu have given to our paper.¹ The suggestions they have offered provide us with an opportunity to delve into why and how the classification and its algorithms were constructed, something we were unable to outline in the recent manuscript due to the limitations of space.

As they have affirmed, the Coronal Plane Alignment of the Knee (CPAK) classification has significant merits compared with previous classifications for coronal plane alignment of the knee.²,³ First, its simplicity is key to optimizing its widespread adoption as research in the field of individualized alignment evolves. The CPAK classification describes nine possible knee phenotypes, of which only six are common. This straightforward system is essential in the analysis of which patients benefit most when their unique constitutional alignment and joint line obliquity (JLO) are actually restored, rather than significantly altered.¹

At their core, CPAK algorithms uniquely define each patient’s constitutional lower limb alignment (arithmetic hip-knee-ankle angle (aHKA)) and JLO, regardless of whether the individual has arthritis or not. The two algorithms have been intentionally derived to keep simplicity, consistency, and reproducibility at the fore. Both use the coronal mechanical joint line angles of the distal femur (lateral distal femoral angle (LDFA)) and proximal tibia (medial proximal tibial angle (MPTA)). The constitutional lower limb alignment is determined by the algorithm aHKA = MPTA - LDFA (Figure 1).¹,⁴,⁵
Figure 1. Arithmetic hip-knee-ankle angle (aHKA) algorithm

Joint line obliquity is defined by the algorithm $JLO = MPTA + LDFA$ (Figure 2).\(^1\)

Figure 2. Joint line obliquity (JLO) algorithm

The $\alpha$ and $\beta$ angles Huang and Hsu propose are the complements of LDFA and MPTA. Adding more variables for surgeons and researchers to remember inevitably adds a further layer of complexity and confusion to these fundamental concepts. Further, neither $\alpha$ nor $\beta$ is a commonly used anatomical descriptor, unlike MPTA and LDFA. In order to disseminate this important concept effectively, we chose to use terminology that is already widely employed in our field.

We did consider their proposition that JLO should be the mean of the two joint line angles. However, once again, in the pursuit of developing the first straightforward method to determine JLO, we opted for minimalism over complexity. The concept of JLO is to illustrate the direction of the joint line of the knee, regardless of the stage of arthritis and associated joint space changes. It is not a numerical value of the angular deviation relative to the ground, which is the mean of the MPTA and LDFA (or $\alpha$ and $\beta$ angles). Finally, having JLO centred on 180° creates a point of differentiation from the aHKA, which is centred on 0°. It is not by chance that these two angular relations are relatively perpendicular to one another and also the inverse of each other.

When categorizing phenotypic traits for coronal plane alignment of the knee, it is critical to respect population-based statistical boundaries of variance. The CPAK boundaries for aHKA and JLO are hence based on population SDs of 1,000 normal and arthritic knees, rounded to the nearest whole number. The boundaries for neutral aHKA are $+/-2^\circ$, inclusive (SD 1.8°), and for neutral JLO are $+/-3^\circ$, inclusive (SD 2.9°) (Figure 3).
Figure 3. The Coronal Plane Alignment of the Knee (CPAK) classification

On their last point, the alignment boundaries of $0^\circ \pm 3^\circ$ have recently been brought into question. Despite having been espoused as important for achieving a satisfactory outcome for more than three decades, there is now convincing evidence that systematically restoring each knee to this mechanical alignment target may result in significant soft-tissue imbalance, disturbance of normal gait pattern, and potentially inferior patient outcomes. Further, when recent high-quality studies using long leg imaging were compared with earlier studies that only used short knee imaging, knees that were aligned outside $0^\circ \pm 3^\circ$ had no impact on long-term survivorship of the prosthesis. Registry data have supported these findings, with kinematically aligned implants showing excellent survivorship at seven years. The use of data sets from normal and arthritic populations to define what is truly normal is fundamental in our quest to understand the complex relationship between alignment of the knee, restoration of kinematic function and, most importantly, better outcomes for our patients.

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