The rebirth of computer-assisted surgery. Precise prosthetic implantation should be considered when targeting individualized alignment goals in total knee arthroplasty

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To match increasing patient expectations and hip replacement's clinical results, significant improvements in total knee arthroplasty (TKA) clinical outcomes are required. Rates of dissatisfaction and residual symptoms (e.g. pain, instability, stiffness) following mechanically aligned (MA) TKA of 15% and 50% respectively are an ongoing concern [1]. In addition, patients' perception of their prosthetic knee is rarely "natural" and Forgotten Joint Scores are disappointing [2]. Last, MA TKA fails to restore individual native knee joint kinematics, viewed as an important factor for knee function, joint perception, and patient satisfaction after surgery [3, 4].

Use of computer-assisted surgery (CAS) to increase alignment precision in TKA has not resulted in corresponding improvements in patient outcomes with a mechanical alignment target [5]. Kim et al. randomized 296 patients undergoing bilateral, simultaneous TKA to MA-CAS for one knee and MA with use of conventional instruments (CON) for the other. At a minimum of 14 years, no benefit with CAS in terms of pain, function, or implant survivorship was observed [6]. In a larger study, Roberts et al.

analyzed outcomes in 19,221 TKAs from the New Zealand Joint Registry by comparing 2 cohorts of patients: those performed by routine CAS surgeons and those performed by routine CON surgeons. No difference in survivorship or patient outcomes to support the use of CAS in TKA was found [7]. Conversely, the Australian Orthopedic Association National Joint Replacement Registry reported reduced overall revisions and revisions for loosening and lysis rates in patients under the age of 65 with use of CAS [8]. Last, a meta-analysis of 9 RCTs including over 2000 TKAs with a minimum 8 years follow-up revealed more precise implant orientation but no significant differences in patient outcomes or revision rates between the two techniques [9].

When assessing the performance of precision tools such as CAS, patient-specific cutting guides, and robotic-assisted cutting arms, we are assuming that MA was the targeted alignment in the vast majority of these studies. It is then important to differentiate the terms 'precision' and 'accuracy' [10]. When targeting for a neutral lower limb alignment according to MA technique with sophisticated tools, there is an increase in the precision of implantation in comparison with CON but this may be deviated from the real alignment goal and not accurate at all (Fig. 1). Increasing precision when targeting the wrong goal is unlikely to produce better results.

Our understanding of knee anatomy and biomechanics has evolved over recent years as we now consider that a more personalized joint reconstruction may be a better targeted goal [11]. The current systematic MA concept does not consider the individual variability of the lower limb's native coronal alignment [12]. In a population of 4884 pre-operative lower limb CT scans of patients undergoing TKA, only 4% of tibia and 5% of femur had neutral joint line orientation (medial proximal tibial angle and lateral distal femoral angle equal to 90°, respectively). Only 0.1% of knees had both joint lines, the tibial and the femoral, in neutral orientation, which is the goal of MA technique [13]. Hirschmann

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Fig. 1 Differences between surgical error, precise alignment, and accurate alignment

et al. recently proposed a new classification system for the lower limb alignment, based on a patient's phenotype. The functional knee phenotype representing a MA target was observed in only 5.6% of the males and 3.6% of the females [14]. Systematically aiming for MA in every TKA creates significant abnormalities to soft tissue balance and tibiofemoral and patellofemoral joints biomechanics [3, 15, 16]. This highlights the technical limitations that are inherent to the MA technique, in that it produces a non-physiological prosthetic knee [15, 17–19].

Moreover, the static frontal plane alignment is only one important variable when considering the 3-dimensional anatomy of knee joint and its related kinematics. Individual variability in collateral ligament laxity [20], wide variances between posterior femoral condylar and transepicondylar axes (range: 0.3–9.7°) [15], significant patellofemoral joint morphology variability [21], and the poor correlation

between static and dynamic HKA [22] are further examples of this diversity and the complexity of human anatomy.

There is no downside to improving surgical precision [23]. However, instead of “Rethinking the Value of Computer-Assisted Surgery” [24], we should ask the question; “What should be the optimal target to improve our TKA results [11, 25]?” It has been shown that a personalized surgical technique using the kinematic alignment (KA) method more closely replicates native knee anatomy and soft tissues laxities, and may improve clinical outcomes [26–28] and in-vivo biomechanics [3, 29, 30]. This may explain the non-inferior mid-term implant survivorship of KA compared to MA TKA that has been observed at 10 years follow-up in case series by Howell [31] and at 7 years follow-up in the Australian and New Zealand registries [32]. Favorable 2-year radio-stereometric implant migration [33] has also been shown with KA TKA. This is where more precise

surgical tools such as CAS or robotic-assistance may provide several advantages in TKA including real time information in millimeters to obtain accurate bone cuts, reduced soft tissue injury [34], and achieve the target joint reconstruction which may lead to improved patient satisfaction [35].

Two recent papers published in this journal reported the potential clinical benefits of precision tools when combined with a more personalized surgical technique [3, 36]. Blakeney et al. compared 18 MA TKAs and 18 restricted KA TKAs, all surgeries performed with CAS [3]. They found knee kinematics parameters of patients with restricted KA TKAs more closely resembled that of normal healthy controls than that of patients with MA TKAs. This was associated with significantly higher Knee Osteoarthritis Outcome Scores in the restricted KA group in comparison to MA (74.2 vs. 60.7, $p=0.034$). Similarly, Winnock de Graves et al. compared the clinical results of 40 patients with adjusted MA to 40 patients with restricted KA where all surgeries were performed with robotic-assistance. They found a greater proportion of patients with restricted KA TKAs achieved the patient-acceptable symptom state thresholds for Oxford Knee Score and satisfaction [36].

There is no doubt that greater accuracy in TKA surgery is warranted through a more individualized approach [25]. Perhaps the reason why this greater precision has not resulted in better clinical outcomes was that surgeons were aiming for the wrong alignment target. We need to step up from the systematic goal of achieving a neutral HKA and joint line and use proven tools that more accurately and precisely reproduce a patients' knee anatomy and kinematics. Following KA principles and considering each patient's unique knee phenotype may be helpful improving our TKA outcomes [14, 25]. With a better target in mind, a personalized alignment goal for each patient, with improved precision provided by precision tools, may reveal their true value.

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