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EDITORIAL

Knee biomechanics

WILL WE EVER KNOW THE TRUTH?

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Kang et al[1] have ably demonstrated the role of finite element analysis (FEA) in deciphering the complex interplay between component positioning of the implanted total knee arthroplasty (TKA) and the kinetics of key soft-tissue structures. This work extends our knowledge of the role of the central posterior restraint (posterior cruciate ligament (PCL)) and the impact of varying posterior condylar offset (PCO) and posterior tibial slope upon final tibiofemoral flexion, muscle load, and by inference, final construct stability. Using an established computer model of TKA, the fine balancing of the knee after arthroplasty has been keenly exposed. The extension of this modelling work to examine muscle load in the quadriceps and patellofemoral articulation is of particular interest, and supports previous *in vitro* cadaveric work.[2,3] It would appear that there is, in effect, a form of length tension effect when determining optimal offset and tibial slope. Perhaps the addition of the flexor hamstring in a future computer mixed-modelling analysis could delineate the true force couple effect at any instantaneous point of motion. Purists may argue that translation of such hypothetical FEA theory into clinical practice is hampered by the significant assumptions inherent in such work. However, this work does allow for reliable computation of how small changes that often occur during a manually performed TKA can have a significant impact upon the biomechanics of the prosthetic joint. Building upon these findings through *in vitro* work will direct our study hypotheses to delineate the role of other factors such as preoperative deformity, soft-tissue envelope behaviour and femoral component geometry upon final construct performance.

PCO allows for improved clearance of the tibial component in deep flexion, and through resolution of forces, will act with the anterior patellofemoral offset to optimise the lever arm in flexion. PCO has been shown to correlate with functional outcome after revision TKA, with decreasing offset associated with a worse outcome.[4] The effect of PCO should be maximal in mid to late flexion and Kang et al[1] are to be congratulated on comprehensively defining the patterns of load across the patellofemoral joint in their model. There would intuitively appear to be perfect balance for controlled load through both the tibiofemoral and patellofemoral articulations at each point of flexion which maintain correct tension in the anterior (e.g. quadriceps, patellar retinaculae) restraints. This work stresses the importance of maintaining normal anatomy, and indeed, such a philosophy could be extended to the role of accurate restoration of soft-tissue constraint through intraoperative tension and load measurement systems. There is a move away from the simplistic two-point measurement of gap geometry at full extension and 90 degrees of flexion, and this work highlights the value of examining the behaviour of the knee during this functionally important phase of knee flexion. The importance of PCO in determining ultimate knee flexion was recognised by Bellemans[5] and others.[6] However, others have failed to find such a relationship.[7] It is known that the PCL acts as a restraint to posterior tibial subluxation and is at risk of avulsion, with increased tibial slope angle.[8] This relationship is further complicated by the knowledge that *in vivo*, the PCL is often diseased and may not exhibit true elastic behaviour.[9] The PCL may also be deficient, be it inherent or traumatic, and when this is the case there is increased force transmitted to the patellafemoral joint that may lead to increase cartilage wear and degeneration.[10]

It is difficult to input such confounding variables into the current FEA models, limiting their applicability. This confusion is further increased by the inconsistent clinical results from high flexion, single radius and rotating platform knee designs. Therefore, linking of FEA data, cadaveric time zero biomechanical work and clinical study outcomes will synergistically inform us of optimal mechanics after TKA. With the advent of newer technology, yet to be substantiated, there is a continued need for early modelling of biomechanical behaviour in order to inform us of the potential influence of implant position on the outcome of TKA. Reverse engineering from newer technologies such as robotic-assisted surgery, offers the promise of building a preoperative FEA that comprehensively factors in patient-specific anatomy, surgical geometry, and soft-tissue performance, thus potentially optimising the functional outcome of TKA.

Component alignment is a critical aspect of TKA. Coronal alignment of the TKA has been shown to influence the load in the medial compartment, which my effect the wear of the polyethylene, and ligamentous stability, laterally.[11] Femoral rotation has been demonstrated to have a direct effect on the force transmitted through the medial tibiofemoral compartment and patellofemoral joint, with internal rotation increasing the force through these compartments.[12] The majority of TKA designs sacrifice the anterior cruciate ligament, and others also sacrifice the PCL, which changes the joint kinematics.[10] To address this, some surgeons have employed a bi-cruciate retaining TKA, which restores the normal joint kinematics on FEA.[13] However, even if a bi-cruciate TKA is used and placed in the correct alignment and rotation it is often not replicating the patients pre-operative anatomy.[14] In an effort to replicate the patients knee kinematics, the implant can be aligned according to their own specific mechanics, and this is defined as kinematic alignment. Kinematic alignment has been shown to replicate the normal biomechanics of the knee joint in FEA.[15] There have been contrasting clinical results of kinematic alignment compared with conventional mechanically-aligned TKA.[15,16] The most recent randomised controlled trial concluded significantly improved functional outcomes in the kinematic group, but this was at the expense of more outliers with a poor outcome, which were thought to have been due to malalignment of the prothesis.[16]

A major limitation during TKA is the variability of implant positioning. One in ten patients are outliers with an implant that is more than 3° from planned alignment.[17] This variability will most likely result in abnormal joint kinematics. Robotic-assisted surgery is significantly more accurate at achieving correct implant alignment,[18] which has the potential to reproduce native joint kinematics more reliably. Whether the kinematics vary according to anatomy, or if they influence outcome after TKA remains unknown.

References

1. **Kang KT, Koh YG, Son J, et al.** A computational simulation study to determine the biomechanical influence of posterior condylar offset and tibial slope in cruciate retaining total knee arthroplasty. *Bone Joint Res* 2018;7:69-78.
2. **Manning WA, Ghosh K, Blain A, Longstaff L, Deehan DJ.** Tibiofemoral forces for the native and post-arthroplasty knee: relationship to maximal laxity through a functional arc of motion. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1669-1677.
3. **Manning WA, Ghosh KM, Blain A, et al.** Internal femoral component rotation adversely influences load transfer in total knee arthroplasty: a cadaveric navigated study using the Verasense device. *Knee Surg Sports Traumatol Arthrosc* 2017. (Epub ahead of print)
4. **Clement ND, MacDonald DJ, Hamilton DF, Burnett R.** Posterior condylar offset is an independent predictor of functional outcome after revision total knee arthroplasty. *Bone Joint Res* 2017;6:172-178.
5. **Bellemans J, Banks S, Victor J, Vandenneucker H, Moemans A.** Fluoroscopic analysis of the kinematics of deep flexion in total knee arthroplasty. Influence of posterior condylar offset. *J Bone Joint Surg [Br]* 2002;84-B:50-53.
6. **Malviya A, Lingard EA, Weir DJ, Deehan DJ.** Predicting range of movement after knee replacement: the importance of posterior condylaroffset and tibial slope. *Knee Surg Sports Traumatol Arthrosc* 2009;17:491-498.
7. **Hanratty BM, Thompson NW, Wilson RK, Beverland DE.** The influence of posterior condylar offset on knee flexion after total knee replacement using a cruciate-sacrificing mobile-bearing implant. *J Bone Joint Surg [Br]* 2007;89-B:915-918.
8. **Sessa P, Fioravanti G, Giannicola G, Cinotti G.** The risk of sacrificing the PCL in cruciate retaining total knee arthroplasty and the relationship to the sagittal inclination of the tibial plateau. *Knee* 2015;22:51-55.
9. **Kuriyama S, Ishikawa M, Nakamura S, et al.** Posterior tibial slope and femoral sizing affect posterior cruciate ligament tension in posterior cruciate-retaining total knee arthroplasty. *Clin Biomech (Bristol, Avon)* 2015;30:676-681.
10. **Kang KT, Koh YG, Jung M, et al.** The effects of posterior cruciate ligament deficiency on posterolateral corner structures under gait- and squat-loading conditions: A computational knee model. *Bone Joint Res* 2017;6:31-42.
11. **Suh DS, Kang KT, Son J, et al.** Computational study on the effect of malalignment of the tibial component on the biomechanics of total knee arthroplasty: A Finite Element Analysis. *Bone Joint Res* 2017;6:623-630.
12. **Kang KT, Koh YG, Son J, et al.** Measuring the effect of femoral malrotation on knee joint biomechanics for total knee arthroplasty using computational simulation. *Bone Joint Res* 2016;5:552-559.
13. **Koh YG, Son J, Kwon SK, et al.** Preservation of kinematics with posterior cruciate-, bicruciate- and patient-specific bicruciate-retaining prostheses in total knee arthroplasty by using computational simulation with normal knee model. *Bone Joint Res* 2017;6:557-565.
14. **Waterson HB, Clement ND, Eyres KS, Mandalia VI, Toms AD.** The early outcome of kinematic versus mechanical alignment in total knee arthroplasty: a prospective randomised control trial. *Bone Joint J* 2016;98-B:1360-1368.
15. **Nakamura S, Tian Y, Tanaka Y, et al.** The effects of kinematically aligned total knee arthroplasty on stress at the medial tibia: a case study for varus knee. *Bone Joint Res* 2017;6:43-51.
16. **Calliess T, Bauer K, Stukenborg-Colsman C, et al.** PSI kinematic versus non-PSI mechanical alignment in total knee arthroplasty: a prospective, randomized study. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1743-1748.
17. **Clement ND, MacDonald D, Burgess AG, Howie CR.** Articular surface mounted navigated total knee arthroplasty improves the reliability of component alignment. *Knee Surg Sports Traumatol Arthrosc* 2017. (Epub ahead of print)
18. **Blyth MJG, Anthony I, Rowe P, et al.** Robotic arm-assisted versus conventional unicompartmental knee arthroplasty: exploratory secondary analysis of a randomised controlled trial. *Bone Joint Res* 2017;6:631-639.

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