Variability And Reliability Of MRI Landmarks For Patient-Specific TKA Guide Generation

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Introduction: Total knee arthroplasty (TKA) performed using standard intra- and extra-medullary cutting guides has been associated with both coronal and rotational malalignment, potentially resulting in higher failure rates and worse functional outcomes. Patient-specific cutting (PSC) guides were developed to improve the alignment of TKA implants, utilizing preoperative three-dimensional imaging to aid in the fabrication of custom, single-use templates designed to fit the articular surface of each patient’s knee. While the specific algorithms used to generate these guides remain proprietary, they all require manual identification of bony landmarks on CT or MRI scans. To date, no study has assessed the accuracy and precision with which these landmarks can be identified radiographically.

Methods: MRI scans were obtained of 114 knees prior to PSC TKA. Fifty four of the knees were of male patients and sixty were of female patients, with an average age of 64 (range 44 to 90). Two orthopaedic surgeons and two musculoskeletal radiologists independently reviewed each MRI in duplicate, defining landmarks commonly used in templating PSC TKAs such as the transepicondylar axis (TEA), posterior femoral joint line, tip and medial third of the tibial tubercle, geometric center of the tibial shaft, and insertion of the posterior cruciate ligament (PCL).

Results: On average, the TEA was externally rotated 1.34 degrees relative to the posterior femoral joint line (range 3.31 degrees to 6.15 degrees of external rotation). Thirteen percent deviated from the physiologic mean by greater than 3 degrees and none deviated by greater than 5 degrees. Intraclass correlation coefficients (ICC) were then calculated to evaluate intra- and inter-rater reliability for the TEA. The four reviewers were found to have good to very good intra-rater agreement (ICC = 0.76-0.97) and good (ICC = 0.66-0.67) inter-rater agreement. In terms of absolute magnitude of variability, the average range of values for the angle between the TEA and posterior femoral joint line among reviewers was 3.47 degrees (average st dev = 1.19 degrees).

The tip of the tubercle was externally rotated an average of 25.08 degrees relative to the geometric center and the posterior border of the tibia (range 4.20 to 42.55 degrees). Forty nine percent deviated from the physiologic mean by greater than 5 degrees and 15% deviated by greater than 10 degrees. The medial third of the tubercle was externally rotated an average of 12.38 degrees relative to the apex of the PCL insertion and the posterior border of the tibia (range 0.15 to 25.99 degrees). Thirty two percent deviated from the physiologic mean by greater than 5 degrees and 7% deviated by greater than 10 degrees. Intra-rater agreement was good to very good for the tip (ICC = 0.75-0.92) and also for the medial third of the tubercle (ICC = 0.67-0.84). Among reviewers, inter-rater agreement was good (ICC = 0.67-0.69) for the tip of the tubercle and moderate to good (ICC = 0.53-0.64) for the medial third. The average range of values was 12.36 (average st dev = 4.31) for the tip of the tubercle and 10.18 degrees (average st dev = 3.50) for the medial third.

Discussion: Bony landmarks used in TKA can be identified on MRI with a good to very good degree of intra-rater reliability and a moderate to good degree of inter-rater reliability. The large range over which the landmarks were identified by different reviewers indicates that there is considerable variability with which PSC guides can be made. Additionally, the high degree of physiologic variability among patients suggests that assuming standard relationships among various anatomic landmarks when placing TKA components may lead to rotational malalignment.

Significance: Our data suggest that there is a high degree of variability with which custom PSC guides can be made based on MRIs performed in the setting of arthritis and may explain why alignment achieved with PSC guides is better in theory than in practice. Moreover, we found a high degree of variability in axial plane anatomic landmarks among patients, calling into question the current gold standards for rotational alignment in TKA.

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References: