Quantification of Total Knee Replacement Medial/Lateral Kinematics During UHMWPE Wear

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Statement of Purpose: Knee simulating machines are currently used in the analysis of TKR design performance as well as in the investigation of the relationships between TKR design, kinematics and wear. Although in-vitro kinematic analysis during wear simulation is a common part of testing protocol, analysis of medial/lateral (M/L) motion within the TKR is often neglected. Recent studies have shown that multi-directional motions accelerate UHMWPE wear. It is therefore imperative that in-vitro performance analyses provide a more complete picture of TKR kinematics to improve TKR function and long-term wear performance. The purpose of this study was to characterize M/L motion of a clinically successful TKR design in an effort to create a more accurate kinematic description for in-vitro TKR performance analysis, as well as to observe changes in M/L motion as wear occurred.

Methods: Four right femoral/tibial knee implants (NexGen CR, Zimmer, Inc. Warsaw, IN) were installed into a Stanmore/Instron knee wear simulator and wear tested to 5 million gait cycles using the proposed 1999 ISO force-control testing standard, #14243, at 1 Hz.

To facilitate M/L measurement, custom kinematic measurement fixtures were integrated into the Instron/Stanmore knee simulator testing system. M/L translation, anterior/posterior (A/P) translation, and internal/external (I/E) rotation were measured with a resolution of ±0.08mm and ±0.098 degrees. The implants were aligned in zero (neutral) A/P displacement and I/E rotation with respect to the tibial mid-line. Springs simulating in-vivo capsular constraints were set to provide a linear reaction force of 20 N/mm to A/P displacement and a reaction torque of 0.27 N-m/deg to I/E rotation, and a 50% (+0.2% NaN_3) bovine serum lubricant was used during testing. Kinematic measurements were recorded and 13 cycle averages were analyzed at 0, 2, and 4 million cycles. Statistical comparisons were made using Students-T tests (α=0.05). Contact point pathways for each condyle with respect to the tibial insert were generated using femoral component digitization and positional mapping of the lowest point of the femoral component on the tibial insert.

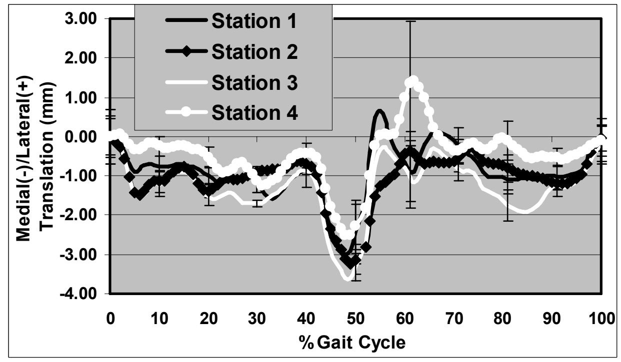

Figure 1: Global M/L Translation at 4 Million Cycles

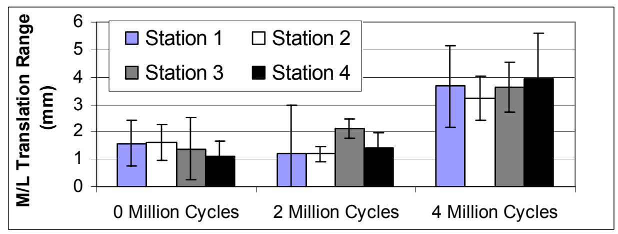

Figure 2: Ranges of Avg. M/L Translation

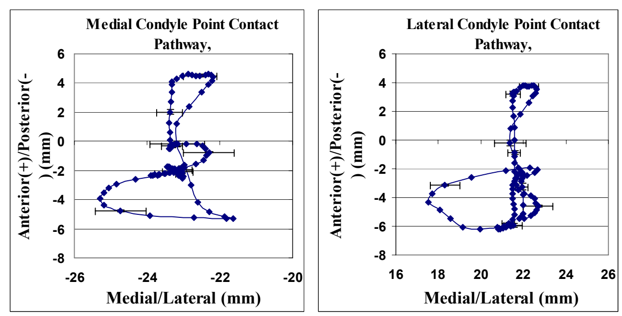

Figure 3:Tibio-Femoral Contact Pathway at 4 Million Cycles

Results/Discussion: Noticeable increases in M/L translation and inter-specimen variation were apparent at approximately 50%-65% of the gait cycle. Across specimens, the minimum and maximum ranges of average M/L translation were 1.13±0.51mm and 3.93±1.5mm respectively. M/L ranges of motion towards the end of testing (3.61±0.29mm @ 4 million cycles) were significantly larger ($p<0.001$) than M/L ranges of motion at the start (1.43±0.22mm @ 0 million cycles). In the force-controlled simulator used for this study, the M/L direction was unforced and unconstrained, allowing the greatest M/L inter-specimen variation and translation to occur during the swing phase where the implant was least constrained by the input forces. The difference in M/L range of motion between the beginning and ending of the wear test could be attributed to a change in the tibial geometry due to wear on the tibial insert. Previous wear studies have shown changes in A/P motion over time and suggested the cause to be changes in the tibial surfaces that were brought about by wear [1]. The results attained in this study show a change in M/L motion as well, which is significant, especially as an indication of change in cross-shear motion which causes cross-shear wear.

Conclusions: The measurement of M/L motion in this study allows a more complete characterization of TKR kinematics as wear occurs. This thereby aids in the ongoing investigation into the relationship between TKR kinematics and TKR wear.

References: **[1]** J Biomed Mater Res, 2001. **58**(5): p. 496-504.

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