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Single-Radius Total Knee Implant Outperforms Multi-Radius Design in Level Walking Kinematics and Kinetics

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Introduction: This study evaluates the impact of radii-related differences in posterior cruciate ligament retaining (PCR) primary total knee arthroplasty (TKA) prosthetic designs on knee biomechanics during level walking 1-year after surgery. The multi-radius (MR) design creates at least two instantaneous flexion axes by changing the radius of curvature of the femoral component throughout the arc of knee motion. The femoral component of the single-radius (SR) design has only one radius and therefore a fixed axis.

Methods: Subjects scheduled for computer-navigated TKA (n=37: SR n=20 [9M, 11F], MR n=17 [8M, 9F]; 69.8 ± 7.1 years, 87.6 ± 20.8 kg, 1.68 ±0.09 m), and demographic-matched controls without knee pathology n=23 [13M, 10F], provided informed consent under the Banner IRB (Sun Health panel). All surgical subjects received similar pre-, peri-, and post-operative care under the direction of three surgeons from a single orthopedic practice. Position and force data were collected using 28 reflective markers (modified Helen Hayes [Kadaba et al 1990]) tracked by ten digital IR cameras (120Hz) (Motion Analysis Corp., Santa Rosa, CA) and four force platforms (1200Hz) (AMTI, Watertown, MA) embedded in an 8m walkway. Data were recorded and smoothed (Butterworth filter, 6Hz) using EVaRT 5.0.4 software (Motion Analysis Corp.). Gait cycle parameters were calculated using the 'Functional Hip Center' and 'Original Knee Axis' models in Orthotrak 6.6.1 (Motion Analysis Corp.). Data from each group were height and weight normalized and ensemble averaged by affected limb (right limb for controls) using custom code written in Labview (National Instruments Corp, Austin, TX). Descriptive statistics for the maximum and minimum knee kinematic, kinetic, and temporal spatial values in the stance and swing phases of the gait cycle were generated for each group. Between-group comparisons were made using an ANOVA with post hoc testing as appropriate (SPSS 14.0 (SPSS Inc, Chicago, IL)).

Results: Total range of motion was similar between surgical groups but MR was 5º more extended than SR throughout stance ($p<0.05$) (Figure 1). MR knee power absorption (Figure 2) and medial knee force were less than controls ($p<0.05$). SR and controls were similar for several knee parameters ($p>0.05$) (Table 1).

Discussion: The performance of the SR design was more control-like in several parameters at one year. A shifting radius of curvature, which alters patella-femoral moment arm geometry and resulting quadriceps force [D'Lima et al 2001], may contribute to reduced knee power in the MR group. The fluctuating radius of curvature may also generate collateral ligament laxity with increasing flexion angles [Wang et al 2005, Whiteside et al 1989] contributing to the observed deficit in medial knee forces. The increased knee extension angles in the MR group are indicative of a stabilizing adaptation throughout the range of motion. While previous biomechanics studies following TKA have revealed few to no significant differences in gait performance due to implant design, the use of computer navigation and standard order sets, which control for alignment and other confounding variables, may generate tighter data sets that reveal differences masked by variation within surgical groups rather than between them.

Figures

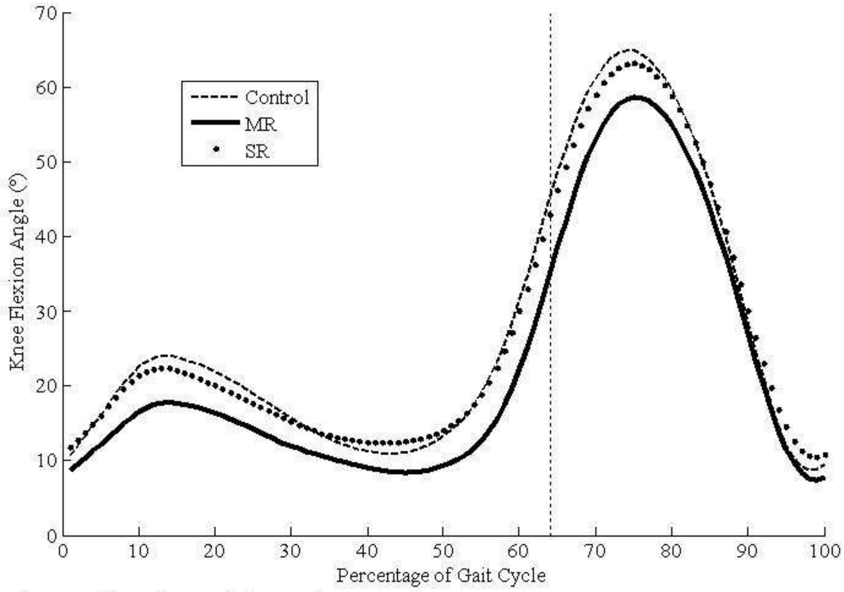

Figure 1. Affected Knee Flexion Angle 1-Year After TKA

Figure 1

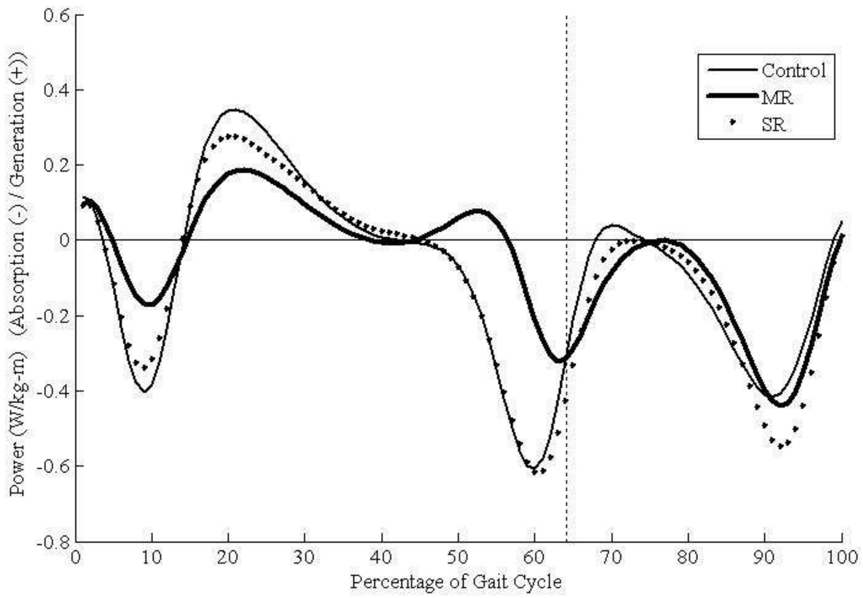

Figure 2. Affected Knee Power 1-year After TKA

Figure 2

Table 1. Descriptive statistics for selected parameters ($p<0.05$) at 1-year after surgery

Parameter		1-year		
		SR (n=20)	MR (n=17)	Control (n=23)
Knee Flexion (°)	Stance Max	42.84 ± 6.83*	**37.75 ± 6.29***	44.73 ± 4.46
	Stance Min	9.79 ± 6.21	5.95 ± 6.17	9.87 ± 4.41
	Swing Max	63.70 ± 5.20*	**59.20 ± 5.14***	66.00 ± 3.71
	At Toe-off	46.10 ± 6.72*	**41.28 ± 6.14***	48.09 ± 4.41
	Total ROM	53.70 ± 5.25	**52.30 ± 6.26**	56.70 ± 4.57
Knee Power (W/kg-m)	Stance (Absorption)	-0.66 ± 0.23*	**-0.37 ± 0.21***	-0.73 ± 0.27
Knee Forces (N)	Stance Min (Lateral)	-0.04 ± 0.02	**-0.02 ± 0.02**	-0.05 ± 0.02

*: statistical difference between surgical groups; **Bold**: statistically different from controls

Figure 3

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