Implant Rotational Alignment in Total Knee Arthroplasty May Affect Knee Pivot Motion Patterns During Gait

Rémi Courteille[1], Alix Cagnin[2], Alex Fuentes[2], Laurence Chèze[3], Nicola Hagemeister[1]
[1]École de technologie supérieure, Montréal, QC, Canada, [2]Emovi, Montréal, QC, Canada, Université Lyon 1, Lyon, France
Email of Presenting Author: remi.courteille.1@ens.etsmtl.ca

Disclosures: Rémi Courteille (N), Alix Cagnin (3A-Emovi), Alex Fuentes (3A,4-Emovi), Laurence Chèze (N), Nicola Hagemeister (5-Emovi)

INTRODUCTION: Total knee arthroplasty (TKA) is often used as last treatment for knee osteoarthritis. While this is a well-known and effective surgery, up to 20% of patients remain unsatisfied and report functional limitations after TKA [1]. Among the different causal factors, studies reported associations between implant components malrotation and poor TKA outcomes (i.e., pain, dissatisfaction, etc.) [2,3]. Implants are designed to guide knee kinematics and more specifically knee pivot motion (KPM), also known as the center of rotation (COR) behavior. While it is accepted that the knee' COR position changes as the knee flexes [4], the relationships between components malrotation and the KPM pattern during weight-bearing (WB) tasks is still unknown. Thus, the aim of this study was to evaluate associations between implant component rotational alignment (ICRA) and KPM pattern during gait in TKA patients.

METHODS: We conducted a retrospective study on 30 patients (i.e., 30 knees) who underwent TKA. All participants provided informed written consent to participate in this IRB-approved study. All knees had patella resurfacing and benefited from a similar posterior-stabilizing implant (i.e., Genesis-II/Legion). Three-dimensional knee kinematics were captured non-invasively through a Knee Kinesiography exam between 12- and 36-month post-surgery. This exam is conducted in-clinic while the patient is walking on a commercial treadmill. The KPM was assessed by projecting the transepicondylar axis (TEA) on the tranverse plan (i.e., tibial plateau) throughout gait. The tibial plateau was normalized from -1 (lateral condyle) to +1 (medial condyle) with 0 being the center of the knee and was divided in four zones: the lateral (from -1.4 to -0.33), central (-0.33 to +0.33), medial (+0.33 to +1.4), and extra-articular zones (<-1.4 or >+1.4). The knee COR location, corresponding to the intersection of two consecutive TEA projections, was determined at each percentage of the gait cycle (GC) and used to classify pivot motion in four distinct patterns (Fig.1). Pattern I corresponded to an antero-posterior translation of the TEA (i.e., no significant rotation) when the COR was located in extra-articular zones. Patterns II to IV corresponded to a rotation respectively around a lateral COR (II), a medial COR (III), or a central COR (IV). The predominant pivot pattern (i.e., the most frequent COR behavior) was determined independently in seven phases of the GC: four WB phases during stance (loading, mid-stance, end-stance, push-off), and three non-WB phases (initial swing, mid-swing, and terminal swing). Knees who presented the same predominant KPM pattern in all WB phases were classified as "single pivot" and the others as "multi-pivot". The same was done for non-WB phases. A single radiologist blinded to patient's data assessed excessive ICRA on CT-scans according to Berger's method [5]. Positive values corresponded to excessive external rotation from the tibial, femoral, and combined (i.e., tibial+femoral) components compared to normative values [5]. Independent Student T-tests were used to assess differences in the three ICRAs between "single pivot" and "multi-pivot" knees for both WB and non-WB gait phases.

RESULTS: There was 53.6% of women, the mean age was 65.9 years (95%CI: 62.5;69.3). A total of 13 knees (43.3%) exhibited a "single pivot" during WB, corresponding to knees maintaining the same KPM pattern throughout stance. These knees presented with significantly less excessive external tibial (0.3° vs 5.7°) and combined (-1.2° vs 4.9°) rotations compared to "multi-pivot" knees (both p=0.03, see Table 1). There was no difference on IRCA between "single pivot" (N=10) and "multi-pivot" (N=20) knees during the non-WB swing (all p≥0.25). Interestingly, all "single pivot" knees during WB exhibited a central KPM (i.e., a rotation of the knee around a COR near the center of the tibial plateau, see type IV on Fig.1).

DISCUSSION: Results suggest that tibial and femoral implant component rotational alignment may influence KPM pattern during gait. Knees with components positioned less in external rotation (i.e., tibial) or slightly in internal rotation (i.e., combined) were constrained in a single pivot pattern during WB phase. Interestingly, ICRA did not seem to significantly influence KPM during the non-WB phase of gait. This can constitute relevant data for surgeons to consider in their pre- and per-TKA procedure as well as for implant designers to develop functional prothesis during WB and non-WB tasks. Additionally, internally rotated components have been identified as a cause of anterior knee pain post-TKA [2], which could indicate that ICRA, KPM, and outcomes may be intrinsically linked. Thus, study results invite to further explore the associations between KPM during gait and outcomes post-TKA. A significant limitation of this study lies in its exclusive focus on one specific implant design. Subsequent research should assess these relationships on other designs (i.e., dual pivot, medial pivot, cruciate retaining, etc.) and their link with patient-reported outcomes. The KPM assessment methodology used in this study has not been validated against fluoroscopy data. However, its non-invasive aspect and the study results reinforce the relevance of this promising approach. Additional studies are needed to confirm the reported associations on larger cohorts.

SIGNIFICANCE/CLINICAL RELEVANCE: This study is the first to report significant associations between knee pivot motion pattern and implant component rotation in TKA. While additional studies are needed to confirm these results, this study presents a promising method to better understand knee pivot behavior and may ultimately help surgeons personalizing surgeries to achieve better patient outcomes.

REFERENCES: 1. Bourne et al. (2010) *Clin Orthop Relat Res*. 2. Nicoll et al. (2010) *J Bone Jt Surg Br*. 3. Bhattee et al. (2014) *Knee*. 4. Banks et al. (2004). *Journal of Arthroplasty*. 5. Berger et al. (1998) *Clin Orthop Relat Res*.

ACKNOWLEDGEMENTS: The present work is supported by a Research Chair Grant from École de technologie supérieure.

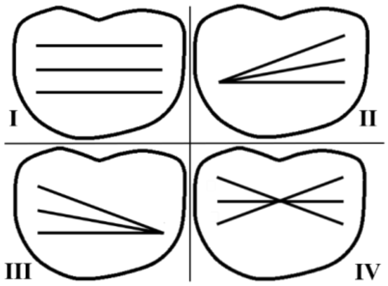

Fig.1. The four knee pivot motion patterns. Superior view of the transverse plane (anterior side at the top, left knee).

	"Multi-pivot" knees	**"Single pivot" knees**	**T-test**
ICRAs	*Mean (95%CI)*	*Mean (95%CI)*	*p-value*
WB:	**N=17**	**N=13**	
Tibial	5.7° (2.3;9.0)	0.3° (-3.5;4.2)	0.03*
Femoral	-0.8° (-1.9;0.3)	-1.5° (-3.4;0.4)	0.49
Combined	4.9° (1.2;8.5)	-1.2° (-5.7;3.4)	0.03*
Non-WB:	**N=20**	**N=10**	
Tibial	2.4° (-0.4;5.1)	5.3° (-0.8;11.4)	0.27
Femoral	-1.3° (-2.6;0.0)	-0.7° (-2.4;1.0)	0.57
Combined	1.1° (-2.0;4.1)	4.6° (-2.4;11.6)	0.25

Table 1. Mean excessive implant component rotational alignments (IRCAs) for multi- and single-pivot knees (WB and non-WB phases).