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Basic Science

No Differences Identified in Transverse Plane Biomechanics Between Medial Pivot and Rotating Platform Total Knee Implant Designs

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ABSTRACT

Background: Total knee arthroplasties (TKAs) using well-designed, fixed bearing prostheses, such as medial pivot (MP), have produced good long-term results. Rotating-platform, posterior-stabilized (RP-PS) mobile bearing implants were designed to decrease polyethylene wear. Sagittal and coronal plane TKA biomechanics are well examined and correlated to polyethylene wear. However, limited research findings describe this relationship in transverse plane. We assumed that although axial plane biomechanics might not be the most destructive parameters on polyethylene wear, it is important to clarify their role because both joint kinematics and kinetics in all 3 planes are important input parameters for TKA wear testing (International Organization for Standardization 14243-1 and 14343-3). Our hypothesis was that transverse plane overall range of motion (ROM) and/or peak moment show differences that reflect on wear advantages when compared RP-PS implants to MP designs.
Methods: Two groups (MPs = 24 and RP-PSs = 22 subjects) were examined by using 3D gait analysis. The variables were total internal-external rotation (IER) ROM and peak IER moments.
Results: No statistically significant difference was demonstrated between the 2 groups in kinetics (P = .389) or kinematics (P = .275).
Conclusion: In the present study, no wear advantages were found between 2 TKAs. Both designs showed identical kinetics at the transverse plane in level-ground walking. Kinematic analysis could not illustrate any statistically significant difference in terms of overall IER ROM. Nevertheless, kinematic gait pattern differences observed possibly reflect different patterns of joint surface motion or abnormal gait patterns. Thus, wear testing with various input waveforms combined with functional data analysis will be necessary to identify the actual effects of gait variability on polyethylene wear.

The long-term survival of total knee arthroplasty (TKA) has been well established; however, functional outcomes remain controversial. When TKA kinematics appears to be more normal postoperatively, it has been shown to produce better knee function. More normal kinematics can be obtained by using implants with optimized surface geometry. Thus, TKA designs with an appropriate surface geometry are likely to provide superior long-term functional outcome.

Total knee arthroplasties using well-designed, fixed bearing prostheses have produced good long-term results [1-3]. The medial pivot TKA is a fixed bearing prosthesis with a conforming medial compartment and a nonconforming (flat on flat) lateral compartment. Such implant geometry is designed to pattern the normal knee motion of sliding or pivoting medially and rolling back laterally [4]. The medial pivot fixed bearing prosthesis (Advance; Wright Medical, Arlington, TN) was developed specifically to enhance stability and reduce polyethylene wear by creating a near constant femoral component radius so as to reduce contact stresses and produce more normal knee kinematics [5-9].

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Mobile bearing TKAs, therefore, were developed as an alternative solution for the limitations of fixed bearing designs. These knee prostheses were designed to provide more conforming surface shapes with reduced polyethylene contact stresses and presumably reduced wear [10-12]. Several authors have suggested that a mobile bearing TKA could minimize bone-prosthesis interface stresses of the tibial component [13,14]. Rotating-platform posterior-stabilized (RP-PS) implants were developed to take advantage of both rotating platform mobile bearing system benefits and posterior stabilized fixed bearing system with post and cam mechanism [15]. The RP-PS knee was designed to decrease polyethylene wear and to address loading challenges associated with low contact stress mobile bearing implants [16]. Fixed and mobile bearing total knee arthroplasties are still discussed controversially [17].Despite their theoretical advantages, the clinical outcomes of TKAs with RP-PS mobile bearing implants remain to be determined. In theory, compared to medial pivot fixed bearing systems, clinical performances of mobile bearing knees could show functional advantages because of their relatively small constraint by the prostheses. Limited previous findings have detailed biomechanical advantages after implantation with mobile bearing prostheses after total knee replacement (TKR) surgery during walking [18]. Several factors, including knee kinematics and compressive load (mediolateral or rotational), have been implicated to influence wear. External knee moments (a representative value for load) have been correlated with the medial and lateral wear scar areas of TKAs since 1986 [19]. Nowadays 2 separate standards for knee joint prosthesis wear testing are recommended from the International Organization for Standardization (ISO). Input based on joint kinematics is described by ISO 14243-3. ISO 14343-1 determines forces as input for TKA wear testing too. Ngai and Wimmer (2015) stated that IE rotation moment significantly influences wear. [20,21]. Likewise, Johnson et al have shown that small variations in IE rotation motion can have a large effect on polyethylene wear in TKA [9]. Moments and motion in all 3 planes are equally important for an integrated biomechanical approach of polyethylene wear. Because limited findings correlated the relationship of kinetics and kinematics in axial plane to polyethylene wear, our hypothesis was that transverse plane overall ROM and/or peak moment during waking show differences that reflect on wear advantages when compared RP-PS implants to MP designs. Therefore, the purpose of this double blind study was to determine whether differences in transverse plane kinetic data (internal-external rotation moments) or/and kinematic parameters (overall internal-external rotation ROM) during walking could offer RP-PS implants functional (kinetic or kinematic) or wear advantages over medial pivot designs.

Materials and Methods

Subjects

Two groups of patients were included in the research: group A medial pivot TKA and group B RP-PS TKA. All TKAs were performed by the same surgeon (associate professor of orthopedics). Initially, the study included 202 patients who were clinically tested by the same clinician. To ensure that all subjects were comparable with regard to general health, a number of patients were excluded for various reasons: 18 patients who had undergone revision of TKA, 1 patient due to bilateral TKR, 5 patients diagnosed with Parkinson's syndrome, 1 patient due to fracture, 5 passed away before the measurement procedure, 25 due to other illnesses (cancer, dementia, and so forth), 1 due to contralateral knee arthroscopy, 15 patients who were using walking aids. Eighty-five people who were clinically evaluated refused to proceed to gait analysis. Finally, 156 subjects were excluded from the research.

From the initially selected 202 people, 46 patients participated in the study ($n = 46$). Group A (medial pivot TKA), $n1 = 24$ subjects (average age = 70.25 years, standard deviation [SD] = 1.96) and group B (RP-PS TKA), $n2 = 22$ subjects (average age = 72.92 years, SD = 1.46). The average age of the participants was 71.6 years.

The Knee Society Clinical Score and the Knee Functional Score

The Knee Society clinical score (KSCS) as well as the knee functional score (KFS) were used to evaluate the patients post-operatively at 2- to 3-year follow-up. The knee clinical score is based on clinical parameters that evaluate pain, range of motion (ROM), and stability in the coronal and sagittal plane. It also offers deductions for flexion contractures, extension lag, and misalignment (Table 1). The KFS assesses how patients perceive their knee function in relation to specific activities (walking distance and stair climbing with deduction for walking aids; Table 2) [22].

The maximum for both scores is 100 points with consideration as follows:

Scores of

1. 100-80 points: excellent results,
2. 79-70 points: good results,
3. 69-60 points: fair results,
4. <60: poor results.

Radiological evaluation was carried out based on the Knee Society score, and the radiographs were evaluated for the alignment of the knee and the femoral and tibial component positions. The position of the joint line was determined in anterior-posterior films by calculating the distance between the tip of the fibular head and the distal margin of the lateral femoral condyle at 2-3 years

Table 1
The Knee Society Clinical Score.

Objective Scoring	Score
Pain	
None	50
Mild or occasional	
Stairs only	45
Walking and stairs	30
Moderate	
Occasional	20
Continuous	10
Severe	0
Range of motion (5° = 1 point)	25
Stability	
Anteroposterior	
<5 mm	10
5-10 mm	5
>10 mm	0
Mediolateral	
<5°	15
6°-9°	10
10°-14°	5
15°	0
Flexion contracture	
5°-10°	−2
10°-15°	−5
16°-20°	−10
>20°	−15
Extension lag	
<10°	−5
10°-20°	−10
20°	−15
Alignment	
0°-4°	0
5°-10°	3 Points each degree
11°-15°	3 Points each degree