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Gait analysis of fixed bearing and mobile bearing total knee prostheses during walking: Do mobile bearings offer functional advantages?

Samuel G. Urwin [a,c,*], Deiary F. Kader [b,c], Nick Caplan [a,c], Alan St Clair Gibson [a,c], Su Stewart [a,c]

[a] Department of Sport, Exercise, and Rehabilitation, Faculty of Health and Life Sciences, Northumbria University, Newcastle upon Tyne, UK
[b] Orthopaedics and Trauma, Queen Elizabeth Hospital, Sheriff Hill, Gateshead, UK
[c] Orthopaedic and Sports Injury Research Group, Queen Elizabeth Hospital, Sheriff Hill, Gateshead, UK

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ABSTRACT

Background: Limited previous findings have detailed biomechanical advantages following implantation with mobile bearing (MB) prostheses after total knee replacement (TKR) surgery during walking. The aim of this study was to compare three dimensional spatiotemporal, kinematic, and kinetic parameters during walking to examine whether MBs offer functional advantages over fixed bearing (FB) designs.
Methods: Sixteen patients undergoing primary unilateral TKR surgery were randomised to receive either a FB ($n = 8$) or MB ($n = 8$) total knee prosthesis. Eight age and gender matched controls underwent the same protocol on one occasion. A 12 camera Vicon system integrated with four force plates was used. Patients were tested pre-surgery and nine months post-surgery.
Results: No significant differences between FB and MB groups were found at any time point in the spatiotemporal parameters. The MB group was found to have a significantly reduced frontal plane knee range of motion (ROM) at pre-surgery than the FB group (FB = 14.92 ± 4.02°; MB = 8.87 ± 4.82°), with the difference not observed post-surgery. No further significant kinematic or kinetic differences were observed between FB and MB groups. Fixed bearing and MB groups both displayed spatiotemporal, kinematic, and kinetic differences when compared to controls. Fixed bearing and MB groups differed from controls in six and five parameters at nine months post-surgery, respectively.
Conclusions: No functional advantages were found in knees implanted with MB prostheses during walking, with both groups indicative of similar differences when compared to normal knee biomechanics following prosthesis implantation.
Level of evidence: Level II.

1. Introduction

In total knee replacement (TKR) surgery, mobile bearing (MB) prostheses facilitate planar rotation about the vertical axis of the tibia [1,2], with a view to reducing sub-surface stress through dual surface articulation at both the superior and inferior surfaces of a polyethylene insert [3,4]. Dual surface articulation promotes load sharing between the relative displacements of the tibial and femoral components, dissipating knee moments and shear forces to the surrounding soft tissues in a similar manner to the normal knee [5].

Many theoretical benefits of the MB design, including the improvement in kinematics [5], have yet to be substantiated, with numerous authors documenting no improvements in outcomes when compared to fixed bearing (FB) designs [6–10]. The majority of studies comparing FB and MB prostheses have used questionnaire based outcome measures that have been shown to be less sensitive than gait analyses when detecting changes in gait [11]. Gait analysis has been previously used to measure functional outcome following TKR surgery [12], with current systems able to calculate the biomechanics about the knee to a high degree of accuracy, establishing gait analysis as an important tool in the clinical management of knee problems [13].

Previous findings have been inconclusive in the comparison of FB and MB prostheses by means of gait analysis, with four previous authors assessing walking [14–17]. The differences in study design, instrumentation, and methods between the studies make it difficult to extract meaningful conclusions. Mockel et al. [16] and Kramers-de Quervain et al. [17] presented results in favour of MB prostheses [5] that warrant further investigation. Mockel et al. [16] found increased stance phase knee flexion in MB knees (14.1°) when compared to FB knees (10.8°), an indication of a more effective shock-absorbing mechanism during loading response [22].

Kramers-de Quervain et al. [17] detailed greater maximum knee flexion during the swing phase of gait in MB knees (52.4 ± 7.56°) when compared to FB knees (47.1 ± 4.74°) in bilaterally implanted TKR patients. A greater maximum knee flexion during swing

* Corresponding author at: Department of Sport, Exercise, and Rehabilitation, Faculty of Health and Life Sciences, Northumberland Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK. Tel.: +44 7870856930.
E-mail address: samuel.urwin@northumbria.ac.uk (S.G. Urwin).

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demonstrates an improved ability for limb advancement and foot-clearance [18], in addition to increasing overall range of motion (ROM) which is an important determinant of functional activity following TKR surgery [19]. The aim of this study was to substantiate these previous limited findings of functional improvement in knees implanted with MB total knee prostheses during walking by means of three dimensional gait analysis.

2. Patients

Ethical approval was granted by an NHS Regional Ethics Committee. Nineteen patients with late stage primary knee osteoarthritis (OA) were recruited after giving written informed consent for participation. Patients were randomised to receive a FB (Sigma® Fixed Bearing Knee System, DePuy International, Leeds, UK) or MB (Sigma® Rotating Platform Knee System, DePuy International, Leeds, UK) total knee prosthesis. In contrast to a rotating platform where the femoral–tibial bearing surfaces are in substantial conformity from 0 to 60° of flexion, the MB knees in this study use the same multiradius femoral component and hence the femoral–tibial bearing is not in conformity.

Eight patients, five males and three females, received a FB prosthesis and had a mean age of 59.3 ± 8.8 years, height of 1.66 ± 0.09 m, mass of 87.85 ± 16.06 kg, body mass index (BMI) of 31.93 ± 4.86 kg/m^2, and pre-surgery Oxford Knee Score (OKS) of 39 ± 7.64. Eight patients, five males and three females, received a MB prosthesis and had a mean age of 59.6 ± 7.7 years, height of 1.7 ± 0.09 m, mass of 91.21 ± 12.43 kg, BMI of 31.92 ± 6.8 kg/m^2, and pre-surgery OKS of 37.42 ± 5.32. Inclusion criteria were patients between 45 and 80 years of age. Patients were excluded if they had previous hip or knee replacement surgery, gross ligament instability, valgus/varus displacement of ≥20°, significant infection of the knee joint post-surgery, or any other significant unrelated lower limb injury or chronic condition that was deemed to have the potential to affect ambulation. Both FB and MB prostheses were posterior cruciate ligament sacrificing, posterior stabilised, and had the patella resurfaced in all cases. One senior orthopaedic surgeon (DK) performed all of the procedures.

Eight age and gender matched asymptomatic participants, five males and three females, who had a mean age of 60.5 ± 7 years, height of 1.67 ± 0.12 m, mass of 72.58 ± 9.43 kg, and BMI of 26.06 ± 1.21 kg/m^2 were recruited as a control group. Table 1 details the demographic and anthropometric parameters of the FB, MB and control groups.

3. Method

3.1. Gait analysis

A 12 camera (T20, Vicon, Oxford, UK) three dimensional motion analysis system (Vicon MX, Oxford, UK) was calibrated through a standard dynamic protocol, exhibiting an image error of <0.2 mm. Participants had their height and mass taken, along with bilateral leg length, and knee and ankle widths in order to fit the participant's specific dimensions to the lower body 'Plug in Gait' model (Vicon, Oxford, UK). Fourteen retroreflective markers (Ø = 14 mm) were placed bilaterally over the anterior superior iliac spine, posterior superior iliac spine, lateral distal third of the thigh, lateral distal third of the shank, lateral malleolus, heel on the calcaneus, and the head of the second metatarsal. Kinematic data were subsequently captured at 200 Hz into Vicon Nexus (1.7.1, Vicon, Oxford, UK).

Four force plates (OR6-7, AMTI, Watertown MA, USA) were embedded within a 7 m walkway and amplified into Nexus at a gain of 1000 (MiniAmp MSA-6, AMTI, Watertown MA, USA), with kinetic data captured at 1000 Hz. Two knee alignment devices ((KADs) Vicon, Oxford, UK) were then placed bilaterally over the medial and lateral epicondyles to independently define the alignment of the knee flexion/extension axis during static capture. These were removed during dynamic trials and two retroreflective markers (Ø = 14 mm) were placed bilaterally over the lateral epicondyles of the knee. The participants undertook a number of barefoot walking trials until three were collected in which the ipsilateral foot contacted a force plate during both initial contact and toe off. Patients were tested pre-surgery and nine months post-surgery.

3.2. Data analysis

Raw data were processed in Vicon Nexus by filling marker trajectory gaps using a Woltring quintic spline routine when the gaps were less than 10 frames [25]. Marker trajectories and kinetic data were filtered using a fourth order low pass Butterworth filter with zero lag. A cutoff frequency of 6 Hz and 300 Hz was used for marker trajectories and kinetic data, respectively. The processed data were imported into Polygon Authoring Tool (3.5.1, Vicon, Oxford, UK) to normalise the trials to gait cycle percentage. Moments were normalised to Newton metres per kilogramme of body mass. Discrete kinematic and kinetic variables of the affected knee were processed following data normalisation in Polygon Authoring Tool. Discrete parameters encompassing the maximum, minimum, and range were chosen over continuous waveforms as they have a greater potential to characterise knee gait patterns [20].

3.3. Statistical analysis

Normality of distribution was determined by calculating skewness and kurtosis in order to verify the assumptions of the ANOVA parametric tests in PASW Statistics (Version 18, Chicago, IL, USA). Skewness and kurtosis were converted to z-scores. The resultant z-score was indicative of a normal distribution if the magnitude was <1.96 [21]. A one way repeated measures ANOVA was then undertaken to analyse differences between groups (FB, MB, control) at pre-surgery and nine months post-surgery. Sphericity was assumed if Mauchly's test was not significant ($p > 0.05$). In data where sphericity was not assumed, the violations were adjusted for by using the Greenhouse–Geisser correction. If the

Table 1
Demographic and anthropometric parameters of the fixed bearing (FB), mobile bearing (MB), and control groups.

	FB		MB		Control		ANOVA		FB–control	MB–control	FB–MB
	Mean	SD	Mean	SD	Mean	SD	*F*	*p*	Sig	Sig	Sig
n	8	–	8	–	8	–	–	–	–	–	–
Male	5	–	5	–	5	–	–	–	–	–	–
Female	3	–	3	–	3	–	–	–	–	–	–
Age (years)	59.3	8.8	59.6	7.7	60.5	7	0.046	$p = 0.96$	–	–	–
Height (m)	1.66	0.09	1.7	0.09	1.67	0.12	0.44	$p = 0.65$	–	–	–
Mass (kg)	87.85	16.06	91.21	12.43	72.58	9.43	4.73	*	0.069	*	0.86
BMI (kg/m^2)	31.92	6.8	31.92	6.8	26.06	1.21	3.86	*	0.063	0.064	1
OKS (pre-surgery)	39	7.64	37.42	5.32	–	–	0.018	$p = 0.89$	–	–	–
OKS (three months post-surgery)	25.88	12.18	24.5	9.62	–	–	0.018	$p = 0.89$	–	–	–
OKS (nine months post-surgery)	19.57	5.65	21.14	9.53	–	–	0.018	$p = 0.89$	–	–	–

'OKS' equates to 'Oxford Knee Score'; 'SD' to 'standard deviation'; '*' to 'significant at the 0.05 level'.