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Total knee arthroplasty with computer-assisted navigation more closely replicates normal knee biomechanics than conventional surgery

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ABSTRACT

Background: Computer-assisted navigation in total knee arthroplasty (TKA) reduces variability and may improve accuracy in the postoperative static alignment. The effect of navigation on alignment and biomechanics during more dynamic movements has not been investigated.

Methods: This study compared knee biomechanics during level walking of 121 participants: 39 with conventional TKA, 42 with computer-assisted navigation TKA and 40 unimpaired control participants.

Results: Standing lower-limb alignment was significantly closer to ideal in participants with navigation TKA. During gait, when differences in walking speed were accounted for, participants with conventional TKA had less knee flexion during stance and swing than controls ($P < 0.01$), but there were no differences between participants with navigation TKA and controls for the same variables. Both groups of participants with TKA had lower knee adduction moments than controls ($P < 0.01$).

Conclusions: In summary, there were fewer differences in the biomechanics of computer-assisted navigation TKA patients compared to controls than for patients with conventional TKA. Computer-assisted navigation TKA may restore biomechanics during walking that are closer to normal than conventional TKA.

1. Introduction

For patients with disabling knee osteoarthritis (OA), total knee arthroplasty (TKA) is widely considered as the most viable and successful management option. Following TKA, most patients can expect long-term reduction in pain and improvements in quality of life [1,2], and between 72% and 86% of patients report that they are satisfied with their postoperative outcome [3–5]. However, these improvements in function may not be sustained over longer periods of time. Functional performance may decline as little as three years after surgery, but perhaps more importantly up to 10% may require revision surgery within 10 years of the initial TKA primarily because of prosthesis loosening [6]. The most important determinants of failure secondary to prosthesis loosening are poor positioning of the prosthesis and subsequent malalignment of the postoperative lower limb. A recent meta-analysis found that as little as three degrees of deviation from ideal alignment in the coronal plane significantly increased the risk of TKA failure [7]. Greater bone stress on the medial side of the knee in failed arthroplasties suggests that lower-limb malalignment alters the distribution of forces across

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the knee and that this in turn accelerates prosthesis failure [8]. Clearly, strategies that increase the accuracy of prosthesis positioning may improve long-term prosthesis survival rates for patients.

Computer-assisted navigation was introduced as an adjunct to TKA surgery with the potential to improve positioning and alignment of the TKA prosthesis. A recent meta-analysis demonstrated that although the average coronal plane alignment after computer-assisted navigation TKA was not different from conventional TKA, the variability in the outcome was reduced [7,9,10]. It was therefore concluded that computer-assisted navigation TKA may be employed as a method of reducing error in prosthesis positioning and subsequent limb alignment. Computer-assisted navigation is now widely used to facilitate improved accuracy of postoperative lower-limb alignment.

In addition to measurement of static limb alignment, we have the ability to measure knee joint alignment and motion during more dynamic tasks. Assessment of patients during walking using three-dimensional motion analysis allows measurement of the motion of the joint as well as the forces acting across the knee. The external knee adduction moment remains the closest non-invasive estimate of the forces acting on the medial knee joint, and higher moments have been associated with higher risk of prosthesis failure [11,12]. Three-dimensional motion analysis has been able to detect subtle differences in function between patients with different prosthesis designs and technical approaches [13–15], and may therefore detect subtle differences in outcome between patients with navigated TKA and those with conventional TKA. We are unaware of any studies that compare knee biomechanics during walking between patients with navigated and conventional TKA, and that is therefore the aim of this study. We hypothesised that patients with computer-assisted navigated TKA would walk with biomechanics that more closely resembled normal gait than patients with conventional TKA.

2. Material and methods

This study was approved by the institution's Human Ethics Committee. All participants gave informed consent prior to participation.

2.1. Participants

All consecutive patients of a single experienced knee surgeon between April 2005 and June 2008 were invited to participate in the study if they had received a primary TKA in the management of disabling knee OA at least 12 months prior to testing. Patients also needed to be able to walk 10 m without the use of gait aid, and be free from other orthopaedic, neurological or visual disturbances that may affect gait, including advanced knee OA of the contralateral knee and other joint replacement. From an initial pool of 166 consecutive patients, 111 were eligible and invited to participate in the study. Of these, 81 agreed to participate and attended the gait laboratory at La Trobe University for biomechanical testing. All patients received a Genesis II PS TKA prosthesis (Smith and Nephew, Memphis, TN, USA) with traditional technique and patellar resurfacing. In 42 of these patients the Image Free BrainLAB Navigation System (BrainLAB, Munich, Germany) was used by the surgeon during surgery. These patients were not randomised, but received navigation TKA as it was introduced into routine practice following a period of surgeon training in using the navigation system. A smaller cohort of these patients has been reported previously [16–18]. A control group recruited for this previous work was used as a comparison cohort in the current study. These participants were without knee surgery or knee pain.

2.2. Equipment

All participants attended a single session at the gait laboratory for biomechanical assessment. Thirteen passive reflective markers were fixed to anatomical bony landmarks according to the Modified Helen Hayes model using double-sided adhesive tape [19,20]. These landmarks included a single marker on the sacrum, and bilateral markers on the anterior superior iliac spines of the pelvis, lateral epicondyles of the knee, lateral and medial malleoli, calcanei and head of the fifth metatarsals. Markers on five-centimetre wands were placed bilaterally on the thighs and shanks, and a Knee Alignment Device (Vicon, Oxford, UK) was used to calculate the centre of the knee joint in three dimensions. An additional two markers were placed over the lateral aspect of the iliac crest to facilitate definition of the pelvis given the challenges of pelvis marker placement and occlusion in this population [21].

An eight-camera Vicon motion analysis system (Vicon Motion Systems Ltd., UK) was used to collect video data from the passive reflective markers as the participants walked through the calibrated space (approximately six metres in length, two metres in width and two metres in height) at a sampling rate of 100 Hz. Two force platforms (Kistler, Switzerland and AMTI, MA, USA) embedded into a 10-m walkway were used to collect ground reaction force data at a sampling rate of 400 Hz.

2.3. Gait analysis protocol

All participants were asked to walk at a self-selected comfortable speed along a 10-m walkway. Participants were not informed of the embedded force platforms, but starting position was adjusted to facilitate stance of at least a single limb within a force platform. After a period of familiarisation (at least 10 passes of the walkway), data was collected until six trials of force platform data had been collected on each limb.

2.4. Clinical assessment

The American Knee Society Knee Score was completed by all participants.

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