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Radiographic outcome of limb-based versus knee-based patient specific guides in total knee arthroplasty

Catherine Crane [a], Kanniraj Marimuthu [b], Darren B. Chen [a,b], Ian A. Harris [c], Emma Wheatley [d], Samuel J. MacDessi [a,b,*]

[a] Department of Orthopaedic Surgery, The Canterbury Hospital, Canterbury, NSW, Australia
[b] Sydney Knee Specialists, St George Private Hospital, Sydney, NSW, Australia
[c] Ingham Institute for Applied Medical Research, South Western Sydney Clinical School, UNSW, Australia
[d] Bryant Radiology, St George Private Hospital, Sydney, NSW, Australia

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ABSTRACT

Background: Patient specific guides (PSG's) were developed to improve overall component alignment in total knee arthroplasty (TKA). The aim of this study was to undertake a comparative radiographic study of two commonly used PSG and determine whether the radiographic technique used to construct the PSG had a significant effect on overall alignment.
Methods: This prospective cohort study examined the accuracy of limb-based (n = 112) versus knee-based (n = 105) MR PSG in restoring the mechanical axis in three planes according to post-operative Perth CT scan protocol.
Results: Limb-based MR and knee-based MR PSG systems both restored overall hip–knee–ankle angle (HKAA), femoral coronal alignment, tibial coronal alignment, femoral sagittal alignment, tibial sagittal alignment and femoral rotation alignment to within 3° of a neutral mechanical axis with similar precision (91.1% vs. 86.7% p = 0.30, 97.3% vs. 96.2% p = 0.63, 97.3% vs. 97.1% p = 0.94, 94.6% vs. 89.4% p = 0.16, 90.2% vs. 81.0% p = 0.05, 91.1% vs. 86.7% p = 0.30, respectively). However, when the secondary outcome measure of alignment within 2° was assessed, limb-based MR PSG restored HKAA, femoral coronal and tibial sagittal alignment with greater precision than knee-based MR PSG (73.2% vs. 64.8% p = 0.016, 93.8% vs. 80.8% p = 0.004 and 82.1% vs. 62.9% p = 0.001, respectively).
Conclusions: The findings of this study recommend the use of limb-based MR PSG for improved precision in the restoration of neutral mechanical alignment over knee-based MR PSG in TKA.
Level of Evidence: Therapeutic level III

1. Introduction

A cornerstone to the success of total knee arthroplasty (TKA) is founded in component alignment. It is well documented that coronal malalignment, particularly varus malalignment is associated with increased wear, higher strain, possible premature failure of the construct and in some cases poorer outcomes [2–5].

Conventional instrumentation (CON), using a combination of intra-medullary and extra-medullary jigs remains the most common technique to restore a neutral lower limb mechanical axis. Computer-assisted navigation surgery (CAS) has been shown to decrease the number of outliers when compared to CON [6]. However, its popularity has not increased over recent years, potentially due to longer operative times, increased staff and equipment required in the operating room and problems associated with pin trackers [7].

Patient specific guides (PSG) are manufactured pre-operatively and are available from the majority of orthopedic implant manufacturers. These guides conform to the patient's anatomy during surgery, allowing femoral and tibial resections to be performed based on pre-programmed variables. They have been theorized to improve alignment when compared to CON, as well as reduce operative time and avoid the perceived complexity and initial set-up expenses that are often associated with CAS [8,9]. Despite these instruments being available for use for several years, there remains a paucity of data on their accuracy, especially when compared to the literature available on CON and CAS.

PSG systems differ with regard to the pre-operative imaging used to define the joint topography, anatomic and mechanical axes and jig function (pinning or cutting guides). Systems based on one imaging modality (CT or MR) use a scanogram or spot scans of the hip and ankle to define the mechanical axis in addition to detailed imaging of the knee for joint topography. Other PSG systems use a combination of CT or

* Corresponding author at: Sydney Knee Specialists, Suite 8, 19 Kensington Street, Kogarah, NSW 2217, Australia.
E-mail address: samuelmacdessi@sydneyknee.com.au (S.J. MacDessi).

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MR to map the joint topography, while using plain radiography for mechanical axis restoration.

At this stage, there is limited evidence to suggest that component alignment is superior with guides manufactured from a particular imaging modality. The aim of this study is to undertake a comparative radiographic study of two commonly used PSGs that utilize different radiographic techniques. The hypothesis of our study is that a whole limb-based MR PSG (LPSG) would offer better alignment in all three planes when compared to a knee-based MR PSG (KPSG) that utilizes plain radiographs for coronal reconstruction only.

2. Materials and methods

A consecutive cohort of 217 patients who had undergone a TKA using PSG by two consultant surgeons (SJM, DBC) from May 2010 until March 2013 at one institution were prospectively studied. From May 2010 all patients who were consented to undergo a TKA by the consultant surgeons were eligible for inclusion in the study. Inclusion required sufficient preoperative time to manufacture PSGs and informed consent for participation in the study. Exclusion criteria included contraindications to MR examination including the presence of cardiac and cerebral implants, or metal implants close to the knee joint and other patient specific factors that inhibited MR examination. Patients who did not meet the inclusion criteria or those who met exclusion criteria underwent CON TKA. Hospital ethics board approval was gained.

A total of 217 knees were replaced using MR based PSG during the study period and they comprised the two study groups. At the time of consent, patients were sequentially assigned to the study groups, firstly to KPSG then to LPSG. A formal sample size calculation was not performed for this study.

Group 1 (LPSG group) included 112 consecutive patients who had undergone TKA using limb-based MR guides (Patient Specific Instrumentation (PSI), Zimmer, Warsaw, IN). The PSI system utilizes MR only, both for joint surface mapping as well as mechanical axis restoration in the coronal, sagittal, and axial planes.

Group 2 (KPSG group) comprised of 105 consecutive patients who had undergone TKA using knee-based MR guides (Visionaire, Smith and Nephew, Memphis, TN). The Visionaire system utilizes a combination of MR to map the knee joint topography with long leg (hip to ankle) plain radiography to assess the femoral and tibial mechanical axis in the coronal plane.

The mean age in Group 1 was 68 years (range 66 to 69 years). The mean age in Group 2 was 69 years (range 67 to 71 years). The majority of PSG TKAs in each group were performed by one surgeon SJM; 89 of 112 in Group 1 and 74 of 105 in Group 2.

For both systems, a perpendicular resection in the coronal plane to the mechanical axis (MA) of the distal femur and proximal tibia was planned. In the sagittal plane, neutral femoral flexion angle was planned for the distal femur and posterior slopes of 7° and 3° were planned for the LPSG and KPSG systems respectively according to the manufacturer's recommendations. Femoral component rotation was set parallel to the surgical transepicondylar axis in both groups. In both groups, tibial rotational positioning was achieved by manually aligning the component parallel to the axis from the PCL foot print to the junction of the medial and middle one-third of the patellar ligament. The PSGs were not used in either group for tibial rotational positioning and as such were not measured as part of the analysis of the accuracy of these guides.

2.1. Surgical technique

All operations were performed by two fellowship-trained knee arthroplasty surgeons (SJM, DBC) who were experienced with PSG TKA techniques. Both surgeons utilized equivalent surgical techniques. All surgeries were performed under spinal anesthetic combined with sedation. A tourniquet was used for initial soft tissue dissection and then deflated for the remainder of the case. A medial parapatellar approach was undertaken for surgical exposure. The distal femoral followed by proximal tibial resections were performed using the PSGs and then the extension gap was assessed to ensure adequate bone resection and coronal alignment. The femoral preparation was then completed using the pre-drilled distal holes from the PSGs. All patients received posterior stabilized fully cemented implants using either Zimmer NexGen LPS Flex (LPSG) or Smith and Nephew Legion High Flex systems (KPSG). The patella was resurfaced in all cases.

2.2. Radiographic assessment

All patients underwent a post-operative CT scan in accordance with the Perth protocol [1] using a low dose radiation of 2–3 mSv. A 2 mm slice helical scan from acetabulum to ankle joint was reconstructed to measure component alignment.

All scans were analyzed by an experienced CT radiographer (EW) and a subset of 20 random scans was reviewed (KM) to test inter-observer reliability.

2.3. Outcome measures

The hip–knee–ankle angle (HKAA) was measured in the coronal plane as the angle between the femoral coronal mechanical axis (FMA) and the tibial coronal mechanical axis (TMA). A line was drawn from the center of rotation of the femoral head to the center of the knee on the distal femur and another line was drawn from the center of the proximal tibia to the midpoint of the talar dome of the distal tibia and the HKAA is the angle between these two lines. A valgus alignment was given a positive (+) value; a varus alignment was given a negative (−) value. HKAA was considered satisfactory if it deviated 3° or less from neutral alignment (Image A).

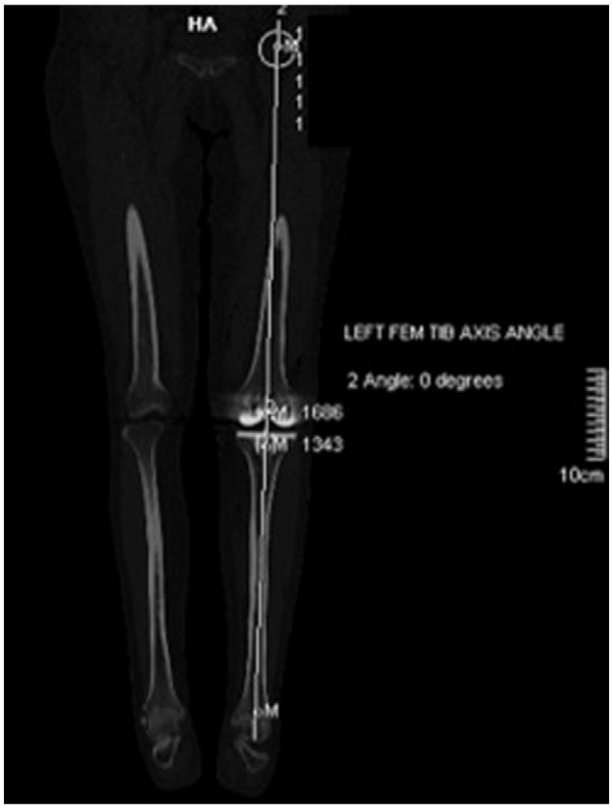

Image A. Hip–knee–ankle angle (HKAA)