A retrospective review was performed of patients undergoing primary cementless total knee replacement (TKR) using porous tantalum performed by a group of surgical trainees. Clinical and radiological follow-up involved 79 females and 26 males encompassing 115 knees. The mean age was 66.9 years (36 to 85). Mean follow-up was 7 years (2 to 11). Tibial and patellar components were porous tantalum monoblock implants, and femoral components were posterior stabilised (PS) in design with cobalt–chromium fibre mesh. Radiological assessments were made for implant positioning, alignment, radiolucencies, lysis, and loosening. There was 95.7% survival of implants. There was no radiological evidence of loosening and no osteolysis found. No revisions were performed for aseptic loosening. Average tibial component alignment was 1.4° of varus (4° of valgus to 9° varus), and 6.2° (3° anterior to 15° posterior) of posterior slope. Mean femoral component alignment was 6.6° (1° to 11°) of valgus. Mean tibiofemoral alignment was 5.6° of valgus (7° varus to 16° valgus). Patellar tilt was a mean of 2.4° lateral (5° medial to 28° lateral). Patient satisfaction with improvement in pain was 91%. Cementless TKR incorporating porous tantalum yielded good clinical and radiological outcomes at a mean of follow-up of seven-years.

Cite this article: Bone Joint J 2014;96-B(11 Suppl A):87–92.
the mechanics of performing the TKR operation. This may represent a potential advantage to both the general Orthopaedic surgeon who performs TKR infrequently, as well as to the higher volume arthroplasty specialist. Perhaps the greatest potential cost saving is derived from the reduction in operating room time. A 2005 survey of 100 U.S. hospitals demonstrated operating room charges ranging from $22 to $133/minute, charged in 15-minute intervals ($930 to $3495 per 15-minute interval).\textsuperscript{14} At our institution (a Level 1 county trauma centre with an Orthopaedic residency training program) we typically spend an average of 19 minutes of operating room time for the cementing of a TKR. Our operating room charges are $1500 per 15-minute interval. The savings in our hospital operating room time charge is $3000 per case when performing all cementless TKRs. Our average time expended for insertion of all three cementless implants is less than 60 seconds. The potential one to one and a half hour time savings each day in an operating room committed to TKR may bring further cost savings in the form of a reduction in nursing and surgical technician overtime and benefits costs. Savings in cumulative surgical time over the course of several cases in a day may also allow the performance of an additional surgery, thereby increasing operating room efficiency and enhancing use of resources.

From the standpoint of the patient, the shorter operating time reduces the time under anesthesia, the blood loss for those surgeons who do not use a tourniquet, as well as the infection risk, optimising the conditions for a potential reduction in post-operative complications, directly impacting a potential reduction in morbidity and mortality.\textsuperscript{15-17} Overall, as a result of shortened operating time, the performance of all cementless TKRs brings potential advantages to the patient in the form of a reduction in complications and an improvement in outcomes.

An innovative biomaterial introduced into Orthopaedics for cementless fixation is porous tantalum (Trabecular Metal, Zimmer, Warsaw, Indiana). This material is 80%
porous by volume, with an average pore size of 550 microns. Every pore has a dodecahedron geometry (a 12-sided figure with each side shaped like a pentagon), and all pores are 100% interconnecting (Fig. 1a). Compared with other commonly used materials for cementless fixation such as titanium, large sintered beads, small sintered beads, and fibre mesh, porous tantalum has the highest surface friction against bone, improving initial stability at the implant-bone interface as a prerequisite for long-term biological fixation of the reconstruction. A monoblock cementless tibial component with direct compression molded polyethylene was introduced 12 years ago (Fig. 1b), followed one year later by a monoblock patellar component of similar design (Fig. 1c).

Pulido et al\textsuperscript{22} reported the five-year Mayo Clinic experience with cementless TKR using the highly porous monoblock tibial component in 117 knees and found no difference in survivorship compared with cemented fixation with a re-operation rate of 3.5% in both groups. They had no revisions of the uncemented monoblock tibial components for aseptic loosening.\textsuperscript{22} These early to intermediate results reflect our own experience with this prosthesis described below. Unlike some single surgeon series where the clinical outcomes have been a challenge to reproduce by surgeons in the general Orthopaedic community, the cases in our series were all performed by Orthopaedic residents.

**Patients and Methods**

Between January 2003 and December 2009, 145 patients (172 knees) underwent primary cementless TKR at Harbor-UCLA Medical Center. Of this group, six patients died and 34 patients were lost to follow-up. The lost patients are representative of the transient nature of our largely indigent county hospital population. Retrospective clinical and radiological follow-up were obtained for the remaining 79 females and 26 males encompassing 115 knees. Bilateral procedures were performed on ten patients. The mean age was 66.9 years (36 to 85). In this group, 35% (37/105) of patients were less than 65 years of age, and 65% (68/105) were greater than 65 years of age. The mean body mass index (BMI) was 32.5 kg/m\textsuperscript{2} (20.4 to 44.5) of which 66% (69/105) had a BMI greater than 30 kg/m\textsuperscript{2} and 10% (11/105) had a BMI greater than 40 kg/m\textsuperscript{2}. The mean follow-up was seven years (2 to 11). Patients with a minimum follow-up of at least five years constituted 73% (77/105) of the group. There was 5% (5/105) of the group that had a minimum of ten years follow-up. Pre-operative diagnoses are as listed in Table I. Tibial and patellar components (NexGen, Zimmer, Warsaw, Indiana) were monoblock implants with direct compression moulded polyethylene into a porous tantalum substrate. The femoral components were all cobalt chromium (C-C) posterior stabilised design with diffusion bonded C-C fibre mesh (NexGen, Zimmer, Warsaw, Indiana). Fixation of the tibial component was achieved through the interference fit of hexagonal pegs protruding from the inferior surface of the tibial component into anchor holes that were dimensionally smaller in diameter drilled perpendicularly into the tibial resection surface according to the manufacturer’s recommended surgical procedure. All patellae were prepared using a patellar reaming system in order to machine a flat planar surface (Fig. 2) followed by interference fit of a single hexagonal patellar fixation peg into an anchor hole that is dimensionally smaller in diameter drilled into the patellar bone. A patellar clamp is used to ensure that opposing surfaces at the implant-bone interface approach each other in a parallel fashion. Radiological assessments were made of implant positioning and alignment, and for the presence of radiolucencies, lysis and loosening. A modified Knee Society zonal system\textsuperscript{23} as described by O’Keefe et al\textsuperscript{24} was used to assess radiological findings. All radiographs were independently reviewed by a radiologist (MDD) in our Institution’s Department of Radiology. Their usual and customary internal radiographic quality assurance criteria were applied to ensure uniformity in image quality and limb positioning in the standard radiographs obtained. Radiological alignment of implants was measured according to the Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. Electronic measuring tools built into the Institutional PACS system were used to determine the actual angles on digital images.

Clinical outcome data was extracted regarding pain relief and function using a modified and abbreviated Knee Society questionnaire\textsuperscript{25} using the subjective portion only. This modification of using the abbreviated questionnaire only has not been validated. All surgeries were performed by Orthopaedic residents from the postgraduate years one to five levels of training during this period, under the supervision of a single senior surgeon (LMK).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoarthritis (OA)</td>
<td>87</td>
</tr>
<tr>
<td>Inflammatory arthritis</td>
<td>9</td>
</tr>
<tr>
<td>Post-traumatic OA</td>
<td></td>
</tr>
<tr>
<td>Tibial plateau fracture</td>
<td>3</td>
</tr>
<tr>
<td>Distal femur Fracture</td>
<td>1</td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>1</td>
</tr>
<tr>
<td>ACL\textsuperscript{*} deficiency</td>
<td>1</td>
</tr>
<tr>
<td>Post-mensicectomy</td>
<td>3</td>
</tr>
</tbody>
</table>

\textsuperscript{*} ACL, anterior cruciate ligament
Results
There was 95.7% survival of implants. Four patients were revised for infection (4 of 115, 3.5%), and one for femoral component mismatch. In a worst case scenario analysis, if the 57 knees lost to follow-up all represented failures due to aseptic loosening requiring revision, then the implant survival would be 59%. In those patients available for follow-up, there was no radiological evidence of loosening and no osteolysis was found. Implant bone interfaces typically demonstrated trabecular patterns streaming up to the porous tantalum surface without intervening radiolucencies or demarcation lines (Fig. 3). No revisions were performed for aseptic loosening. One patient died from pulmonary embolism. Other complications include one each of intra-operative patellar fracture, post-operative patellar fracture, symptomatic DVT, wound dehiscence, and two periprosthetic fractures all with retention of implants (6 of 115, 5.2%). The patient with the post-operative patellar fracture had presented for three month follow-up with a history of having sustained a fall onto the

Photographs showing patella reaming system to ensure preparation of a planar surface for intimate bone apposition to implant.
operated knee six weeks prior to presentation. Follow-up radiological knee series at that time demonstrated a minimally displaced fracture of the patella in this clinically well-functioning patient. While the possibility of loosening and the need for revision surgery was discussed with the patient, she opted not to proceed with surgical intervention, and has continued to do well clinically, with no radiological evidence of failure or further change in implant position. Subsidence of 4 mm into a stable varus position of a tibial component was found in a morbidly obese, asymptomatic and well-functioning patient. Mean tibial component alignment was 1.4° of varus (4° valgus to 9° varus), and 6.2° of posterior slope (3° anterior to 15° posterior slope). The mean femoral component alignment was 6.6° (1° to 11°) of valgus. Average tibio-femoral alignment was 3.6° of valgus (7° varus to 16° valgus). Patellar tilt was a mean of 2.4° lateral (5° medial to 28° lateral).

Based on the results of the patient questionnaire, asymptomatic stair climbing was found in 85% of patients. Patient satisfaction with improvement in pain was reported in 91% of subjects at follow-up. There was no effect of stratifying by age or by BMI.

Discussion
As a Level I county trauma centre serving a largely indigent population, the 3.5% revision for infection in this series is a reflection of the higher risk population of patients served by our Institution. One patient with infection had previously sustained a comminuted tibial plateau fracture treated with open reduction and internal fixation, followed by a local rotation flap for wound necrosis, and eventually hardware removal following union of the fracture. Following the primary cementless arthroplasty procedure on that knee performed by our Institution, the patient underwent an arthroscopic procedure on the replaced knee by an outside private Orthopaedic surgeon at another institution. He subsequently developed a post-operative haematoma following the arthroscopy that required surgical evacuation by that surgeon, eventually developing peri-prosthetic infection for which he underwent revision knee replacement. A second infection patient was a morbidly obese (BMI 41.2 kg/m²) female with insulin-dependent diabetes mellitus and peripheral vascular disease. Because of persistent wound drainage at two weeks, the patient was taken to the operating room for presumed early surgical site infection. As the tibial component is a non-modular, monoblock implant, and the components not biologically fixed at two weeks, all implants could be removed as a part of the debridement procedure, and a single-stage re-implantation performed. While all intra-operative cultures were negative, this was deemed an early post-operative infection. A third patient, an 82-year-old male with steroid-dependent rheumatoid arthritis developed a wound dehiscence three weeks following surgery. The patient underwent a single-stage revision with a local rotation flap. Intra-operative cultures were positive for methicillin sensitive Staphylococcus aureus and he was successfully treated without further sequelae. The fourth patient was a 60-year-old female (BMI 34.7 kg/m²) with no other identifiable risk factors for infection.

While mean implant alignment in our unselected series seemed good for all components, the large ranges found in association with each element might be consistent with the learning curve of the Orthopaedic residents in training who performed the procedures. The technical variability in alignment found in this series would not be reflective of what would be expected in a high-volume single surgeon series. Results suggest a tolerance of the material and fixation interfaces to departures from optimal implant positioning and alignment with no apparent compromise in the durability of the reconstruction nor in the clinical results at intermediate follow-up. Neither age nor BMI was found to have an effect on outcome in this series. Our results also suggest that new technology, implant design, and/or...
biomaterials appear to have addressed prior reported problems associated with a high rate of patellar component failure that was not seen in this unselected series of all cementless TKRs.

This study is limited by the retrospective nature of this investigation, as well as the number of patients lost to follow-up largely due to the nature of our patient population. A prospective ten-year multi-centre outcomes trial is currently being implemented in order to address the deficiencies of the current study.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This paper is based on a study which was presented at the 2013 Current Concepts in Joint Replacement® – A Short Course held in conjunction with the 8th International Congress of the Chinese Orthopaedic Association in Beijing, China, 8th November.

References


