A Comparison Between Robotic-assisted and Manual Implantation of Primary Cementless Total Hip Arthroplasty Femoral Components; Minimum Five Years Results

Nobuo Nakamura1, Nobuhiko Sugano2, Takashi Nishi3, Hidenobu Mik4, Akhiro Kakimoto1, Hideki Yoshikawa2
1Center of Arthroplasty, Kyowakai Hospital, 2Department of Orthopaedics, Osaka University Graduate School of Medicine, 3Department of Orthopaedic Surgery, Osaka National Hospital

Introduction: Although there are several short-term reports that have compared robotic-assisted surgery with hand-rasping technique for implanting femoral components during total hip arthroplasty (THA), the benefits of robotic techniques are still controversial. The purpose of this study was to prospectively compare the results and complications of robotic-assisted and hand-rasping stem implantation techniques.

Materials and Methods: We performed a prospective randomized study. The mean follow-up period was 67 months; the minimum follow-up was five years. We performed 146 THA on 130 patients who were undergoing primary THA, mainly for a diagnosis of osteoarthritis secondary to hip dysplasia. Robotic assisted primary THA was performed on 75 hips and a hand-rasping technique was used to prepare the proximal femur on 71 hips. Postoperatively, the hip function was evaluated using the Japanese Orthopedic Association (JOA) clinical score. Plain radiographs were analyzed for evaluation of limb length discrepancy, implant fixation, stress shielding, and heterotopic ossification.

Results: At two and three years postoperatively, the JOA hip score was significantly better in the robotic-assisted group (p=0.04; and p=0.0003 respectively). At five years follow-up, the differences in the JOA scores were not significant (p=0.05). Postoperative limb lengths of the robotic milling group had significantly less variance than the hand-rasping group (F-test; P=0.004). Plain radiographs showed bone ingrowth fixation for all the stems and cups in both groups. There were no signs of mechanical loosening in any implant. At two years postoperatively, there was significantly more stress shielding of the proximal femur in the hand-rasping group (Mann-Whitney exact test; p=0.03); this difference was more significant at five years postoperatively (p=0.002).

Discussion: Robotic milling THA was associated with better clinical scores until three years postoperatively; at five years postoperatively, the clinical scores were not significantly different. Significantly more precise implant positioning seemed to have led to less variance in limb length inequality and less stress shielding of the proximal femur at five years postoperatively.

Cement removal from the femur using the ROBODOC system in revision total hip arthroplasty

Mitsuyoshi Yamamura1, Nobuhiko Sugano2, Nobuo Nakamura3, Akhiro Kakimoto2, Masaki Takao2, Takashi Sakai2, Takashi Nishi2, Hideki Yoshikawa2
1Department of Orthopaedics, Osaka Kouseienkin Hospital, 2Department of Orthopaedics, Osaka University Graduate School of Medicine, 3Department of Orthopaedics, Kyowakai Hospital

Introduction: In revision total hip arthroplasty (THA), perforation and fracture of the femur are serious complications which considerably affect postoperative protocols and clinical results. A computer-assisted surgical system called ROBODOC has been used in clinical settings and is highly regarded for its accuracy of the surgical process. The ROBODOC system can remove bone cement from the femoral canal selectively in revision THA. The purpose of our study was to evaluate clinical and radiographic results of revision THA using the ROBODOC system.

Materials and Method: Participants were 19 patients who underwent revision THA with the ROBODOC system. Average age was 70 years, and average follow-up period was 5.8 years. Prior to revision surgery, two locator pins were implanted into the greater trochanter and lateral condyle of the affected femur under local anesthesia and a computed tomography (CT) scan of the femur was taken. The CT data were imported into a preoperative planning workstation (ORTHODOC) that displayed a three-dimensional image of the femur. The surgeon created a 3-dimensional cutting path for cement removal on ORTHODOC. At operation, registration was performed using the two locator pins, and then the ROBODOC milled the femoral canal to remove bone cement, and a long straight tapered stem was then inserted. The clinical results were measured with Merle d'Aubigné and Postel score. We evaluated the extent of remaining bone cement on postoperative radiographs of the femur, timing of weight-bearing and complications.

Results: The average clinical score increased from 10 points preoperatively to 14 points at the latest follow-up. Bone cement was completely removed in all cases. No instances of perforation or fracture of the femur occurred during removal of cement or stem insertion. Of 19 cases, full weight-bearing was possible within one week in 9 cases and in all remaining patients within two months. Stem subsidence was seen in two cases, but all stems were considered to be stable at the latest follow-up. Dislocation occurred in one case and it was successfully treated with an abduction brace. There was no nerve palsy or infection in this series.

Discussion: Using the ROBODOC system, bone cement could be safely removed, and no serious complications occurred. As the system allows circumferential preservation of the femoral cortex, full weight-bearing was possible earlier in the postoperative course.
Development of a robot system for less invasive arthroplasty

Kazuo Fujiwara, Nobuhiro Abe, Hirosuke Endo, Shigeru Mitani, Toshihumi Ozaki, Masahiko Suzuki, Naohiko Sugita, Yoshikazu Nakajima, Mamoru Mitsuishi, Takayuki Inoue

1Department of Medical Materials for Musculoskeletal Reconstruction, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama, Japan, 2Department of Orthopaedic surgery, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama, Japan, 3Department of Orthopaedic surgery, Chiba University Graduate School of Medicine, Chiba, Japan, 4Department of Engineering Synthesis, School of Engineering, The University of Tokyo, Tokyo, Japan, 5Nakashima Medical co., Okayama, Japan

Introduction: ROBODOC is a well known tool for a computer assisted arthroplasty. However, the incision is tend to enlarge with the system because of the restriction of range of motion. We have developed the robot system for minimally invasive arthroplasty. This report shows the accuracy of our system composed of original planning software, navigation and bone cutting robot.

Material and Method: We took the DICOM data of cadaver knees from computed tomography. The data were transferred to the workstation for planning. Matching points for registration and cutting planes were determined on the planning software. Cutting tool was the 6th robot which was able to recognize the locations of its apex and the cadaver knee with navigation system. We made five planes on femur and one plane on tibia. We evaluated the accuracy by measurement the location of cutting plane under navigation system and by CT data.

Results: The registration errors of femur and tibia were less than 1.5mm about cadaver knees. The errors of cutting planes were 1.3 mm about the distal end of femur and 0.5 mm about the proximal end of tibia. The accuracies of the angles of cutting planes were 1.9 degrees and 0.8 degrees compared to the mechanical axis.

Discussion: The errors of anterior and posterior plane of femur were increased compared to the distal plane. It was because the accuracy of registration were correct in axial direction but was not satisfied in rotational direction. The error was considered by the location of points which decided the rotation alignment. We will make effort to minimize the errors of registration and put it into practical use as soon as possible.

Robotically Assisted UKA is More Accurate than Manually Instrumented UKA

Thomas M Coon, Matthew D Driscoll

1St Elizabeth Community Hospital, Red Bluff CA, USA,
2Scott & White Memorial Hospital, Temple, TX, USA,
3MAKO Surgical Corp, Ft Lauderdale FL, USA

Introduction: Successful clinical outcomes following unicompartamental knee arthroplasty (UKA) depend on accurate component alignment, which can be difficult to achieve using manual instrumentation. A new technology has been developed using haptic robotics that replaces traditional UKA instrumentation. In addition to potentially improving accuracy, this technology utilizes a bone preserving inlay tibal design (as opposed to traditional onlay designs), which may result in reduced post-operative pain and quicker recovery due to preservation of the medial tibial plateau periphery and its densely innervated periosteum. This study compares the accuracy of UKA component placement and early clinical outcomes with traditional jig-based instrumentation versus robotic guidance.

Materials and Methods: 77 UKA patients were included in this study. 44 onlay UKAs performed using standard manual instrumentation were compared to 33 inlay UKAs performed with a robotically guided implantation system employing a haptic-guided burr for all bone resection. Each was performed using a minimally invasive surgical approach. The two groups were identical in terms of age (p=0.74), gender (p=0.65) and BMI (p=0.72). The coronal and sagittal alignment of the tibial components as well as the height of tibial resection were measured on pre- and post-operative AP and lateral radiographs. All patients received the same pain management and rehabilitation protocol and the length of hospital stay was measured. Knee society scores (KSS) were collected preoperatively and at three, six, and twelve week follow-ups.

Results: The RMS error of the tibial slope was 3.5° manually compared to 1.4° robotically. In addition, the variance using manual instrumentation was 2.8 times greater than the robotically guided implantations (p=0.0001). In the coronal plane, the average error was 3.3° ± 1.8° more varus using manual instruments compared to 0.1° ± 2.4° when implanted robotically (p<0.0001). The average depth of medial tibial plateau resection was significantly less with inlay tibial components (3.7 ± 0.8mm) relative to onlay tibial components (6.5 ± 0.8mm, p<0.0001). While the average length of hospital stay was the same for both onlay (LOS = 1.0 ± 0.2days) and inlay (LOS = 0.9 ± 0.5days) UKA procedures, a significantly higher percentage of inlay patients went home the day of surgery (18% vs. 2%, p=0.0001). There was no significant difference in terms of average KSS, change in KSS, or Marmor rating between the two groups at any of the three follow-ups. Furthermore, there were no significant differences in the measures that comprise these scores, such as range of motion, pain, and use of assist devices (p > 0.05).

Conclusions: Tibial component alignment in UKA is significantly more accurate and less variable using robotic guidance compared to manual, jig-based instrumentation. Also, a significantly higher percentage of inlay patients are able to be treated as outpatients, possibly as a result of the less invasive, bone-preserving nature of this technique. Clinical results of this initial series of UKAs using a new haptic-guided surgical technique are comparable to those using established techniques, thus alleviating concerns regarding the acquisition of a new skill set and inferior outcomes at the beginning of the learning curve.
Clinical Evaluation of "Direct Tunneling Technology" in UKA

Chun Tek Lee, Marty Trabish, Oh Myoung Kwon, Miro Kang, Hang Jae Lee, Joon Sik Park
Department of Orthopaedics, LCT Hospital S.Korea, &LCT Robotic Joint Research Center, S. Korea

Introduction:
Current robotic platforms do not support Uni-Compartmental Arthroplasty. Due to the large cutter head and bulky sleeve, and a volumetric removal rate top-down cutting sequence, a complete redesign to promote minimal retraction, yield fast, safe and accurate implantation is eminent therefore “Direct Tunneling Technology” is invented. New software is developed to facilitate the tissue sparing approach to eliminate collateral damage and promote better surgical execution, earlier ambulation and a faster route to full rehabilitation and early recovery over increasing patient satisfaction.

Method & Materials:
20 patients were selected to participate in this study. All patients were diagnosed with isolated compartmental disease, 110 deg ROM, stable collateral bands, ACL intact, normal RA indicators. Valgus deformities greater than 20 degrees, flexion contracture greater than 15 degrees, were excluded from this study. All patients underwent CT & Image processing using 3D planning software where HKA alignments were set to 2 degrees of alignment.

Results:
Average incision size 5 cm. Intra-operative exposure assessment was retraction-free during bony surface preparation. Mean operative time recorded to be 45 minutes (learning curve factored). Post-Op radiographic assessment confirms under-correction within 2 degree range. Femoral-Tibial Angle measured to comply with the anatomical structure. Clinical findings reveal decreased pain and discomfort level, 1st leg-raising time mean time 2 hours post-op, 1st walking 4 hrs mean time, mean blood loss at 150cc.

Discussion:
Published findings reveal that 35% of UKA’s had fair/poor results with a high incidence of degeneration of opposite tibio-femoral component. (Instoll) consequently leading to the decrease in UKA popularity. Proper execution of surgical technique remain critical to optimize outcome. UKA under limited incision adds several risk factors that are addressed and factored into a new technique and design. Innovative software and new hardware has been developed and used in this assessment. To overcome the burden of increased time associated with existing scalping robot platforms, a novel “Direct Tunneling Technology” (DTT) was used to implement the surgical plan, a system that precisely implements a pre-surgical plan without outliers and minimal collateral damage. A system whose emphasis is the preservation of uninvolved tissue & bone, reduction of operative time compared to the best practitioners with a high degree of accuracy and fail safe was the approach sort after.

Conclusion:
In current UKA it is important to preserve the integrity of vital and surrounding soft tissue, implement a prosthesis position that gives 1 degree of under-correction. Using direct tunneling technology is proven to this in a surgical time under 45 minutes promoting early ambulation and recovery and increased patient satisfaction hence increasing the survivorship of UKA procedures. Based on results the DTT is a viable candidate for becoming the gold standard in all compartmental arthroplasty.

Limb alignment and position of the components in bilateral total knee replacement with robotic and conventionally manual support (a prospective, randomized study)

Eun Kyoo Song, Jong Keun Seon, Sang Jin Park, Dam Seon Lee
Department of Orthopaedics, Chonnam National University Hwasun Hospital

Introduction: Computer assisted navigation systems have developed to help surgeons improve alignment accuracy, and have been shown to reduce some alignment errors. However, navigated TKA still depends on the use of cutting blocks and oscillating jigs which could result in inferior bone resection. To further improve the accuracy of implant selection, position and alignment as well as bone resection, robotic systems for TKA have been developed. Only few data exist concerning outcomes after total knee arthroplasty (TKA) using a surgical robotic system. We conducted this study to evaluate the clinical and radiographical results in robotic-assisted implantation of TKAs compared with conventionally manual implantation in bilateral knees.

Material and Method: Bilateral sequential total knee replacement with a Zimmer NexGen prosthesis (Zimmer, Warsaw, Indiana) was carried out in 30 patients. One knee was replaced using a robotic-assisted implantation (ROBOT side) and the other conventionally manual implantation (CON side). There were 30 women with a mean age of 67.8 years (50 to 80). The mean follow-up was 2.3 years (2 to 3). The radiographic measurement with regard to the change of mechanical axis, and the inclination of the femoral and tibial components were assessed. Outliers were defined as > 3° of optimum. Also we evaluated clinical results with the range of motion (ROM), Hospital for Special Surgery (HSS) scores, and Western Ontario and McMaster University (WOMAC) scores.

Results: The operating and tourniquet times were longer in the ROBOT side (p < 0.001). There were no significant pre- or post-operative differences between the functional knee scores of the two groups (p = 0.288 and p = 0.429, respectively). Mean mechanical axes were not significantly different in the two groups (p = 0.815). However, there were more outliers in the CON side (8) than in the ROBOT side (1) (p = 0.013). In the coronal alignment of the femoral component, the CON side (8) had more outliers than the ROBOT side (1) (p = 0.013) and the CON side (3) also had more outliers than the ROBOT side (0) in the sagittal alignment of the femoral component (p = 0.043). In terms of outliers for coronal and sagittal tibial alignment, the CON side (1 and 4) had more outliers than the ROBOT side (0 and 2).

Discussion: Use of a surgical robot system in TKAs provides good clinical and radiographical results at least 2 years follow-up. Robotic-assisted total knee replacement resulted in more accurate orientation and alignment of the components than that achieved by conventional total knee replacement. A clear advantage of robot-assisted TKA seems to be ability to execute a highly precise preoperative planning and intraoperative procedures which result in excellent alignment. But current disadvantages such as increased operating times and inability of adjusting the preoperative planning during the procedure have to be resolved in the future.