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Research Article

Clinical, Functional and Radiological Results of Robotic Unicondylar Knee Arthroplasty Cases

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Abstract

Objectives: The outcomes of unicondylar knee arthroplasties (UKA) have demonstrated inconsistent long-term survival. In this study, we had the intention to report the clinical series of UKA using a semi-active robot system for the implantation of an inlay unicondylar knee arthroplasty.

Methods: 108 knees in 100 patients who underwent robotically-assisted tibiofemoral arthroplasty between November 2010 and November 2012 included in the study. Minimum follow-up was 24 months (mean 28 months). The patients with a broad BMI range and a wide range of deformity are included in this study. Oxford Knee Score (OKS), Knee Society Score (KSS) and Functional Score were recorded in the clinical follow-ups of patients.

Results: The OKS improved from preoperative mean of 21.90±8.16 to a mean of 38.92±6.26, the KSS improved from preoperative mean of 53.69±11.23 to a mean of 86.37±9.31, the FS degree improved from preoperative mean of 46.81±16.25 to a mean of 80.80±13.43 at 2 years follow up.

Conclusion: We noticed that OKS, KSS and FS was remarkably improved in the robotic unicondylar prosthesis patients with a broad BMI range and a wide range of deformity.

Keywords: Knee arthroplasty, robotic, surgery, unicondylar

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The use of unicondylar knee arthroplasty (UKA) as a treatment option for degenerative arthritis of the knee has been a contentious issue since its introduction in the early 1970s. Over the last two decades, advances in UKA implant design and surgical technique have generated promising survivorship statistics.[1-3] As a consequence of these and other similar statistics UKA is steadily increasing in application; although in 1997, only 1 % of all knee implants were UKAs, in 2000, %6 and in 2007 %8 of all implanted knee prostheses were UKAs.[4]

Recently, minimally invasive techniques have achieved an overall reduction in soft tissue and bone trauma, however it has been noted that minimal invasive techniques are not as accurate as standard UKA with regard to the anteroposterior tibial placement and the postoperative leg alignment and the overall increased revision rate for the minimally invasive techniques.[5, 6] Achieving the optimal medium between under-correction and overcorrection is challenging and often dependent on the experience of the operating surgeon.[7] Technical developments in the 1990s included the use of robot assisted techniques. Because of their invasive nature and lack of physician control these robots were not widely used and also image guidance navigation systems were developed but their outcomes were not found

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to be superior to conventional techniques.[8-10]

Recently, "semiactive" system have been developed. These systems give the surgeon active control over the robot. This allows for more accurate reproduction of the preoperative plan of implant placement and allows one to reproduce the normal kinematics of the knee as well as improve the overall leg alignment.[11, 12]

The purpose of our paper is to report the short term outcome using the Oxford Knee score in 100 patients with a broad range of knee pathology treated with robotically controlled unicondylar or bicondylar arthroplasty. Our hypothesis is that patients will have very satisfactory Oxford scores despite the severity of their arthritis in the preoperative state.

Methods

Between November 2010 and November 2012, 100 consecutive patients (108 knees) Mako Unicondylar Knee System arthroplasties using the Mako robot were performed at Baptist Health Centre Medical School for the treatment of unicondylar osteoarthritis of the knee. The average age of the patients at the time surgery of robotic group was 63 years (range, 39-85 years). The robotic surgeries were all performed by, or under the direct supervision of senior orthopedic surgeon (G.P.).

The inclusion criteria allowed patient's varus deformity up to 15°, valgus deformity up to 17°, flexion contracture up to 15°, tibial shift maximum of 10 mm, BMI up to 74, and patellofemoral arthritis up to a Grade 4 Kellgren-Lawrence Grading Scale (KLGS). Contraindications included joint instability, the surviving medial or lateral compartment had less than 4 mm of joint space and inflammatory arthritis.[13]

The indications for UKA was severe pain and difficulty with walking and performing daily activities. In radiographs OA of the knee (KLGS 1-4) was noted.[14, 15] Patellofemoral (PF) joint class 1-4 degeneration was accepted. Oxford scores of all patients were included before the surgery and one year post-operatively. The age was not a contraindication. Anterior cruciate ligament (ACL) laxity without instability was not a contraindication.[16] Varus deformity was correctable and a there was a good passive range of motion (at least 15°-100°) in all knees.

Patients were seen for first followup at 2 weeks, at which point radiographs comprising weight-bearing long-leg AP, flexion lateral and Merchant views were taken. Patients were seen again for followups at 6 months and 1 year postoperatively at which stage new radiographs were performed. Radiographs were assessed to monitor to correction degree of varus or valgus alignment. Data collection was performed by a research nurse and measurements of radiographs performed by two orthopedic surgeons. Measurements recorded included preoperatively and postoperatively femorotibial angle (FTA), preoperative tibial shift (TS), patellofemoral osteoarthritis (PFOA), tibiofemoral osteoarthritis (TFOA) using Kellgren-Lawrence grading scale (KLGS). Age, gender, Body mass Index (BMI), Oxford Knee Score (OKS), Knee Society Score (KSS), Functional Score (FS) and perioperative complications were recorded. We used the modified method of calculating the OKS from 0 (worst outcome) to 48 (best outcome) to allow for comparison. Functional data was gathered at the preoperative assessment and again at the 6 month, 12 month and 24 month follow-up.

Preoperative Planning and Operative Technique

Customize CT-based planning is performed before every operation. Slices are taken through the hip and ankle (5mm slices) as well as the knee joint (1mm slices). The scans are saved in DICOM 3 format and transferred into the TGS software (MAKO Surgical Corp). The bone surfaces are segmented in the software to produce a three dimensional (3-D) model. Based on the preoperative CT image, the system allows for operative planning of the femoral and tibial implant position.

The TGS (MAKO Surgical Corp) consist of 3 components: robotic arm, optical camera, and operator computer cart. The distal end of the robot is connected to a high-speed burr. The surgeon moves the robotic arm by guiding the force-controlled tip within the defined boundaries (haptic field). The robot gives the surgeon active feedbacks (haptic and audio) and allows for a quick burring process of even the complex shapes of the femoral and tibial bone surface. In addition, excessive pressure against the limits of the 3-D cutting volume or rapid movement of the patient's anatomy immediately stops the cutting instrument, preventing unintentional resection outside the implantation area.

The burr system consists of high- speed 75.000 rpm electric burr (eMax2 from the Anspach Effort, Palm Beach Gardens, Fla) which is operated via finger control. The complete burring process is displayed on a dedicated surgeon display, which also shows the 3-D model of the knee, indicating the bone material remaining to be removed (Figs. 1, 2).

The Mako Unicondylar Knee System (Mako Corporation) consists of a nonmetal-backed polyethylene tibial inlay insert and a CoCr femoral component with 2 pegs (Fig. 3).

All surgeries were performed under spinal anesthesia, with tourniquet control and antibiotic prophylaxis using a third-generation cephalosporin. Patients were administered chemical thromboprophylaxis (ASA in most cases) postoperatively.

Figure 1. The complete burring process is displayed on a dedicated display on the navigation system.

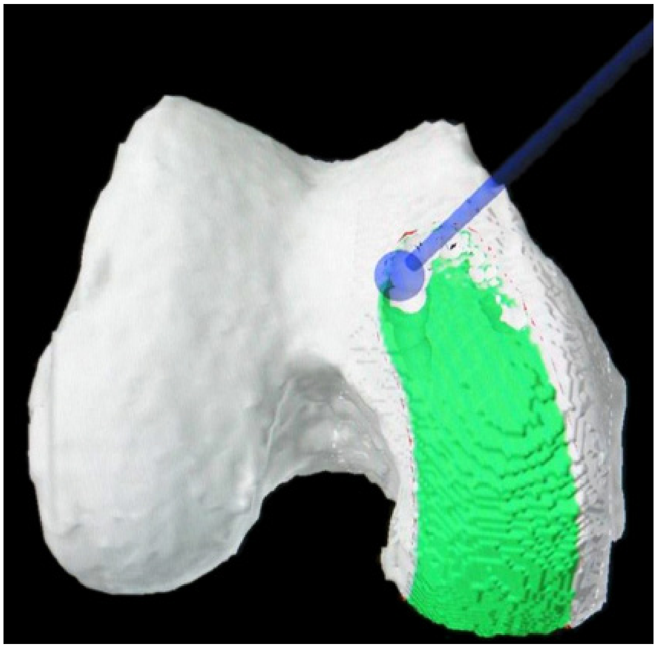

Figure 2. A 3-D model of the knee during the burring process indicates the bone material remaining to be removed.

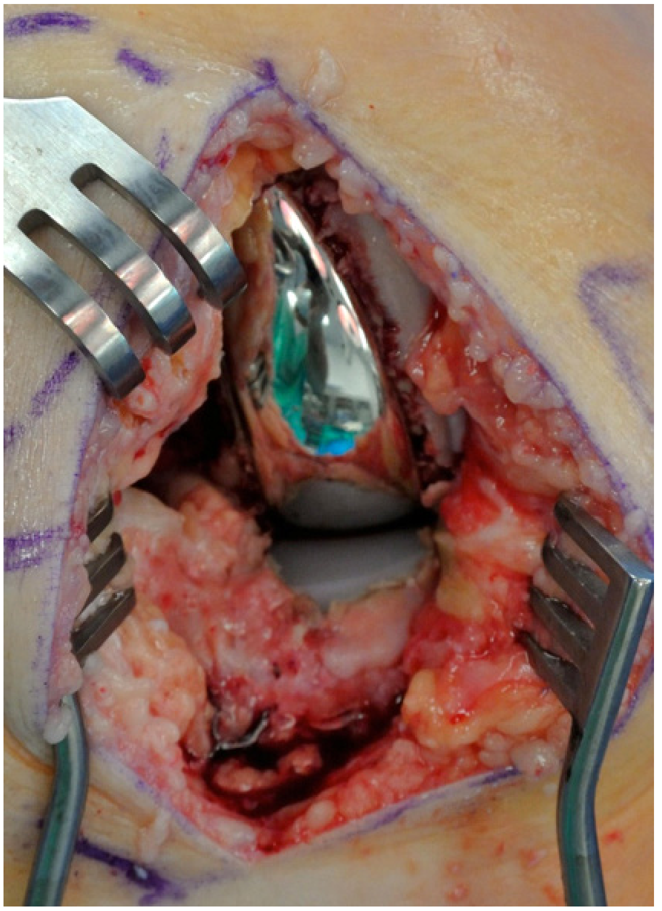

Figure 3. Intra operative wiev after completed implantation.

The robot assists the surgeon during defined burring of the tibial and femoral component cavities. After then, both implant components are cemented. Before the incision closure, both mini checkpoints and bone reference arrays are removed.

All patients were mobilized as rapidly as their comfort allowed many within the hours after their surgery under the direct supervision of one of the physiotherapists. The patients initially began static quadriceps rehabilitation and ROM exercises as tolerated. Full weight-bearing was encouraged as soon as the patient had quadriceps control. Most patients returned at the 2 weeks visit without side supports.

Statistical Analysis

Statistical analyses were performed with SPSS 17.0 for windows. Descriptive data were presented as mean±standard deviation (Sd) and median (minimum-maximum). The Shapiro–Wilk test was used to analyze normal distribution assumption of the quantitative outcomes. The intra-group data (beginning data vs data after one year) were compared with the nonparametric Wilcoxon's signed rank test. A p value less than 0.05 was considered as statistically significant.

Results

None of those patients died postoperatively and undergone revision surgery. None had failed and complicated. All of the patients were stayed hospital 1 day before the surgery and discharged 1 day after surgery. The average body mass index (BMI) was 26.3 (21-74). There were 61 women and 39 men, with 48 right and 65 left, 91 medial, 17 lateral, 11 patients had second UKAs performed during this time period. There were 4 patients that had medial and patellofemoral arthroplasty and 2 patients that had lateral and patellofemoral arthroplasty and patients with patellofemoral arthroplasty were excluded from the study. Minimum follow-up was 24 months (mean 28 months).

The FTA corrected in varus knees from a preoperative mean of 4.0° varus (15°-0°) to 0.4° varus (10° varus- 5° valgus) and corrected in valgus knees from preoperative mean of 6.16° valgus (0-17°) to 4.5° valgus (2° varus -10° valgus). The mean TFOA was 2.97 (1-4) and mean PFO was 2.3 (1-4) as KLGS. No patient had an ACL or other ligament instability. Preoperative and postoperative radiological results of the patients with gonarthrosis are shown in figure 4. All these measurements of femora-tibial angle were measured radiologically.

The OKS improved (p<0.01) from preoperative mean of 21.90±8.16 to a mean of 38.92±6.26, the KSS improved (p<0.01) from preoperative mean of 53.69±11.23 to a mean of 86.37±9.31, the FS degree improved (p<0.01) from preoperative mean of 46.81±16.25 to a mean of 80.80±13.43 at 1 year follow-up (The results of statistical studies are shown at table I and figure 5, 6, 7).

Figure 4. Radiological results of the patients with gonartrosis preoperative and postoperative.

Table 1. The results of statistical studies of the robotic unicondylar group

Variables	Mean±Sd	Median (Min-Max)	p
Preop OKS	21.90±8.16	22.00 (5.00-39.00)	<0.001
Postop OKS	38.92±6.26	40.00 (20.00-48.00)	
Preop KSS	53.69±11.23	54.00 (10.00-89.00)	<0.001
Postop KSS	86.37±9.31	80.00 (60.00-99.00)	
Preop FS	46.81±16.25	50.00 (5.00-80.00)	<0.001
Postop FS	80.80±13.43	80.00 (40.00-100.00)	

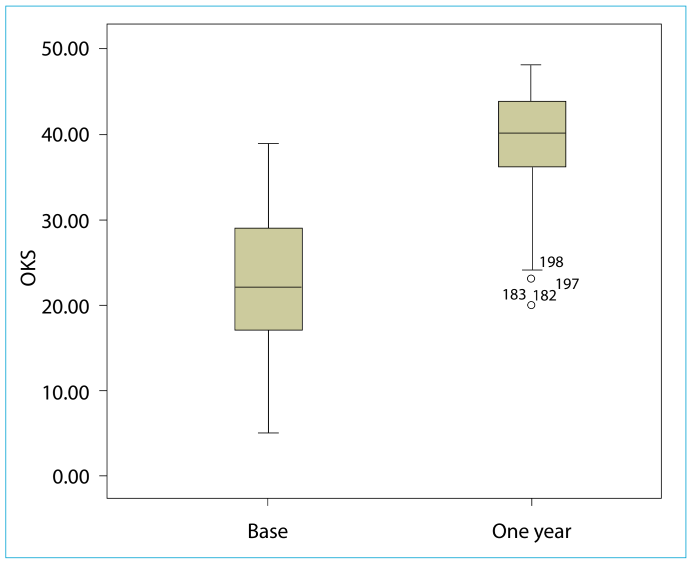

Figure 5. Graph of OKS results.

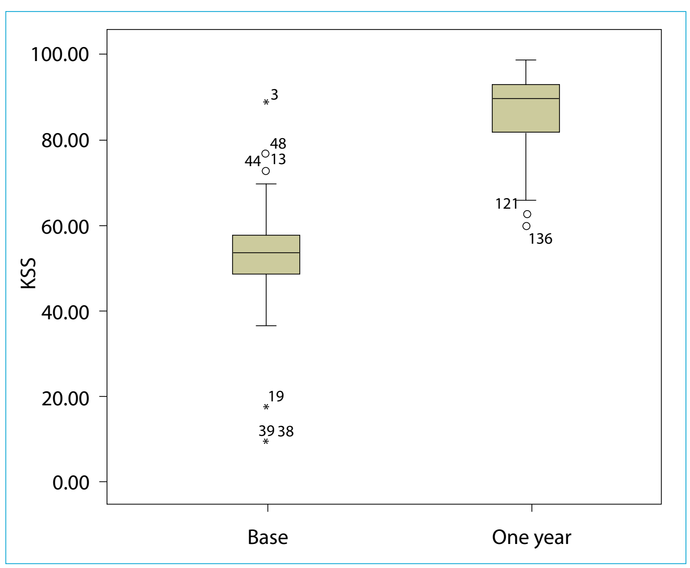

Figure 6. Graph of KSS results.

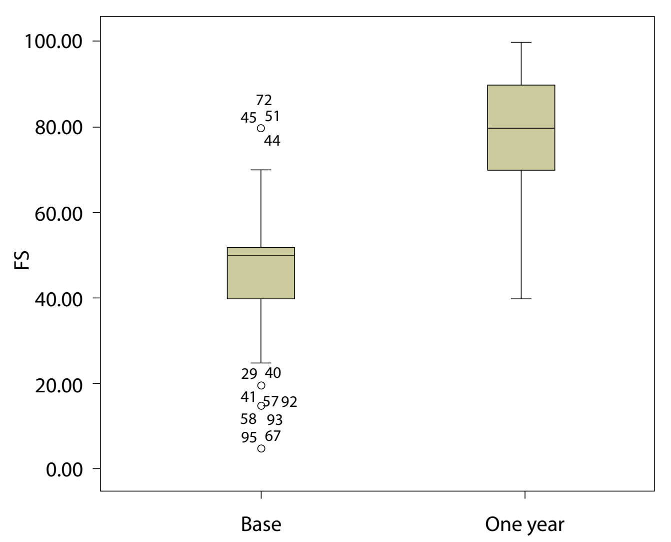

Figure 7. Graph of FS results.

Discussion

We have demonstrated robot- assisted UKA in a series of 108 knees with a broad range of passive pathology that we found 91% were in the good or excellent category based on the Oxford knee score. There are multiple studies in the literature about UKA which leads to different results. Single center studies of unicondylar arthroplasty report results comparable to total knee arthroplasty (TKA). However in large registry studies, results of unicondylar arthroplasty are inferior to TKA.[17, 18] Positive outcomes in this study are not only related to implant design and patient selection but also depend on the surgical technique used in UKA.[19] Although it has been shown that correct implant placement affects the clinical short term and long term outcome of UKA, this new technique may be able to improve the positioning based on the patients individual anatomy and therefore maintaining normal kinematics.[8, 20-22]

As the previous studies have shown, minimally invasive UKA has resulted in higher rates of revision and more frequent aseptic loosening than conventional UKA, which is likely to be due to the increased difficulty aligning the prosthesis.[23-25] At this point Robot-assisted technology improves the success of the surgeons and supports them. Current navigation system provides the surgeon with a set of surgical parameters like cut orientation, component dimensions, valgus angle that should assure good alignment and joints kinematics similar to that of the intact knees.[26, 27] Intra-operative kinematics analysis could provide additional data capable to improve the accuracy of navigation system, including easier restoration of the joint line, adequate limb axis correction, and improved ligamentous stability, along with component size and rotations of the femoral component according to kinematic pathway of the knee.[28] Up to the study of Andrew Pearle et al., in general CT–based planning allows for better feedback of implant position and intra-operative simulation of implant overlap during complete knee movements. Consequently, it enables the surgeon to alter his plan and include more patient specific data intraoperatively. The joint line and the orientation of the implant can be planned and executed more accurately than with conventional techniques. Lukas et al. have reported their unicondylar knee arthroplasty OKS results of 1 year with minimally invasive technique as 36.2.[29] Mark et al.[30] have reported their OKS results as 32.7. KSS results are reported as 78.6 and 84.0 at the literature in some studies.[31, 32] Our results and similar literature results are shown at table 2. However we used a much broader indications for UKA. Other studies used indication as advocated by White, Goodfellow and O'Connor.[33]

Table 2. Relative OKS-KSS and FS results

	n	OKS	KSS	FS
Our results (year)	108	38.9 (1)	86.3 (1)	80.8 (1)
Mark (year)	48	32.7 (4.5)		
Lukas (year)	216	36.2 (4.2)	90.8 (4.2)	88.2 (4.2)
Pandit (year)	101	39.2 (5)	78.6 (5)	
Luscombe (year)	78	38.3 (2)	84.0 (2)	

Loosening and pain are the predominant failure mechanisms in UKA and is accelerated by prosthesis malpositioning.[34] Positioning of the prosthesis is very sensitive to the routine of the surgeon,[35] but even experienced reconstructive knee surgeons produce a high number of suboptimal implant positions.[36] Surgical technique is one of the multifactorial causes for early implant failure[37, 38] and strategies to ensure optimal alignment and ligament balancing are controversial.[39, 40] Patients FTA degree with varus deformity changed from preoperatively 4.0° varus to postoperatively 0.4° varus and patients FTA degree with valgus deformity changed from preoperatively 6° valgus to postoperatively 4.5° valgus. Overcorrection of the preoperative deformity is associated with an increased risk of degenerative changes in the opposite compartment. Conversely, under-correction is associated with increased wear of the tibial component.[26, 41, 42] Most well- balanced UKAs will have a postoperative alignment similar to patients' premorbid alignment.[43] In our study, the mean FTA was changed from preoperative status only by 3.5° and 1.5° and we didn't notice overcorrection. Matthew B et al.[44] and Newman J et al.[45] found postoperative varus degree as 2° varus with non-robotic technique.

The indications for UKA have changed significantly in recent years. With improvements in UKA prosthesis design, wear properties of the polyethylene and surgical technique, the indications have expanded to include younger patients with mild PFOA and some patients with ACL deficiency.[46] In our patients, there were not any ACL deficiency seen and mean degree of PFOA was about Kellgren – Lawrence 3. However in our experiment we have not experienced patellofemoral or anterior knee pain. We think that age and obesity are not rigid and restricting factors with Robot – assisted UKA applications. Pennington et al.[47] do not consider obesity and age as a contraindication especially with lateral UKA.[48] Average age in our series was 63 (39-85) and BMI was 26.3 (21-74). We have not seen any problem with in extreme age and BMI group in early follow-up.

Short term follow-up results of the patients from OKS, KSS and FS are highly satisfactory. This technique provides a good quality of life in young and active patients. Even if the robotic unicondylar knee prosthesis seems expensive due to highly technologic robotic system, it seems a well treatment choice since it shortens the hospital stays and diminishes the complications with earlier return to work. Other than the advantages of this technique, overall cost of the system is high, excluding additional costs for CT scanning and regular maintenance of the robot. Also it is not known that how much side effects CT has on the body. Mentioned as Andrew et al. the relatively complex setup of the robot in the OR has to be fully defined and established before sterile draping of the patients and to be specifically tailored to each case. CT- based system fail to incorporate soft tissue tension into the planning. Gap kinematics are tracked intra-operatively by tracking a manual flexion/extension cycle of the knee before the burring process.[7]

We know that limited number of patient and post-operative follow-up in our study detracts from our ability to draw conclusions.

Conclusion

We remarkably improved the OKS, KSS and FS of the robotic unicondylar prosthesis in patients with a broad BMI range and a wide range of deformity. Robot-assisted UKA is a good treatment option for the selected patient and it improves the quality of life but the high economic cost of this system must be considered.

Disclosures

Ethics Committee Approval: The study was approved by the Local Ethics Committee.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – G.P.; Supervision – G.P.; Data collection &/or processing – A.P., U.T.; Literature review – S.C.; Writing – S.C.

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