Original Article

Accuracy of tibial component positioning in the robotic arm assisted versus conventional unicompartamental knee arthroplasty

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ABSTRACT

Background: Our study aims to determine the planned accuracy of the tibial component placement in robotic arm assisted unicompartamental knee arthroplasty (UKA) versus the conventional jig based UKA of the initial cases done in India for the first time with this particular robotic system.

Materials & Methods: Study group 1 consisted of patients who underwent robotic arm (MAKO, Stryker, USA) assisted UKA. Group 2 consists of patients who underwent a standard conventional jig based (Oxford knee, Biomet, UK). Post-operative radiographs were taken to determine the Tibial Implant position and orientation which were compared to their preoperative plan respectively by two independent observers. The mean error value was obtained for both study groups respectively and compared to determine the accuracy of the post-operative tibial implant placement.

Results: In the Robotic arm assisted UKA, the deviation of post-operative varus angle from preoperative planned angle was about 0.43° and post-operative Tibial slope alignment differed from preoperative plan was 0.41° . In the Conventional UKA group post-operative varus angle differed from preoperative planned angle by about 2.12° and post-operative Tibial slope alignment deviation from preoperative plan was 2.47° .

Conclusions: Robotic arm assisted system was more accurate compared to the conventional jig-based technique in achieving the planned orientation and alignment of the tibial implant in the initial learning phase of this particular Robotic System used for the first time in India.

Mesh terms: partial knee replacement, robotic assisted surgery.

1. Introduction

Unicompartamental knee arthroplasty (UKA) was introduced in the early 1970s and is nowadays widely used for the treatment of isolated compartmental osteoarthritis of the knee.^{1–3} Currently UKA amounts to 10% of all cases of knee arthroplasty worldwide and is expected to increase to more than 20% in the near future. This surge in the UKA is mainly due to the increasing younger population with early arthritis, procedure with less morbidity, quicker return to activity, better kinematic perception than the total knee arthroplasty and also the technical advances like computer navigation and robotic assisted surgeries.^{4,5}

Robotic-assisted orthopaedic surgery has been available clinically in different forms for over 20 years, and claims have been made that it

improves the results of joint arthroplasty by enhancing the surgeon's ability to reproduce alignment and therefore better restore normal kinematics. Only in the recent past, robotic surgery has gained increasing attention as its acceptance has increased along with its approved surgical indications and a growing body of supporting literature.^{6,7}

Reported advantages of UKA include lower post-operative morbidity, quicker return to normal activities and a better proprioceptive feeling of the knee compared to TKA, which is most likely secondary to better restoration of knee kinematics without sacrificing ligaments.^{8–10} However, UKA being technically more demanding procedure has resulted in early failure due to improper placement of femoral or tibial components leading to under correction or over correction [11–14,15–18,19,20].

With the advent of computer navigation assisted and robotic arm

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assisted surgery, the accuracy in the component placement and the kinematic ligament balancing has improved leading to better outcomes post UKA in the recent past.^{19–21} As per the meta-analysis by Van der List et al., robotic assisted surgeries were superior to the surgeries performed with computer navigation systems with respect to reduced cutting time and more precision of resection of bone in coronal and sagittal plane, more accurate mechanical axis and shorter hospital stay.²²

We report our experience of initial cases of UKA using a semi active robotic system (MAKO, Stryker, USA) for the first time in India. This study aims to determine whether the use of the robotic arm assisted systems provides planned accuracy in tibial implant positioning and orientation as compared to the conventional jig-based technique in the initial learning phase of robotic surgery.

Materials and Methods: The study was conducted in our Institute from the year 2015–2018. After clinical and radiological evaluation, patients diagnosed to have unicompartmental osteoarthritis of the knee joint with no known contraindications for a standard UKA were included in our study. The UKA were performed by two independent surgeons formally trained in joint replacement surgeries with an experience of more than a decade in total knee arthroplasty procedures but with minimal experience in UKA. Age group varied from 48 to 64 years (mean age 57 years). Preoperative mechanical leg alignment values ranged from 0.3° Varus to 8.2° Varus (mean value: 6.8°). These patients were divided into 2 groups. Group 1 consisted of a series of our first 24 knee's which underwent robotic arm assisted UKA (MAKO, Stryker, USA). Out of which 6 were male and 18 female patients. Informed consent was obtained from all the patients undergoing the robotic arm assisted UKA.

Group 2 consist of a series of 12 knee's which had undergone UKA with a fixed bone cutting Jig based conventional UKA (Oxford knee, Biomet, UK) prior to the initiation of robotic arm assisted surgeries in our centre. Out of which 10 were female patients and 2 males. Retrospective data was collected for cases which had undergone conventional jig based UKA in our centre.

For all group 1 (Robotic arm assisted UKA) patients, preoperative CT scans were performed in the supine position. The CT scan protocol includes 5 mm slices through the hip and ankle and 1 mm slices through the knee joint. The data was then transferred into the MAKO software. Bone surfaces were segmented using the software to produce a three-dimensional (3D) model. In all knees, a three-dimensional CT-based preoperative plan was created to determine and decide on: Coronal and sagittal alignment, Overall leg alignment, Gross anatomical deformities, Geometric alignment of Varus/valgus of femoral component to the Varus of the tibia implant, Tibial implant positioning relative to the posterior tibial wall.

An optimal implant position and orientation is defined and saved in the system following the surgeon's approval and the optimal bone resection area is defined and marked for the femoral and tibial components. All group 2 (JIG based UKA) patients underwent the standard radiographic evaluation with knee antero-posterior and lateral x-rays of the knee and skyline views for patella along with a standing hip, knee and ankle full length film. Pre-operative planning was done as per the instructions given for the standard Oxford Unicondylar arthroplasty.

Group 1, MAKO assisted UKA the surgeon utilizes the pre-operative 3D CT scan plan of the knee model to finalize the size and orientation of the components pre-operatively. Intra-operatively, the surgeon registers the bony landmarks with the help of reference optical arrays which are placed into the femur and tibia, hence enabling the computer to match the pre-operative CT model with the actual anatomy of the knee. Intra-operative kinematic data will also be collected for assessment of the flexion and extension gaps, and a fixed cutting zone for the robot is created.

Once bone resection is complete, the implant is trailed to verify alignment and knee kinematics with immediate computer feedback. Once the ligament balancing is finalized the final implants are placed and stability assessed and check points removed before wound closure. There were no intra operative conversion from MAKO assisted UKA to

conventional UKA in any of our cases.

Group 2, Pre-operative planning was done as per the instructions given by the standard Oxford Unicondylar arthroplasty recommendations. Standard Oxford Unicondylar arthroplasty jig-based instruments are used with a fixed femoral and tibial cutting jig. The tibial surface was prepared with a posterior slope of 7° and zero degree of Varus as per the standard jig for all the Group 2 patients. Ligament balancing and stability assessment is done intra-operatively by trialling the components and the final components placed after satisfactory trialling.

Group 1: Post op Knee antero-posterior (AP) and lateral radiographs were taken. The posterior tibial slope (PTS) was measured in lateral radiographs using a standard method as described by Kızılgöz V et al.²³ and compared to their pre-operative plan specific for each patient by two independent observer separately (Fig. 1). Standard deviation error was calculated for each individual patient and subsequently the mean error value was obtained for Posterior Tibial Slope (PTS).

Subsequently tibial implant Varus/valgus angulations was measured in Standard AP view (Fig. 2) and compared to its preoperative planned value and the mean error value was obtained.

Group 2 patients (JIG based UKA), posterior tibial slope and Varus valgus angulations were calculated and compared to the fixed angulations of the cutting jigs of the tibial component and mean error value was obtained for PTS and Varus/valgus alignment of the tibial component. (Fig. 3). Post-operative X-rays of both the groups were as per the Oxford knee protocol.

Statistical analysis was done using the Mann-Whitney test. Tibial implant placement errors for both the MAKO robotic group and the Jig based UKA group were analysed by comparing the preoperatively planned position with postoperatively achieved results. Interclass correlation coefficient (ICC) was applied to determine the correlation of the findings between the two independent observers. The mean error was calculated for the two groups and was used to quantify alignment errors.

2. Results

In the robotic group of patients, the postoperative mean posterior tibial slope error was within 0.41° and the mean Varus/Valgus angulations errors were within 0.43° of the preoperative planned values. In the Jig based UKA group the postoperative mean posterior tibial slope error was within 2.47° and the Varus/Valgus angulations error were within 2.12° of the fixed preoperative tibial jig values. The interclass correlation coefficient was noted to be between 0.75 and 0.90. The ICC was within 95% confidence interval which signifies good correlation between the findings of both the observer (Table 1).

Robotic UKA post-operative Varus angle discrepancy from

Fig. 1. Posterior Tibial slope measurement.

Fig. 2. Measurement of component placement in coronal and sagittal in robotic UKR.

Fig. 3. Measurement of component placement in coronal and sagittal in conventional UKR.

preoperative planned angle was about 0.43°. Post-operative Tibial slope alignment discrepancy from preoperative plan was 0.41°. Conventional UKA post-operative Varus angle discrepancy from preoperative planned angle was about 2.12°. Post-operative Tibial slope alignment discrepancy from preoperative plan was 2.47°. There was statistically

Table 1
Showing interclass correlation coefficient between two observers.

Inter class correlation coefficient between two observer		
Group		Intraclass Correlation
MAKO UKR	Single measures	.774 ^a
	Average Measures	.873 ^c
CONVENTIONAL UKR	Single measures	.927 ^a
	Average Measures	.962 ^c

ICC between two observer is 95% Confidence Interval.
< 0.5: poor.
0.50–0.75: moderate.
0.75–0.90: good.
>0.90: excellent.

significant difference between the findings of Robotic arm assisted and conventional UKA. P value being significant of 0.002 (<0.005). (Table 2 and Table 3).

3. Discussion

Unicompartmental knee arthroplasty is a worldwide accepted procedure for unicompartmental knee osteoarthritis.²⁴ The popularity of the UKA has increased in the recent past in spite of the initial discouraging results. The acceptance of UKA in such a wide scale is mainly attributable to increase in the younger population with arthritis, lesser complication, mortality, morbidity, faster recovery and better knee kinematics when compared to the total knee arthroplasty. Technical advancements and better prosthetic design have also resulted in increase in the numbers of UKA. In spite of all the above mentioned reasons, the biggest drawbacks of UKA is that it is technically more challenging procedure and also the higher revision and failure rates seen in UKA^(24, 25, 26).

The reasons for such higher failure rates are mainly due to improper prosthetic placement in coronal and sagittal plane, aseptic loosening, ongoing arthritis into other compartments of knee joint, over or under correction of the deformity, subsidence of the tibial/femoral component and very rarely periprosthetic fracture or infections.^{26–29} From the above-mentioned causes of failure of UKA, it is very evident that the factor which is under the control of surgeons is an appropriate placement of the components and rest all the factors are beyond the control of surgeons.

In order to overcome such human errors, recent technical advancements in UKA have been adapted. Computer navigation assisted surgeries definitely made a huge difference when it comes to placement of the components and alignment when compared to the conventional jig based UKA. Even though computer navigation is an essential visual aid to improve the accuracy, the final outcome of the procedure is dependent on the surgeon and the mechanic tools performing the procedure. The number of patients with beyond 2° of discrepancy with planned implant position were as high as 15% even with computer navigation assisted UKA.^{30,31}

With the advent of new generation surgical robots, the ease and reproducibility of UKA has tremendously improved. The surgeon is aided by the haptic, stereotactic and kinematic feedback from the pre-operative Computer-tomography (CT) and robotic arm to execute the surgery smoothly within the desired surgical field with great accuracy.^{25,30–32}

In our study, Robotic UKA post-operative Varus angle discrepancy from preoperative planned angle was about 0.43°. Post-operative Tibial slope alignment discrepancy from preoperative plan was 0.41°. Conventional UKA post-operative Varus angle discrepancy from preoperative planned angle was about 2.12°. Post-operative Tibial slope alignment discrepancy from preoperative plan was 2.47° Thus there was statistically significant difference between the Robotic arm assisted and conventional UKA, P value: 0.002 (<0.005).

As per Cobb et al. in their study compared the results of 13 robotic-assisted UKAs (Acrobot Co Ltd, London, UK) with 15 UKAs that were performed using conventional techniques in a randomized prospective study. Unlike our study, the authors used postoperative CT scans to determine postoperative alignment. They measured coronal plane tibiofemoral alignment and individual component alignment and reported all patients treated with robotic bone preparation had coronal plane tibiofemoral alignment within 2° of the planned position with a mean of 0.65° (standard deviation [SD] 0.59; range, 1.6°–0.3°), whereas only 40% in the conventional group achieved this level of accuracy with a mean of 0.84 (SD, 2.75; range, –4.2° to +4.2°).^{21,32}

In our study, the coronal plane average error for Varus/valgus angle was 0.43° ± 0.75° for robotic assisted UKA whereas for conventional UKA it was 2.12° ± 1.4°. In a similar study done by Sinha RK, the coronal plane average error was 3.3° ± 1.8° in conventional UKA and 0.1° ± 2.4°

Table 2

Showing the preoperative and postoperative angles in Robotic UKA.

No	Age	PS (Plan)	PSPO1	PSPO2	PS-PSPO1	PS-PSPO2	ME	VA (plan)	VAP01	VAP02	VA-VAP01	VA-VAP02	ME
1	61	7	7.24	7.36	0.24	0.36	0.3	1	1	0.9	0	0.1	0.05
2	58	7	6.24	6.08	0.76	0.92	0.84	1	1.52	1.42	0.52	0.42	0.47
3	49	5	4.32	4.52	0.68	0.48	0.58	0	0.63	0.48	0.63	0.48	0.55
4	54	7	7.7	7.62	0.7	0.62	0.66	2	2.12	2	0.12	0	0.06
5	64	9	8.44	8.6	0.56	0.4	0.48	0	2	1.6	2	1.6	1.8
6	59	7	6.28	6.02	0.72	0.98	0.85	1	0.82	0.9	0.18	0.1	0.14
7	57	7	6.84	7.1	0.16	0.1	0.13	2	1.8	1.9	0.2	0.1	0.15
8	62	6	5.2	5.5	0.8	0.5	0.65	1	2	1.4	1	0.4	0.7
9	63	12	10.6	11.2	1.4	0.8	1.1	1	1.62	2	0.62	1	0.81
10	60	10	9.64	9.8	0.36	0.2	0.28	0	0.28	0.44	0.28	0.44	0.36
11	55	7	7.44	7.18	0.44	0.18	0.31	1	0.74	0.86	0.26	0.14	0.2
12	52	7	6.78	7.1	0.22	0.1	0.16	1	0.68	0.9	0.32	0.1	0.21
13	49	7	6.59	6.72	0.41	0.28	0.34	0	0.44	0.3	0.44	0.3	0.37
14	57	7	6.88	7	0.12	0	0.06	0	1	0.5	1	0.5	0.75
15	62	8	8.24	8.12	0.24	0.12	0.18	0.5	0.64	0.58	0.14	0.08	0.11
16	60	7	7.42	7.08	0.42	0.08	0.25	1	0.42	0.78	0.58	0.22	0.4
17	49	6	5.88	5.7	0.12	0.3	0.21	0	0.24	1	0.24	1	0.62
18	53	7	6.24	6.56	0.76	0.44	0.6	1	1.4	1.2	0.6	0.2	0.4
19	58	7	6.57	6.7	0.43	0.3	0.36	0	0.42	0.6	0.42	0.6	0.51
20	62	5	4.85	4.9	0.15	0.1	0.12	1	0.68	0.84	0.32	0.16	0.16
21	64	7	7.42	7.08	0.42	0.08	0.25	1	1.49	1.34	0.49	0.34	0.41
22	55	7	6.58	6.72	0.42	0.28	0.35	0	0.24	0.36	0.24	0.36	0.3
23	52	7	6.78	7.1	0.22	0.1	0.16	1	0.68	0.9	0.32	0.1	0.21
24	64	9	8.44	8.6	0.56	0.4	0.48	0	2	1.6	2	1.6	1.8

- PS(Plan): Planned Posterior Slope.
- PSPO1: Posterior Slope Post-operative observer 1.
- PSPO2: Posterior Slope Post-operative observer 2.
- PS-PSPO1: Error between preop and post op Posterior Slope (observer 1).
- PS-PSPO2: Error between preop and post op Posterior Slope (observer 2).
- ME: Mean error of observer 1 and 2.
- VA(Plan): Planned Varus/Valgus angle.
- VAP01: Varus/Valgus angle Post-operative observer 1.
- VAP02: Varus/Valgus angle Post-operative observer 2.
- VA-VAP01: Error between preop and post op Varus/Valgus angle (observer 1).
- VA-VAP02: Error between preop and post op Varus/Valgus angle (observer 2).
- ME: Mean error of observer 1 and 2.

Table 3

Showing the preoperative and postoperative angles in Conventional UKA.

No	Age	PS (Plan)	PSPO1	PSPO2	PS-PSPO1	PS-PSPO2	ME	VA (plan)	VAP01	VAP02	VA-VAP01	VA-VAP02	ME
1	49	7	8.5	9	1.5	2	1.75	neutral (0)	2.98	2.72	2.98	2.72	2.85
2	52	7	3.91	4.3	3.09	2.7	2.89	neutral (0)	2.4	2.1	2.4	2.1	2.25
3	64	7	8.8	7.6	1.8	0.6	1.2	neutral (0)	1.94	1.56	1.94	1.56	1.75
4	55	7	10.85	9.92	3.85	2.92	3.38	neutral (0)	1.78	2.01	1.78	2.01	1.89
5	48	7	9.54	8.9	2.54	1.9	2.22	neutral (0)	2.28	1.88	2.28	1.88	2.08
6	58	7	10.24	9.96	3.24	2.96	3.1	neutral (0)	1.92	1.68	1.92	1.68	1.8
7	53	7	3.99	5.1	3.01	1.9	2.45	neutral (0)	1.89	2.1	1.89	2.1	1.99
8	61	7	8.98	8.78	2.98	2.78	2.88	neutral (0)	2.65	2.87	2.65	2.87	2.76
9	49	7	3.02	3.35	3.98	3.65	3.81	neutral (0)	2.3	1.89	2.3	1.89	2.09
10	51	7	8.18	8.82	1.18	1.82	1.5	neutral (0)	1.84	2.09	1.84	2.09	1.96
11	54	7	9.28	8.72	2.28	1.72	2	neutral (0)	1.91	2.1	1.91	2.1	2
12	50	7	3.90	5.14	3.10	1.94	2.45	neutral (0)	1.89	2.1	1.89	2.1	1.99

- PS(Plan): Planned Posterior Slope.
- PSPO1: Posterior Slope Post-operative observer 1.
- PSPO2: Posterior Slope Post-operative observer 2.
- PS-PSPO1: Error between preop and post op Posterior Slope (observer 1).
- PS-PSPO2: Error between preop and post op Posterior Slope (observer 2).
- ME: Mean error of observer 1 and 2.
- VA(Plan): Planned Varus/Valgus angle.
- VAP01: Varus/Valgus angle Post-operative observer 1.
- VAP02: Varus/Valgus angle Post-operative observer 2.
- VA-VAP01: Error between preop and post op Varus/Valgus angle (observer 1).
- VA-VAP02: Error between preop and post op Varus/Valgus angle (observer 2).
- ME: Mean error of observer 1 and 2.

when using robotic arm assistance.³³ We were able to reproduce results which were similar to the above mentioned studies, thus clearly showing the accuracy of robotic assisted UKA.

The limitation of our studies were mainly the lesser sample size, no clinical follow up involved and also we have not included the assessment of femoral component placement as it is very difficult to determine the

placement of femoral component based on the plane radiographs.²⁵

From our preliminary study, it is very evident that the accuracy of the tibial component placement is much higher in robotic arm assisted UKA than the conventional UKA even in the hands of surgeons in their initial learning phase of robotic surgery of this particular robotic system for the first time in India. However, a larger study group and long term follow up is beneficial in establishing the long-term advantages of robotic arm assisted UKA.

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Patient declaration statement

“The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.”

Declaration of competing interest

None.

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