Original Article
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Comparison of Time Taken in Conventional versus Active Robotic-Assisted Total Knee Arthroplasty

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Background: Computer- and robotic-assisted total knee replacement procedures have been shown to improve the accuracy of the implant size. It also allows dynamic confirmation of the implant and limb alignment during total knee arthroplasty (TKA). The major inhibition of the arthroplasty surgeon in adapting to the robotic-assisted TKA (RA-TKA) is the extra time spent during the registration process and milling of the bone with the robot. The aim of the study was to ascertain the extra time spent during these 2 steps as compared to the conventional TKA (C-TKA).

Methods: It is a prospective study involving 30 patients each in the conventional TKA and RA-TKA operated by the same surgical team. The patients were given a choice between the C-TKA and RA-TKA and consecutive 30 cases in each group were studied by an independent observer. In the C-TKA group, the time for the application of appropriate zigs and execution of the bone cuts and soft-tissue release was recorded whereas in the RA-TKA group, the time taken for fixation of the tibial and femoral arrays and bone registration and bone milling with robot and required soft-tissue release was measured.

Results: The preoperative patient characteristics were the same in both groups. The time taken in the C-TKA and RA-TKA groups was 24.77 ± 1.92 minutes and 25.03 ± 3.27 minutes, respectively, which is statistically insignificant ($p = 0.709$).

Conclusions: The study findings show that RA-TKA does not take additional time than C-TKA.

Keywords: *Total knee arthroplasty, Robotic assisted, Conventional, Learning curve, Operative time*

Total knee arthroplasty (TKA) is the treatment of choice in patients with end-stage bone-on-bone grade 4 arthritis of the knee joint. However, almost 15%–20% of patients remain dissatisfied after TKA.[1-6] Much research and effort are being put into improving the survival of TKA implants and patient satisfaction. These efforts include improvements in the design of implants, including gender-specific and patient-specific implants, and modifications in surgery techniques (computer-assisted TKA and minimally invasive subvastus approach). Unfortunately, gender- and patient-specific implants have failed to modify the outcomes of TKA.[7] Multiple studies have demonstrated that iatrogenic surgical errors are common in TKA.[8] Avoiding or minimizing surgical errors, which are one of the causes of failed TKA, can be very easy. This in turn has the potential to decrease the chances of patient dissatisfaction after TKA.[9]

There are steps that need to be executed with care, which include restoring the joint line, positioning the implant, aligning the limb/implant, determining accurate implant size, and achieving a balanced lateral and medial joint space.[10] Overhang of the TKA implant is considered one of the more important causes of persistent knee pain after TKA. Implant overhang affects almost 27% of cases of post-TKA pain.[11] The accurate sizing of the femur and tibia components has been shown to improve the knee

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balance in flexion and extension. This has a positive influence on postoperative pain, survival of TKA implants, and outcome measures.[12)]

Computer-assisted navigation and robotic-assisted total knee replacement improves the accuracy and alignment of the femur and tibia implants as well as decreases the incidence of outliers as judged by the hip-knee-ankle axis limb alignment. Robotic-assisted TKA (RA-TKA) is shown to have certain advantages over conventional manual TKA.[13-16)] One of the important advantages of RA-TKA is soft-tissue protection during surgery.[13,17)] Londhe et al.[18)] have shown that preoperative three-dimensional computed tomography scan templating is efficient in accurately predicting the correct implant size of the femur and tibia. Accurate prediction of implant size preoperatively has the potential to improve operative efficiency.

One of the most intimidating factors preventing the adoption of this new technology amongst arthroplasty surgeons is the learning curve and the extra time taken for the use of the new technology during TKA. Various studies have shown the figure of 7–10 surgeries for the arthroplasty surgeon to become time neutral with the semi-active RA-TKA procedure.[19,20)] To the best of our knowledge, a comparison of the operative time between fully automated RA-TKA and conventional TKA (C-TKA) has not been studied. The primary objective of the present study was to compare and analyze the time taken for extra steps that are necessary during RA-TKA with that of C-TKA.

METHODS

The study was approved from the Ethics Committee of Holy Spirit Hospital, Andheri, Mumbai, India (No. HSH/EC/A/059/2022). Informed consent was obtained from all individual participants included in the study.

This is a prospective study involving 30 patients each in C-TKA and RA-TKA operated by the same surgical team. Patients with both osteoarthritis and rheumatoid arthritis (end-stage arthritis) undergoing primary TKA were included in the study. Patients undergoing revision TKA and those unwilling to participate in the study were excluded. The sample size was estimated to be 28 patients in each group for an anticipated 10 % increase in operation time with an alpha error of 0.05, a beta error of 0.2, and the power of study being 80%. As the quoted figure for the learning curve of the RA-TKA is 10 cases,[19,20)] the study was started once the surgical team completed their first 10 RA-TKA cases. The patients were given a choice between the C-TKA and RA-TKA and consecutive 30 cases in each group were studied by an independent observer (RP). A tourniquet was used in all the patients. The approach was the medial para-patellar approach. The knee was exposed in a routine fashion in both groups. In both groups, the patients were implanted with posterior-stabilized cruciate-sacrificing freedom knee (Maxx Orthopedics Inc.) implants.

In the C-TKA group, the time for the application of appropriate zigs and execution of the bone cuts along with the release of soft tissue was recorded whereas in the RA-TKA group, the time taken for fixation of the tibial and femoral arrays, bone registration, bone milling with robot, and required soft-tissue release was measured. Preoperative planning was not done according to the kinematic alignment philosophy but was done according to the mechanical alignment. The desired alignment was to achieve a hip-knee-ankle axis of 180°, which was suggestive of neutral alignment. Important steps involved in the preoperative planning involved the establishment of the ankle, knee, and hip center, selection of bony landmarks of the tibia and femur, accurate sagittal, coronal, and transverse plane alignment of the implant, and calculation of the tibia (proximal cut) and femur (anterior chamfer, posterior chamfer, distal, anterior, posterior, and box cut) resection values. After confirming the accuracy of the tibia and femur implant sizes and implant/limb alignments on the planning software summary section, the operating surgeon approved and saved the plan. For the size of the femur implant, the surgeon checked the implant fit in sagittal, coronal, and real-time three-dimensional planes. An implant whose fit was the best in all the planes with no overhang or notching was chosen.

All patients in both the C-TKA and RA-TKA groups were operated on with spinal plus epidural form of regional anesthesia. In C-TKA, the proximal tibia and distal femur were prepared with conventional zigs. Rectangular and symmetrical flexion and extension gaps were achieved with soft-tissue releases as required by a standard approach. Trial implantation was carried out to judge the ligament balancing and stability in flexion and extension, knee range of motion, and patellar tracking. In RA-TKA, the placement of the infrared arrays was done about 12–15 cm proximal to the joint line when we considered the femur and 15 cm below the joint line in the case of the tibia. This was done through separate stab incisions using 4.5-mm threaded pins. This was followed by the registration of the distal femur and proximal tibia with the operating system. The knee was then moved from full flexion to extension. This was followed by monitoring of the lateral and medial pre-bone cut balance in real time on the computer. The robotic system employed was the Cuvis joint robot

(CUREXO Inc.), which is a fully automated system. A difference of up to 1 mm in the lateral and medial values was accepted in 90° of flexion and extension as a well-balanced knee. After registration, using pins and clamps for fixation, the robotic arm was docked to the patient. The fully automatic robotic arm then performed the pre-planned distal femur and proximal tibia bony cuts. The trial implantation was then carried out after disengagement of the robotic arm from the patient. The limb was moved from full extension through flexion, confirming a well-balanced knee throughout the range of motion. Soft-tissue release, if required, was carried out. All patients underwent physiotherapy postoperatively in the form of hamstring and quadriceps muscle strengthening exercises. Initial ambulation and gait training were done with the assistance of a walker, which gradually progressed to a walking stick. Intraoperative data were collected and analysis of this data was done by an independent observer (RP).

Statistical Analysis

Statistical Analysis was carried out with IBM SPSS ver. 21.0 (IBM Corp.). The statistical difference between the times of the 2 groups was measured with a Student *t*-test and a *p*-value < 0.05 was considered significant.

RESULTS

The preoperative patient characteristics were the same in both groups (Table 1). The time taken in C- TKA and RA-TKA groups was 24.77 ± 1.92 minutes and 25.03 ± 3.27 minutes, respectively, which is statistically insignificant ($p = 0.709$) (Tables 2-4). There were no intraoperative or postoperative adverse events in both CA-TKA and RA-TKA patient cohorts.

DISCUSSION

The main finding of our study is that active RA-TKA does not take additional time than C-TKA after crossing the learning curve number of 10 RA-TKA procedures. The fully automated active robotic Cuvis joint system has an excellent safety profile as none of the RA-TKA patients had any device-related complications. This shows that the surgical team using RA-TKA technology can become time neutral for RA-TKA in a short span of time (after crossing the threshold learning curve figure of 10 RA-TKA procedures).

Learning curve assessment also helps in analyzing the complications or difficulties faced by the surgical team during the learning period.[21-23] Orthopedic surgeons

Table 1. Comparison of Preoperative Patient Characteristics between the Conventional and Robotic-Assisted TKA Patients

Parameter	Conventional TKA	Robotic-assisted TKA	*p*-value
Number of patients	30	30	-
Age (yr)	65.2 ± 12.8	64.5 ± 13.5	0.837
Sex (female : male)	25 : 5	26 : 4	0.719
BMI (kg/m^2)	28.3 ± 4.2	27.2 ± 5.3	0.377
Preoperative VAS score	7.5 ± 1.5	7.4 ± 1.6	0.804
Preoperative range of motion (°)	95.5 ± 17.5	97.1 ± 15.4	0.708
Preoperative degree of deformity (coronal plane deformity) (°)	8.1 ± 2.4	7.5 ± 2.5	0.347
Preoperative associated comorbidity			
Cardiac	8 (26.67)	11 (36.67)	0.409
Renal	6 (20.0)	8 (26.67)	0.545
Respiratory	2 (6.67)	3 (10.00)	0.644
Preoperative clinical diagnosis			
OA	28 (93.33)	27 (90.00)	0.644
RA	2 (6.67)	3 (10.00)	0.643

Values are presented as mean ± standard deviation or number (%).
TKA: total knee arthroplasty, BMI: body mass index, VAS: visual analog scale, OA: osteoarthritis, RA: rheumatoid arthritis.

Table 2. Time Taken for Application of Zigs and Bone Cuts with a Saw and Soft-Tissue Releases in Conventional Total Knee Arthroplasty

Serial no.	Side	Total time taken for application of zigs + bone cuts and soft-tissue releases (min)
1	Left	23
2	Right	22
3	Right	24
4	Left	25
5	Right	24
6	Right	24
7	Left	27
8	Left	28
9	Left	26
10	Left	28
11	Left	27
12	Right	26
13	Right	27
14	Right	24
15	Right	24
16	Right	27
17	Left	22
18	Left	25
19	Left	24
20	Left	23
21	Right	26
22	Left	26
23	Right	23
24	Right	21
25	Left	22
26	Left	26
27	Right	27
28	Left	23
29	Left	25
30	Right	24

Table 3. Time Taken for Registration and Robotic Bone Resection and Soft Tissue Releases in Robotic-Assisted Total Knee Arthroplasty

Serial no.	Side	Time taken for registration	Time taken for bony resection and soft-tissue releases	Total time taken
1	Right	6 min	17 min	23 min
2	Left	6 min 1 sec	20 min	26 1 sec
3	Left	7 min	16 min	23 min
4	Right	6 min 4 sec	23 min	29 min 4 sec
5	Left	6 min 4 sec	16 min 4 sec	22 min 8
6	Left	6 min	15 min 38 sec	21 min 38
7	Right	5 min 1 sec	16 min 4 sec	21 min 5 sec
8	Right	7 min	27 min	34 min
9	Right	5 min 1 sec	19 min	24 min 1 sec
10	Right	8 min 1 sec	17 min	25 min 1 sec
11	Left	8 min	23 min	31 min
12	Left	5 min 6 sec	16 min	21 min 6 sec
13	Right	6 min	17 min	23 min
14	Left	7 min	21 min	28 min
15	Right	5 min 1 sec	18 min	23 min 1 sec
16	Left	7 min	21 min	28 min
17	Right	6 min	21 min	27 min
18	Right	5 min	15 min	20 min
19	Right	10 min	15 min	25 min
20	Left	7 min	16 min	23 min
21	Right	6 min	16 min	22 min
22	Left	8 min	17 min	25 min
23	Right	6 min	17 min	23 min
24	Left	8 min	22 min	30 min
25	Right	6 min	21 min	27 min
26	Left	8 min	20 min	28 min
27	Right	10 min	16 min	26 min
28	Left	7 min	17 min	24 min
29	Right	8 min	19 min	27 min
30	Left	7 min	16 min	23 min

Table 4. Comparison of Time Taken during Conventional TKA versus Robotic-Assisted TKA

Parameter	Conventional TKA	Robotic-assisted TKA	*p*-value
Total time for application of zigs/registration (fixation of tibial and femoral arrays with bone registration) + bone cuts with saw/robotic bone resection and soft-tissue releases (min)	24.77 ± 1.92	25.03 ± 3.27	0.709

Values are presented as mean ± standard deviation.
TKA: total knee arthroplasty.

have been inclined towards fast adoption of new surgery-related technology.[24] Between 2008 and 2015, it is shown that there was a threefold increase in the adoption of computer-assisted technology.[25] Different papers have found learning curves of 12, 7, and 7 cases for NAVIO, Mako, and OMNIBotics robotics system, respectively, for RA-assisted TKA.[19,20] Our study findings are similar to those of the study by Mahure et al.,[26] which showed that active robotic TKA has a short learning curve of 10 cases. In view of this quoted literature, we chose to carry out a study comparing the 2 cohorts (C-TKA vs. RA-TKA) after the surgical team completed their first 10 RA-TKA procedures.

The findings of our study will help to alleviate the concerns or apprehensions that arthroplasty surgeons may have in adopting this new technology. Our study has certain limitations. First, the study has limited ethnicity (Asian population) and is not generalizable to other populations. Second, it only tested 30 patients in each group and we acknowledge that the surgical time was affected by multiple factors, especially characteristics of demographics. Third, the study is not a randomized study. Fourth, the study involved only 1 robot system and 1 surgical team. Fifth, the study assessed only the surgical time and did not analyze the patient-reported outcome measures in these 2 cohorts. Further continuation of this study is underway to compare the patient-related outcome scores at 1 year, 2 years, and a longer follow up period. Sixth, our study has very limited power. The strength of our study is that it is the first study to compare and analyze the time taken using a fully automatic active Cuvis joint robotic system for RA-TKA vs. C-TKA.

The findings of this study show that RA-TKA does not take additional time than C-TKA. This study finding will help to alleviate the anxiety and apprehension of arthroplasty surgeons in adapting the robotic technology for the RA-TKA procedure.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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