Robotic Total Knee Replacement Without Tourniquet Via Subvastus Approach -A Single Centre Experience of 100 Cases

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Abstract- Abstract- Knee osteoarthritis (OA) is a prevalent degenerative joint disease that significantly affects quality of life, especially among obese and morbidly obese individuals. The mini-subvastus approach (SA) and robotic-assisted TKA (RA-TKA) are emerging techniques that may address these challenges. This study evaluates the clinical and radiological outcomes of cruciate-retaining (CR) RA-TKA using the mini-subvastus approach. This was a single-centertered and observational study that included 100 consecutive patients who underwent TKA using the Cuvis Joint™ autonomous robotic system from January 2023 to October 2024. Written informed consent was obtained from all participants were included in the study. The primary outcome measure are complications associated with active RA-TKA. The incidence of neurovascular injury, mechanism disruption, and collateral ligament and other soft tissue injuries, and pin-related injury including intra- operative fractures etc were studied and the safety features in the autonomous robotic system were analyzed. The mini-subvastus approach in RA-TKA offers several advantages, including reduced postoperative pain, faster recovery, and improved quadriceps strength, even in obese patients. The use of robotic assistance ensures accurate component positioning and alignment, mitigating the challenges typically associated with obese patients undergoing TKA

I. INTRODUCTION

Total knee arthroplasty (TKA) is an established and highly effective treatment for patients with symptomatic end-stage knee osteoarthritis[1]. The procedure is performed in over 90,000 patients per year in the developing countries. Pooled registry data has shown that implant survivorship, assessed with revision as the primary endpoint, is approximately 82% at 25 years follow-up. However, patient satisfaction and functional outcomes remain inferior to those for total hip arthroplasty[2]. Despite advances in implant design, implant

material, enhanced recovery programmes, thromboembolic prophylaxis, antibiotic prophylaxis, patient-specific implants, and computer navigation, recent studies have shown that up to 20% of patients remain dissatisfied following TKA. Accurate implant positioning, balanced flexion-extension gaps, proper ligament tensioning, and preservation of the periarticular soft tissue envelope are important surgeon-controlled variables that affect functional outcomes, implant stability, and long-term implant survivorship.

Conceptually, technology that enables these technical objectives to be delivered with greater accuracy and reproducibility may help to further improve outcomes in TKA. Robotic technology has been used to improve the accuracy of soft tissue dissection and enhance postoperative rehabilitation in general surgery, cardiology, obstetrics and gynaecology, and ophthalmology. Over the last decade, robotic TKA has gathered momentum as an avenue for improving the accuracy of implant positioning and reducing outliers in limb alignment compared to conventional tourniquet-based TKA[3]. However, many clinicians remain sceptical about robotic TKA owing to the substantive set-up costs and limited long-term evidence comparing clinical and functional outcomes to conventional manual TKA. Hence it is significant to discuss the current role of robotic technology in TKA, explores the benefits of this technology on accuracy of implant positioning and periarticular soft tissue preservation, and highlights the limitations of robotic TKA compared to conventional TKA.

A tourniquet may cause pain, both during and after surgery .In addition to pain, a tourniquet may cause bruising and swelling of the thigh muscles, which it squeezes. Some experts argue that restricting blood flow with a tourniquet can cause clinical problems [4]. However, there is disagreement on whether tourniquet use reduces blood loss in knee replacement surgery. Surgeons should discuss the risks of using a tourniquet with patients before the surgery and offer a choice of using one or not.

Conventional TKA uses preoperative radiographic films, intraoperative anatomical landmarks, and manually positioned alignment tourniquets to guide bone resection and implant positioning. Conventional tourniquet-based

TKA does not provide real-time feedback on the thickness or orientation of the bone cuts. The use of intramedullary referencing guides for bone resection during conventional tourniquet-based TKA may also increase the risk of thromboembolic events and cardiorespiratory complications.

Computer-navigated TKA involves the use of computer systems that provide live on-screen information on patient anatomy and knee kinematics during surgery. Computer navigation provides patient-specific anatomical data with recommendations for bone resection and optimal implant positioning, but the computer system does not actively control or restrain the motor function of the operating surgeon. Robotic TKA uses computer software to convert anatomical information into a virtual patient-specific three- dimensional (3D) reconstruction of the knee joint, which the operating surgeon uses to calculate optimal bone resection and implant positioning. Depending on the degree of control that the robotic device provides the operating surgeon, robotic assistants are classified as either fully active or semi-active systems[5].

Fully active robotic systems work autonomously to perform the planned femoral and tibial bone resections. [6] reported six of their initial 32 fully active robotic TKA procedures had short-term complications including superficial infection, patellar ligament rupture, patellar dislocation, supracondylar fracture, patellar fracture, and common peroneal injury. Semi-active robotic systems enable the surgeon to maintain overall control over bone resection and implant positioning but provide live intraoperative feedback to limit deviation from the preoperative surgical plan. This robotic system offers a computer software program to convert two-dimensional knee radiographs into a three-dimensional patient-specific bone model. Virtual plans on implant positioning and ligament balancing are created before execution of the desired patient-specific plan using the robotically positioned cutting blocks. Meanwhile robotic technology is associated with substantial installation and maintenance costs for the robotic device. Further costs are incurred with additional preoperative imaging, increased operating times during the learning phase, training the surgical team, updating of computer software and servicing contracts, and consumables. Issues with robotic devices have required intraoperative conversion to conventional tourniquet-based TKA. The robotic device, computer screens, and infrared sensors reduce the intraoperative working space, and additional instruments and surgical trays may cause instrument crowding.

Studies have shown that the mini-SA reduces postoperative pain, improves quadriceps strength, enables early mobilization, and shortens hospital stays compared to the conventional medial parapatellar approach as it preserves quadriceps muscle integrity[7] . Importantly, SA can be safely and effectively performed in obese and morbidly obese patients without compromising exposure or increasing the risk of complications. Another possible solution is to use a robotic-assisted (RA) system for TKA, which can provide accurate bone resection and implant alignment based on preoperative planning and intraoperative guidance. This can

potentially reduce the need for soft tissue release, improve implant alignment, and optimize knee kinematics.

[8]evaluated the clinical and radiological outcomes of cruciate-retaining (CR) RA-TKA using the mini-subvastus approach in obese and morbidly obese patients. This study included 114 obese patients (215 knees) with primary OA who underwent CR RA-TKA (Maxx Meril CR knee, USA) using the Cuvis

Joint robotic system. Patients had a BMI of ≥30 kg/m² (n=101) and morbid obesity with a BMI ≥40 kg/m² (n=13). Preoperative planning involved CT scans and the J- planner for optimal implant size and positioning. Surgery was performed without tourniquets, and patients were mobilized postoperatively. Clinical outcomes were assessed using visual analog scale (VAS) scores and the American Knee Society Score (AKSS) at three and six months. The mini-subvastus approach in RA-TKA offers several advantages, including reduced postoperative pain, faster recovery, and improved quadriceps strength, even in obese patients. The use of robotic assistance ensures accurate component positioning and alignment, mitigating the challenges typically associated with obese patients undergoing TKA.

In a similar study using the subvastus approach in obese patients by [9], the authors noted that they did not have to revert the patella primarily at all but only displaced it laterally and that it can be displaced laterally easily if the vastus medialis is released adequately from the intermuscular septum. The synovial division also helped in the lateral displacement of the patella. It was possible to flex the knee more (if the knee was stiff earlier) by the release of the vastus medialis from the septum and the removal of all osteophytes. The knee was "debulked" by removing the osteophytes and releasing the soft tissue, making the exposure easier. After the femur and tibial bone cuts are performed, patellar eversion for resurfacing or debulking (the removal of protruding superior and lateral osteophytes) can be accomplished rather simply since the quadriceps become more relaxed. Repositioning the knee in different degrees of flexion and extension is necessary while performing the surgery through a tiny incision. Although all of the knee's components may not be seen at the same time, sufficient exposure is achieved to complete every step of the procedure. The fundamental components of the subvastus technique are the symbiotic usage of retractors and the employment of a moveable skin window to complete the operation's successive steps.

[10]published their results of 600 primary total knee arthroplasties performed through a subvastus approach. Follow-up was short-term, averaging 28 months. A historical group of 150 total knee arthroplasties performed through a standard medial parapatellar arthrotomy was used as a control. The rate of major complications in the subvastus group was found to be associated with surgical experience, as the rate was reduced by 16% for each additional 50 procedures performed. Mean knee flexion at one year averaged 125° in the subvastus group and 114° in the traditional group.

The average operative time was initially higher in the subvastus group but decreased with experience, so it was less than that of the traditional group in the last 400 subvastus procedures performed.

Limitations of robotic TKA include high installation costs, additional radiation exposure, learning curves for gaining surgical proficiency, and compatibility of the robotic technology with a limited number of implant designs[11]. Further higher quality studies are required to compare differences in conventional TKA versus robotic TKA in relation to long-term functional outcomes, implant survivorship, time to revision surgery, and cost-effectiveness[5]. While these short-term results are promising, longer-term studies are needed to confirm these findings and fully understand the durability and long-term outcomes of this approach. Haptic boundaries also limit the action of the saw to the confines of the preoperative surgical plan to limit iatrogenic soft tissue injury[12]. There is no learning curve for achieving the planned implant position and operative times are equivalent to those for conventional tourniquet-based TKA after the initial learning phase. However, improved radiological outcomes in robotic TKA have not translated to any differences in long-term functional outcomes compared to conventional tourniquet-based TKA. Hence the present study aimed to perform robotic total knee replacement without tourniquet via subvastus approach.

II. MATERIALS AND METHOD

A. Overall description of the work with flow diagram

The Cuvis Joint™ autonomous robotic system is an image based closed-platform robotic system. A preoperative CT scan of the lower limb is uploaded to the preoperative planner (J planner™) according to the manufacturer's protocol.

The software creates a 3D reconstruction of the knee, by auto-segmenting the CT images. Based on the 3D images, the surgeon pre-plans the surgery and determines the following parameters: 1. Center of rotation of the hip, knee, and ankle. 2. Presence of bony deformity. 3. Sizing and positioning of implant. 4. Number of bony cuts required based on the mechanical axis in the frontal and sagittal planes. 5. Marking the femoral and tibial rotation in the axial plane. 6. Registration points required for intra-operative surface registration on the femur.

Fig. 1 a Cuvis Joint™ autonomous robot, b J planner™ software workstation for preoperative planning with real- time numerical data. Cuvis Joint Robotic System is the most advanced surgical cutting edge robotic technology supporting surgeons with Personalized Preplanning and Precise Cutting for predictable and consistent results.

The software compiles the inputs provided by the surgeon and creates a fnal alignment report using numerical data, which is then uploaded to the robotic arm console. During the surgery, the technician calibrates the robot to facilitate moving and working with the armds within a defned 3D workspace. Finally, the arm is covered in a sterile drape. The leg of the patient is fxed in a special positioner (De Mayo V2™, Imp incorporation, Plainville, Connecticut, USA) to prevent any untoward movement during surgery (Fig. 2a). After the initial standard exposure, navigation pins with refective arrays are placed in the femoral and tibial diaphysis, approximately 10 cm from the joint line (Fig. 2b), using a dual pin system on each side provided by the manufacturer (Fig. 2c). The pin size is 4 mm and they are bicortical, as advised by the manufacturer, to prevent pin loosening (Fig. 2d).

This is followed by surface registration of the femur and tibia using a probe. Subsequently, the computer generates a virtual 3D image of the knee, and the system matches it with the CT images. The registration needs to be precise, which is indicated by an fnal root mean square (RMS) error of less than 1.

Fig. 2 (a) Leg positioned over a sterile positioner for RA- TKA; (b) drilling the cortex with 2.5 mm drill bit for the insertion of 4 mm unicortical Steinmann pin; (c) dual pins inserted in femur; (d) refective arrays fxed to the diaphyseal unicortical Steinmann pins

Minimal soft tissue release, osteophytes, and the anterior horns of the menisci can be removed at this stage. The system displays real-time values of the gaps throughout the range of motion and the gaps are balanced according to the surgeon's preference. The robotic arm is on the operating side of the patient and is positioned so that the calibrated robotic workspace overlaps with the surgical workspace; these are visualized on the monitor in real-time. The robotic arm is attached to the patient's leg using metaphyseal

hooktype clamps or 6 mm Steinmann pins, one of which is inserted in the distal femoral and the other in the proximal tibial metaphysis (Fig. 3a). This step fixes the knee to prevent movement of the leg and aids the robot in monitoring the fne movement of the leg during the procedure- this is known as bone movement monitoring (BMM). When the movement exceeds a certain threshold, the cutting arm freezes (Fig. 4a). The predetermined movement allowed in the Cuvis Joint™ robot is 1 mm, set by the manufacturer. It does not require registration tacks or BMM sensors to be placed on the bone, unlike in the older systems. The type of bone resection is decided by the operating surgeon; it could be either extension surface resection or full surface resection. The robotic arm mills each surface systematically, beginning with the resection of the distal femur. The resection is performed with a 6.2 mm burr with continuous automated saline irrigation that mills the bone at a predefined level, based on the input provided by the surgeon (Fig. 4b). Being an autonomous system, the robotic arm follows a predefined pathway for milling each surface. Posterior stabilized implants are routinely used; however, the box cut can be avoided in case a cruciate retaining prosthesis is preferred. Though the robotic arm can prepare the keel for the tibial tray, at our center, the senior surgeon uses the robotic arm for cutting and sizing the proximal tibia, but keel sizing and preparation is performed manually. This helps in soft tissue balancing in case a reduction osteotomy is required. Once all the cuts are completed, the robotic arm is manually detached from the patient's body, and standard procedures such as removal of the remaining bone islands, removal of posterior osteophytes and menisci, and soft tissue release are performed as required. The ligament balance is checked through trials using the values displayed on the monitor and definitive implantation of the knee is initiated. Along with the endpoints indicated above, post-operative radiographs at 6 weeks after surgery were used to determine the accuracy of the overall limb alignment (which the authors intended to be mechanical in principle), as well as the sagittal and coronal component positions. Standing anteroposterior radiographs were utilized to assess the mechanical axis (hip–knee–ankle axis), femur, and tibia coronal (valgus/varus) positioning. Lateral radiographs were utilized to evaluate Tibial sagittal positioning (tibial slope). This finding was used to calculate the mean errors and outliers to determine the accuracy of performing the planned pre-operative surgical plans. Outliers were defned as deviations greater than 3° on each radiograph.

Fig. 3 (a) 6 mm metaphyseal Steinmann pins inserted laterally for the robotic arm to attach to the patient; (b) one 3 mm Kirschner wire inserted in the medial femoral condyle for retraction

Fig. 4 (a) Robotic console fixed to the patient's body; (b) milling of the femur using 6.2 mm burr with continuous saline irrigation

Personalized preplanning

As each person has a different face, the shape of bone is also different. Cuvis Joint Robotic System shows the patient's bone in 3D CT images, and the doctor can use those images for pre-planning of surgery personalized for the patient.

Various cutting options with intraoperative gap check (Pre/intra/post) and plan changing feasibility.

Accuracy

- Submillimeter dimensional accuracy
  Cuvis Joint Robotic System guides you to cut what's precisely planned for each patient, resulting in preserving soft tissue and saving healthy bone.
- Use of milling cutter
  The milling cutter reduces the impact on the patient's weak bone, and thus cuts down the occurrence ratio of side effects such as fractures.
- Active robotic arm assisted surgery
  It can provide the optimized surgical solution with robot cutting technology which provides safe surgery to patients and increases surgical reliability delivering a better medical environment to both doctors and patients.

Safety

Unmatched safety
BMM (Bone Motion Monitor) function can detect the patient's intraoperative slight movement. Once the movement is detected, the robot stops the motion and prevents errors caused by the patient's movement.

Ethical Considerations

Preoperative planning

As each person has a different face, the shape of bone is also different. Meril's artificial joint surgical robot CUVIS Joint shows the patient's bone in 3D images, and the doctor can use those images for pre-planning of surgery personalized for the patient.

The software creates a 3D reconstruction of the knee, by auto-segmenting the CT images. Based on the 3D images, the surgeon pre-plans the surgery and determines the following parameters:

1. Center of rotation of the hip, knee, and ankle
2. Presence of bony deformity
3. Implant size and position
4. Number of bony cuts required based on the mechanical axis in the frontal and sagittal planes
5. Marking the femoral and tibial rotation in the axial plane
6. Registration points required for intra-operative surface registration on the femur.

Fig 5: J planner™ software workstation for preoperative planning with real- time numerical data.

Pre-selection of artificial joint and precise insertion of artificial joint

The precise surgical plan is to select and insert the personalized artificial joint. The doctor uses robot to select an artificial joint for the patient and insert it accurately.

Precise cutting for sub-millimeter accuracy and optimum alignment

The software compiles the inputs provided by the surgeon and creates a final alignment report using numerical data, which is then uploaded to the robotic arm console. Precise cutting serves the optimum result. CUVIS Joint provides the correct alignment of a patient's leg axis with the sub- millimeter dimensional accuracy and precise cutting for the optimal surgical outcome.

The original placement of the implant was selected based on principles of mechanical alignment, and afterwards, the balance was evaluated and adjusted to achieve functional alignment.

Functional Alignment Protocol:

a) Final alignment- 174-180 degree
b) Final sagittal alignment- 0-5 degree (under gravity)
c) Femur- 3 degree varus to 6 degree valgus
d) Femur Flexion- 0-7 degree
e) Femur Rotation (PCA)- 0 IR to 6 ER
f) Tibia Varus- 0 to 6 degree varus
g) Tibia Slope- 3 degree PS/5 degree CR Pre-operative planning

Pre-operative planning for the procedure involved utilizing the Cuvis Joint® robotic system and the J planner on the robot's console. The process included uploading the patient's CT scan onto the Robotic J planner and registering the bony landmarks of the femur and tibia. This allowed for selecting the appropriate implant size and orientation to correct deformities and prevent anterior-posterior (AP) and mediolateral (ML) mismatch of the femoral condyle. The optimal implant size and position were determined by avoiding sagittal plane anterior notching and coronal plane ML overhanging.

Surgical technique

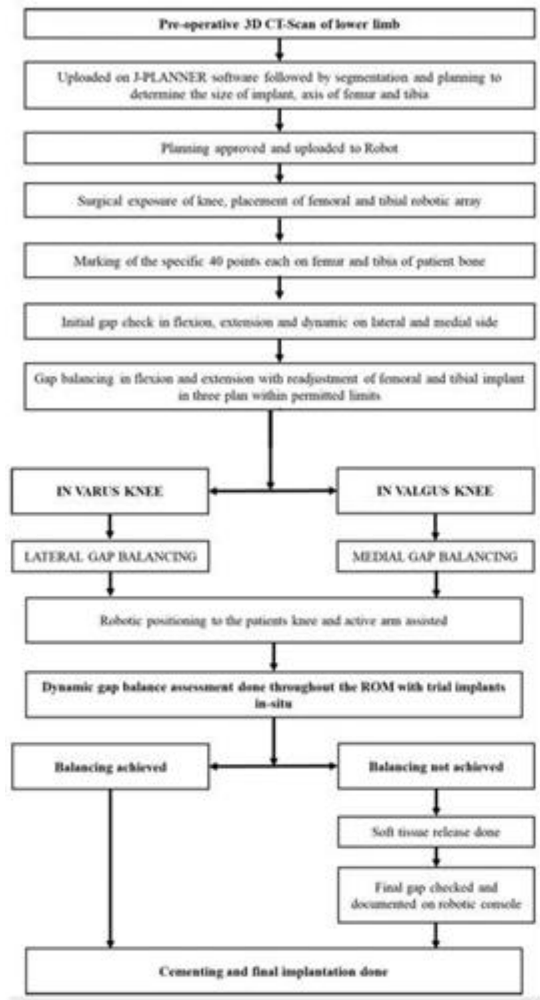


Fig 6: Flowchart of surgical technique

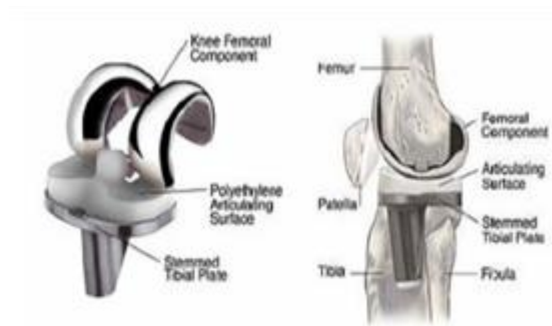
In the present technique, full surface resection was opted for. The cut sequence can be changed or stopped during the burring process. After this, residual bone and osteophytes were removed. Post-resection (robotic burring) final gaps were assessed with trial implants in situ throughout ROM, and confirmation of symmetrical lateral and medial gaps in varying degrees of flexion as well as extension (zero-degree flexion to almost 130° of flexion) was achieved. Hip-knee- ankle (HKA) angle within 5° varus and 5° flexion was accepted based on the patient's pre-operative evaluation. We have accepted the mediolateral gap difference of +2 and −1 mm from the insert size. Once the knee was balanced, the femoral and tibial arrays were taken out, followed by patelloplasty with circumpatellar denervation. A 9 mm poly was used in each case. A pulsatile lavage wash was given, surfaces were dried, and components were implanted with cement. The closure was done in layers without draining using the staple-less technique. Patients were mobilized two to three hours post-surgery with walker support and started on ROM and strengthening exercises. Patients were discharged home on the post of day 3 or 4. All patients were evaluated with visual analogue scale (VAS) scores pre- and post-operatively on days 0, 1, 2, and 3 and using the AKSS clinical and functional scores at three- and six-month follow-ups.

III. RESULTS

Demographic and baseline characteristics of patients

This was a single-centre, retrospective, observational study. The study included 100 consecutive patients who underwent TKA using the Cuvis Joint™ autonomous robotic system from January 2023 to October 2024. Written informed consent was obtained from all participants included in the study. All surgeries are performed by a senior surgeon. Patients in whom the surgery was abandoned midway due to technical errors, were excluded from the analysis. In the case of midway abandonment of the robotic arm for a single side during simultaneous bilateral RA-TKA, data of the side on which the surgery was completed with robotic assistance was included in the analysis. Primary end point was safe execution of the surgery. The primary outcome measure is complications associated with active RA-TKA. The incidence of neurovascular injury, mechanism disruption, collateral ligament and other soft tissue injuries, and pin- related injury including intra-operative fractures etc were studied and the safety features in the autonomous robotic system were analyzed. This study was initiated after protocol was reviewed and approved by the local ethics committee (EC) according to local regulations. The study was carried out in conformity with the protocol and International Conference on Harmonization Guideline for Good Clinical Practice (ICH-GCP).

Reduction of side effect and reoperation - CUVIS Joint reduces side effects like inequality of limb length, pulmonary embolism, and fracture. The risk of infection is also reduced because of fewer instruments in use than in conventional surgery



CUVIS Knee Joint Replacement consists of the following steps:

1. Patient selection:

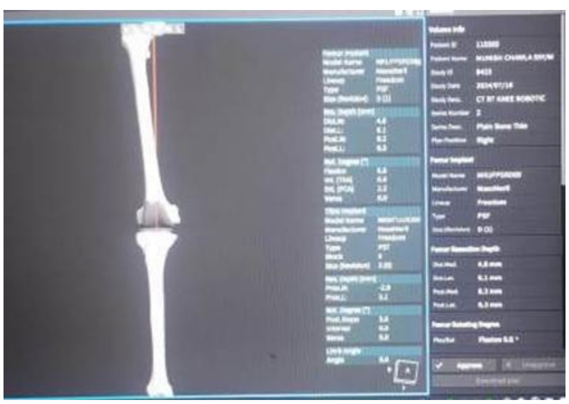
Patients can decide upon robotic artificial joint surgery after consulting with the doctor

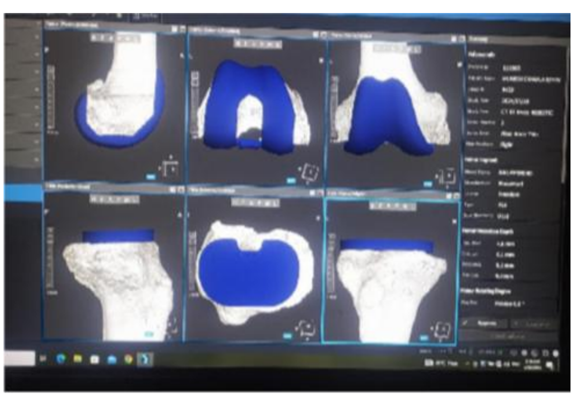
2. CT scanning

3. Pre Surgical Planning:

The scanned CT image is converted into a 3D image for diagnosing the patient's condition and making a surgical plan as required.

a) FMA/TMA setting (Mechanical axis setting)
b) Rotation
c) Implant selection
d) Virtual surgery





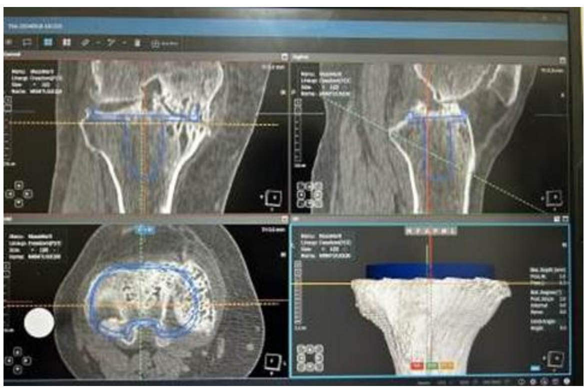
4. Surgical Implementation:
During the surgery, the technician calibrates the robot to facilitate moving and working with the arm within a defined 3D workspace. Finally, the arm is covered in a sterile drape. After registration process, robot reviews the data and cuts the bone precisely with respect to size, position, angle and direction of the implant decided during pre-surgery planning stage. The functional alignment principle in Cuvis software was utilized to alter the position of components until the knee achieved equilibrium, following the acquisition of maximal gaps.

5. Implant Placement:

Insert and fix the decided implant for surgery conclusion.

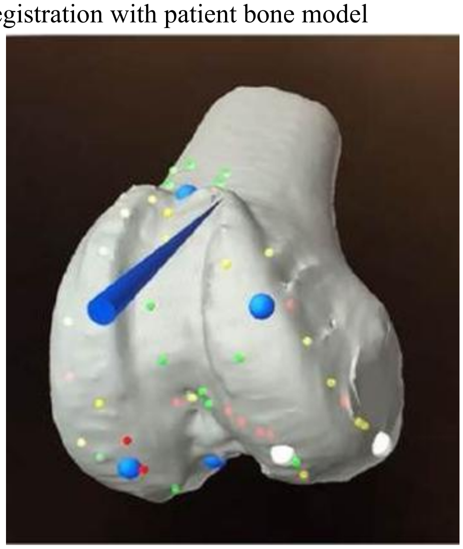
Advantages of CUVIS Joint

1)Surgical Planning
a) CT data loading
b) Set up surgical planning



2)System Diagnosis
a) Non-sterile/Sterile
b) Tool and Base marker positioning

3)Registration
a) Patient setup
b) Registration with patient bone model



4)Cutting/Gap check
a) Measured Resection / Modified gap technique
b) Pre/Intra/Post resection gap check

5)Surgery/Implant Insertion
a) Check cutting results and implant insertion
b) Robot out

Intra-Operative Events

Intra resection gap check and plan changing
1) Initial plan
2) Femoral shift
3) Tibial shift
4) Femoral rotation
5) Re-planning

IV. DISCUSSION

This study investigated the safety and intra-operative surgical complications associated with the use of the Cuvis Joint™ autonomous system for RA-TKA. The subvastus approach in TKA is a muscle-sparing technique that aims to preserve the quadriceps muscle, leading to faster recovery and reduced post-operative pain compared to other approaches. However, obese and morbidly obese patients may be considered unsuitable for this approach due to potential challenges in exposing the surgical site, which can increase the risk of complications such as medial collateral ligament sprain or patellar tendon avulsion. The milling of

the bone surfaces is precise enough to allow for cement-less insertion of the prosthesis, which requires an implant bone gap of 0.1–0.3 mm for osseous integration. . Routinely one 3 mm Kirschner wire is used for medial side retraction in thin individuals and two 3 mm Kirschner wires are used in obese individuals in the medial femoral metaphysis. A Mayo towel clip for the patellar tendon retraction during milling on the lateral side and a smallLangenbeck type retractor medially during the posteromedial milling provides an added layer of protection. Femoral or tibial shaft fracture due to mechanical weakness caused by the pinholes is one of the most dreaded complications of the RA-TKA, with an incidence of 1.4% reported by Beldame et al.

The subvastus technique is found to be less invasive than the standard approach, as it maintains blood supply via the intramuscular descending genicular artery, reducing the risk of vascular complications. Skin necrosis can be avoided by careful subfascial dissection and by not undermining the lateral flap. As is well known, the vascularity of the knee is lateral-based, and by keeping the lateral flap thick, skin necrosis can be avoided.

The short-term follow-up study demonstrates the effectiveness of RA CR-TKA using the SA in obese and morbidly obese patients. This approach provides adequate intraoperative knee exposure even in obese and morbidly obese patients with minimal blood loss and less pain in the immediate postoperative period, thus enabling early mobilization. Additionally, it improves knee range of motion and patellar tracking, leading to a faster recovery and effective rehabilitation. Importantly, despite minimally invasive procedures, the robotic arm assistant maintains proper implant positioning and limb alignment. These findings suggest the potential feasibility of CR RA-TKA in morbidly obese and obese patients, utilizing the subvastus approach without a tourniquet. As with any procedure, there is a definite learning curve associated with the subvastus approach. The senior author's technique and indications have evolved with time and experience. While these short- term results are promising, longer-term studies are needed to confirm these findings and fully understand the durability and long-term outcomes of this approach.

CONCLUSION

Active robotic arthroplasty involving navigation based minimally invasive surgery, achieves accurate preoperative planning, optimal selection of implants, precise osteotomy, and accurate placement of artificial joints owing to the precise control technology of the robotic arm. The Cuvis Joint™ autonomous robotic system is safe with no intra-operative complications. The ability to use the robotic arm without causing any soft tissue injury in the initial cases required extended operating time and involved pausing the robot in between resections to check the integrity of these tissues. However, with further cases, as our knowledge on safe usage of the robot improved, the operating time reduced considerably.

REFERENCES

[1] J. Gao, D. Xing, S. Dong, and J. Lin, "The primary total knee arthroplasty: a global analysis," Journal of orthopaedic surgery and research, vol. 15, pp. 1-12, 2020.

[2] B. Uivaraseanu et al., "Highlighting the advantages and benefits of cementless total knee arthroplasty," Experimental and Therapeutic Medicine, vol. 23, no. 1, p. 58, 2022.

[3] Kamaraj, K. To, K. M. Seah, and W. S. Khan, "Modelling the cost-effectiveness of total knee arthroplasty: A systematic review," Journal of orthopaedics, vol. 22, pp. 485-492, 2020.

[4] Magan, O. Dunseath, P. Armonis, A. Fontalis,Kayani, and F. Haddad, "Tourniquet use in total knee arthroplasty and the risk of infection: a meta-analysis of randomised controlled trials," Journal of experimental orthopaedics, vol. 9, no. 1, p. 62, 2022.

[5] W. Alrawashdeh, J. Eschweiler, F. Migliorini, Y. El Mansy, M. Tingart, and B. Rath, "Effectiveness of total knee arthroplasty rehabilitation programmes: a systematic review and meta- analysis," Journal of rehabilitation medicine, vol. 53, no. 6 (June), pp. 1-12, 2021.

[6] J. K. Lee, H. J. Kim, J. O. Park, and J. H. Yang, "Inferior outcome of revision of unicompartmental knee arthroplasty to total knee arthroplasty compared with primary total knee arthroplasty: systematic review and meta-analysis," Knee Surgery, Sports Traumatology, Arthroscopy, vol. 26, no. 11, pp. 3403-3418, 2018.

[7] B. G. Stubnya et al., "Subvastus Approach Supporting Fast-Track Total Knee Arthroplasty Over the Medial Parapatellar Approach: A Systematic Review and Network Meta-Analysis," The Journal of Arthroplasty, 2023.

[8] S. K. Bhattacharjee, A. K. Choudhury, S. Priyadarshi, A. Prasad, and A. Ahlawat, "Functional Outcome in Obese Patients Undergoing Image-Based Cruciate Retaining Robotic-Assisted Total Knee Arthroplasty Using the Subvastus Approach: A Short-Term Study," Cureus, vol. 16, no. 9, 2024.

[9] N. A. Shah, H. G. Patil, V. O. Vaishnav, and A. Savale, "Total knee arthroplasty using subvastus approach in stiff knee: A retrospective analysis of 110 cases," Indian Journal of Orthopaedics, vol. 50, pp. 166-171, 2016.

[10] W. C. Schroer, P. J. Diesfeld, M. E. Reedy, andR. LeMarr, "Evaluation of complications associated with six hundred mini-subvastus total knee arthroplasties," JBJS, vol. 89, no. suppl_3,pp. 76-81, 2007.

[11] T. Xu et al., "Efficacy and safety of a self-developed home-based enhanced knee flexionexercise program compared with standard supervised physiotherapy to improve mobility and quality of life after total knee arthroplasty: a randomized control study," Journal of orthopaedic surgery and research, vol. 16, pp. 1- 8, 2021

[12] Klug et al., "The projected volume of primary and revision total knee arthroplasty will place an immense burden on future health care systems over the next 30 years," Knee Surgery, Sports Traumatology, Arthroscopy, vol. 29, pp. 3287-3298, 2021.