MENTORS IN ORTHOPEDICS

VELYS™ ROBOT-ASSISTED UNICOMPARTMENTAL KNEE ARTHROPLASTY: INDICATIONS, OPERATIVE TECHNIQUE, AND PRACTICAL CONSIDERATIONS

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SUMMARY

Background: While historical selection criteria for unicompartmental knee arthroplasty (UKA) were highly restrictive, recent consensus from the British Association for Surgery of the Knee and the European Knee Society has expanded indications, suggesting 20% to 50% of arthroplasty candidates may be eligible. Despite clinical advantages over total knee arthroplasty, UKA remains associated with higher revision rates, often attributed to surgeon-dependent factors such as malalignment and improper component positioning.

Objective: This article describes the surgical technique and clinical rationale for using the VELYS™ robotic-assisted system in the implantation of the Sigma™ Partial Knee prosthesis for medial or lateral femorotibial osteoarthritis.

Key Points: The image-free robotic system utilizes optical navigation and a mobile station with an integrated saw to enhance precision. The procedure involves anatomical landmark registration, surface mapping for three-dimensional bone modeling, and dynamic ligamentous gap assessment via the ACCUBALANCE™ tool. Intra-operative planning allows for precise adjustment of implant size, orientation, and joint line restoration. Robotic assistance is utilized for the transverse tibial and femoral cuts, while the sagittal tibial cut remains manual. Evidence suggests that robotic integration improves alignment accuracy and patient satisfaction, potentially offsetting higher initial costs by reducing long-term revision rates and complications.

Conclusion: Robotic-assisted UKA provides a standardized, precise method for implant positioning and ligamentous balancing. By adhering to modern indications and utilizing robotic technology to minimize technical errors, surgeons may achieve clinical outcomes and survivorship rates comparable to total knee arthroplasty.

KEYWORDS

Arthroplasty, Replacement, Knee; Robotic Surgical Procedures; Osteoarthritis, Knee; Bone Malalignment; Treatment Outcome

INDICATIONS

The historical indications described by Kozinn and Scott [13] are as follows:

1. Age > 60 years
2. Unicompartmental osteoarthritis or osteonecrosis
3. Low functional demand
4. Weight less than 82 kg
5. Pre-operative flexion deformity <5°
6. Coronal deformity <15°, correctable
7. Intact Anterior Cruciate Ligament (ACL)

The British Association for Surgery of the Knee (BASK) and the European Knee Society (EKS) are two associations that have collaborated to develop a consensus on the indications for medial or lateral unicompartmental knee arthroplasty [14]. Some data indicate that UKA is underutilised in certain countries and regions of the world.

From these recent consensus works, the following indications have emerged:

1. Femorotibial osteoarthritis or osteonecrosis
2. No age limit, but caution for high-impact sports in young patients
3. No weight limit, but nevertheless some caution for patients with a BMI > 40
4. Anterior knee pain and patellofemoral osteoarthritis are not a contraindication, especially if asymptomatic
5. Chondrocalcinosis is no longer a contraindication
6. Pre-operative flexion deformity < 15°
7. No restriction in coronal alignment, provided the joint line height is respected [15]
8. A deficient ACL is no longer a contraindication provided that the patient does not complain of knee instability and the osteoarthritis is primary

Thus, recent indications suggest that between 20 and 50% of patients who are candidates for a knee arthroplasty would be eligible for a UKA [14].

RISK FACTORS FOR UKA FAILURE AND THE ROLE OF ROBOTICS

The main causes of failure after partial knee arthroplasty are polyethylene wear, aseptic mechanical loosening, and the progression of osteoarthritis. Their incidence has markedly decreased with the introduction of new implants and designs [16],[17]. Furthermore, rigorous patient selection and the introduction of new technologies have considerably reduced the incidence of mechanical loosening and the progression of osteoarthritis [18].

The main causes of aseptic loosening after UKA are often surgeon-dependent: poor component alignment; under-correction of the pre-degenerative deformity; an unevaluated ACL deficiency; and excessive tibial slope. It has been demonstrated that the surgeon performing this procedure could be the main factor in its failure [19].

The question arises as to why surgeons who perform a high volume of procedures have fewer revisions than others [20]. A possible explanation could be that they achieve better component orientation, more accurately restoring the patient's anatomy, and a superior, more reproducible surgical technique, which is crucial for UKA survival. Thus, beyond better patient selection, optimal implant positioning seems crucial to reduce the risk of failure. The use of computer-assisted surgery (CAS) has shown that implant position can be improved. This navigation, used with various robotic tools, improves precision to achieve the target positioning and reduce the risk of failure [21],[22].

THE VELYS™ ROBOT

The VELYS™ robot is a robotic-assisted surgical device developed jointly by Johnson & Johnson and Orthotaxy. It was designed to assist in the implantation of Attune™ total knee arthroplasties (Posterior-Stabilised, Cruciate-Retaining, Medial-Stabilised) as well as Sigma™ Partial Knee unicompartmental prostheses.

This robotic assistance operates without the need for pre-operative imaging.

Our article focuses exclusively on unicompartmental knee arthroplasty (UKA), particularly the implantation of the Sigma™ Partial Knee prosthesis, a cemented, resurfacing-type prosthesis, suitable for the management of medial (Figure 1) or lateral (Figure 2) femorotibial osteoarthritis.

Figure 1: Post-operative radiograph of a medial Sigma™ Partial Knee unicompartmental arthroplasty performed with VELYS robotic assistance.

Figure 2: Post-operative radiograph of a lateral Sigma™ Partial Knee unicompartmental arthroplasty performed with VELYS robotic assistance, associated with a lateral vertical patellectomy.

The VELYS™ system consists of two main units:

1. A base station, including the optical camera and the control console (placed on the opposite side of the limb being operated on);
2. A mobile station, comprising the robotic arm, the integrated saw, and an interactive planning screen.

OPERATIVE TECHNIQUE

1. Surgical Approach

The choice of surgical approach is not dictated by the use of the robot. All approaches are compatible:

- Medial or lateral parapatellar (trans-quadriceps)
- Mid-vastus
- Subvastus

2. Placement of navigation trackers

Femur: Two pins are positioned in the medial condyle through the main incision, sufficiently distal and medial so as not to interfere with the robotic arm during the cuts, approximately 4 cm above the articular joint line.

Tibia: Two options:

- Via the main incision, in the proximal zone near the joint line (approximately 4 cm below).
- Percutaneously on the anteromedial aspect of the tibia.

For lateral UKA, the femoral trackers must be implanted percutaneously at mid-thigh and oriented towards the camera. Two bony landmarks (checkpoints) are marked on the femur and tibia using an awl. They will serve as tibial and femoral verification points before the bone cuts.

3. Acquisition of anatomical landmarks

Using a pointer probe, the following anatomical landmarks are registered to model the mechanical axes (Figure 3):

- Ankle centre (medial and external malleoli).
- Tibial sagittal axis.
- Centre of the tibia and femur (apex of the intercondylar notch).
- Hip centre of rotation.

Figure 3: Acquisition of anatomical landmarks using the pointer probe. The trackers on the femur and tibia have been positioned within the surgical approach.

A three-dimensional model ("bone morphing") of the femoral condyle and tibial plateau is then created by acquiring numerous points on the articular surfaces via "surface mapping". The accuracy of this step is crucial. It is recommended to map the surface extensively, with emphasis on:

- The anterior, medial, and lateral borders of the tibial plateau.
- The anterior and posterior borders of the femoral condyle.

The more complete the mapping, the more reliable the reconstructed bone model, particularly for the geometry of the posterior plateau, which is more difficult to access.

4. Assessment of ligamentous gaps and alignment

The ligamentous gaps are measured passively through the arc of flexion between 0 and 90°, with manual reduction in valgus (for medial UKA) or varus (for lateral UKA).

The measurements are displayed as a dynamic graph via the ACCUBALANCE™ tool.

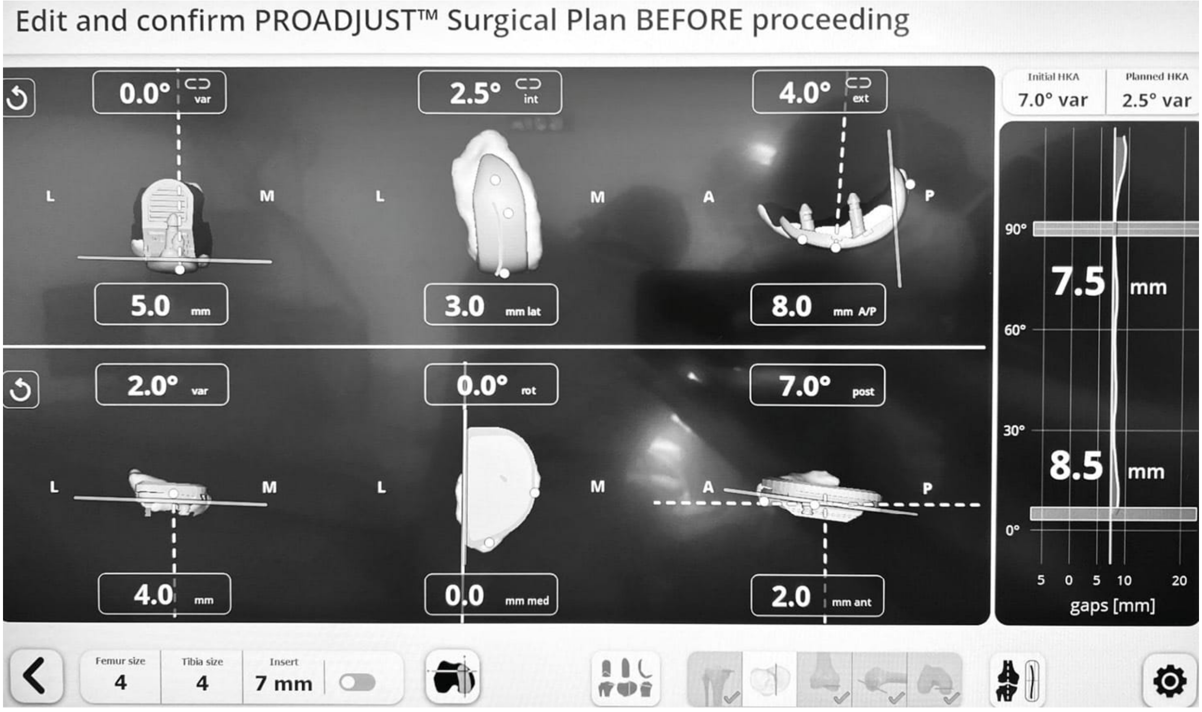
The system also simulates the HKA axis in a "loaded" state. Thanks to the reduction manoeuvre, a target axis (target post-operative HKA) can be determined by reducing the articular wear, taking into account:

- Ligamentous tensions.
- Visual alignment.
- Objective data from the robot.

5. Intra-operative planning

The planning interface allows for the adjustment of (Figure 4):

- The size, position (ML and AP), and orientation (varus/valgus (femoral and tibial), rotation (femoral and tibial), tibial slope, femoral flexion) of the implants.
- Prosthetic contacts, to ensure good kinematics.
- Ligamentous balance through the 0–90° arc, preserving the native articular joint line.
- Prosthetic positioning can be performed in a dependent (femur adapts to the tibia) or independent manner.



Edit and confirm PROADJUST™ Surgical Plan BEFORE proceeding

Initial HKA 7.0° var

Planned HKA 2.5° var

Femur size 4

Tibia size 4

Insert 7 mm

Figure 4: Interface for planning prosthetic positioning with Accubalance (right) showing the ligamentous gaps induced by the prosthetic positioning parameters.

6. Robotic bone cuts

The bone cuts are performed using the robotic arm and an integrated oscillating saw:

Transverse tibial cut (robot-assisted) (Figure 5).

Distal femoral, posterior femoral, and posterior chamfer cuts.

The sagittal tibial cut is not robotised but can be guided by the pointer probe, then performed using a conventional saw or an osteotome.

The cuts can be verified at each stage. In case of discrepancy, recuts are possible.

Figure 5: Tibia-first cut using the robotic arm.

7. Final preparation

Femur: The peg holes are created with the standard instrumentation, guided by the pointer probe to restore the planned medio-lateral positioning.

Tibia: Conventional preparation (peg and keel) with the standard instrumentation, according to the orientation defined during planning.

It is possible to adopt a "tibia first" strategy, then recalculate the ligamentous gaps with a spacer, in order to adjust the position of the femoral component.

8. Final check and validation

A new check with the trial implants allows for a re-evaluation of the alignment, ligamentous gaps, and dynamic stability. Adjustments (recuts, repositioning) are still possible at this stage before cementing the definitive implants.

DISCUSSION

A recent systematic review has shown better functional outcomes, faster recovery, fewer periprosthetic joint infections, and a lower rate of severe cardiac medical complications for UKA than for TKA [23]. These results demonstrate that UKA can be offered as a viable alternative to total knee arthroplasty, provided that modern UKA indications are respected. The therapeutic options must be discussed with the patient to help them make an informed decision, based on the advantages and disadvantages presented to them. It is worth recalling that modern indications suggest that between 20 and 50% of patients presenting for a primary knee arthroplasty may be eligible for a partial arthroplasty [2].

The BASK/EKS consensus group recognised the importance of optimising UKA outcomes [14]. This is particularly relevant when considering the higher revision rate of UKA compared to TKA. Firstly, surgical experience is an essential element in reducing the revision rate. Indeed, poor implant positioning remains one of the main risk factors for failure [24]. It appears paramount that surgeons should regularly perform this procedure to be able to offer it to their patients [14]. Secondly, surgeons should follow the modern indications for UKA. If surgeons apply them and respect the established limits, the results of UKA will improve and the revision rate will decrease to match that of total knee arthroplasties. The UK registry and the BASK/EKS consensus suggest that knee surgeons adapt their practice in terms of patient selection, by adopting a broader spectrum of indications which would increase their volume of UKA, thereby significantly improving their results. The BASK/EKS consensus group acknowledges the necessity and importance of training the next generation of knee surgeons in the practice of UKA. Thirdly, robot-assisted surgery allows for improved precision and implant placement to optimise clinical outcomes and decrease the rate of failures and revisions [21],[22]. Indeed, several systematic reviews have shown better alignment, better knee function, and higher patient satisfaction for those who have undergone robot-assisted UKA compared to a traditional technique [25],[26],[27].

Finally, a recent systematic review evaluates the cost-effectiveness of robotic UKA compared to manual UKA [28]. Although robotic UKA entails higher initial costs due to the use of robotic systems and longer operative times, it can nevertheless be cost-effective in the long term by reducing revision rates, improving implant accuracy, decreasing complication rates, and improving functional outcomes. Moreover, the differences in operative time are surgeon-dependent and may decrease with experience in favour of robotic UKA. Thus, robotic UKA is considered a cost-effective procedure compared to mechanical UKA for patients with isolated unicompartmental osteoarthritis who meet the indication criteria. In order to maximise cost-effectiveness, robotic UKA should ideally be performed in high-volume centres. To this must be added the incomparable educational nature of robotics, whose navigation allows for the previewing of the effect of possible adjustments in terms of component positioning, limb alignment, size selection, and balancing, even before the cuts are made, in a context where joint exposure remains limited.

CONCLUSION

Unicompartmental knee surgery assisted by the VELYS™ robot allows for dynamic and personalised planning, precise execution of bone cuts, and optimised control of alignment and ligamentous gaps. This system, which does not require pre-operative imaging, integrates effectively into a standardised minimally invasive approach, without fundamentally altering operative times.

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