

Robotic Surgery in Knee Osteotomy Associated With Unicompartmental Knee Arthroplasty

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Citation: Confalonieri N. Robotic Surgery in Knee Osteotomy Associated With Unicompartmental Knee Arthroplasty. *Genesis J Surg Med.* 5(2):1-06.

Received: September 01, 2026 | **Published:** September 28, 2026

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Abstract

Knee osteotomies are, in some respects, an outdated surgical technique. The advent of unicompartmental arthroplasty and regenerative medicine has reduced their indications. However, there remains a specific indication: the varus osteoarthritic knee with symptomatic early-stage osteoarthritis, an intact lateral and patellofemoral compartment, intact anterior and posterior cruciate ligaments, and a young adult patient with high functional demands. The association with unicompartmental knee arthroplasty allows for the treatment of varus knees with advanced osteoarthritis—localized to the medial compartment—in adult patients with high functional demands. The use of computer-assisted and robotic systems in this surgical technique enables precise and reproducible correction of the lower limb's mechanical axis.

Our experience is limited to seven patients who underwent computer-assisted medial unicompartmental knee replacement combined with tibial opening-wedge osteotomy. We found no articles in the literature describing similar cases. Clinical studies have shown that computer-assisted robotic platforms improve the precision of less experienced surgeons and shorten their learning curve. However, the cost of most of these technological tools may limit their use in hospitals with low volumes of prosthetic implants.

The advantage of computer-assisted robotics lies in the improved accuracy and precision of postoperative coronal and sagittal alignments. However, further studies are needed to determine whether the improved axis influences long-term outcomes and survival rates to offset the increased surgical time, costs, and potential complications of computer-assisted surgery.

Keywords

Osteotomy; Knee; Arthroplasty; Unicompartmental; Computer robotic surgery.

Introduction

Osteotomies around the knee, and indeed osteotomies in general, have fallen into obscurity due to a combination of clinical and therapeutic factors, not least the competition from unicompartmental knee arthroplasty. Orthobiologics and regenerative medicine, with their intra-articular injections, have also encroached upon the territory of osteotomies, particularly in the knee.



High tibial osteotomy (HTO) is a surgical procedure aimed at altering the mechanical axis of the lower limb by inserting an opening wedge or removing a closing wedge in the proximal tibial epiphysis, typically to correct significant varus deformity. Interest in HTO as an adjunct procedure has recently increased, bucking previous trends, precisely due to technical advances in cartilage repair, meniscus transplantation, and unicompartmental knee arthroplasty, for which malalignment would otherwise serve as a contraindication.

Achieving an accurate correction angle is a key factor for long-term HTO survival because a small alteration in limb alignment can change knee load distribution and cause early degenerative changes and dysfunction.

We are referring particularly to the angle between the proximal tibial epiphysis and its shaft (C.O.R.A.). Although there is no general consensus regarding the degree of deformity that should be corrected, a varus deformity greater than 5°, with compartment-specific pain, in a young active patient (40–60 years) with early osteoarthritic changes, is generally considered an ideal indication.

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DOI: [https://doi.org/10.52793/GJSM.2026.5\(2\)-47](https://doi.org/10.52793/GJSM.2026.5(2)-47)

Furthermore, there is no consensus regarding the degree of alignment correction for HTO either. The postoperative mechanical axis of $\pm 3^\circ$, generally accepted for total knee arthroplasty, may be too broad to achieve good long-term results after HTO.

Generally, for isolated osteotomy, the weight-bearing line is recommended to pass through a point near 60% of the width of the tibial plateau (slight overcorrection), which appears to correspond to a tolerance of $\pm 1^\circ$ from the mechanical axis.

When combined with medial unicompartmental arthroplasty, we believe it is more useful to maintain a small degree of undercorrection so that the final axis after both procedures is close to 0° mechanically, in both flexion and extension.

Combining these two interventions transcends the dichotomy between them. It constitutes a minimally invasive procedure that preserves the knee ligaments, unlike total joint replacement, and through axial correction, serves as a preparatory step for potential future prosthetic revision.

The indication is fairly clear: active patients (55–70 years) with significant varus deformity and cartilage degeneration limited to the medial compartment, no flexion or extension deformity, and an intact and functional anterior cruciate ligament.

However, how can this planning, which is performed only in extension, be measured in the operating room?

Despite various conventional methods using a long rod and a metallic reference on the femoral head, obtaining a perfect view is difficult, and accuracy may be affected by limb rotation, the position of the alignment guide, and image intensifier quality.

Computer-assisted orthopedic surgery (CAOS) aims to improve both the precision and accuracy of orthopedic surgery.

It introduces control of the mechanical axis and, consequently, ligament balance throughout the entire range of motion, from extension to full flexion.

Accuracy refers to the degree of closeness to the target. Precision refers to the reproducibility or repeatability of achieving that position, and greater precision means fewer outlier values.

However, it remains uncertain whether improvements in accuracy and precision will lead to improved clinical outcomes and long-term survival rates in various orthopedic procedures.

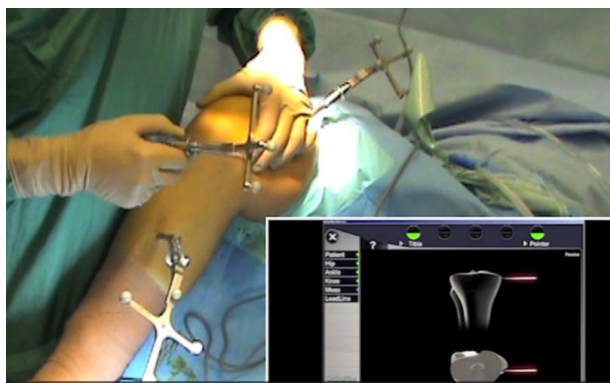
Knowledge of computer-assisted navigation technology, surgical techniques and potential pitfalls, the clinical results of previous studies, and an understanding of the advantages and limitations of computer-assisted navigation are fundamental to the successful application of this new technique in HTO.

Classification of Navigation Systems

Computer-assisted navigation systems can be divided into two types according to the registration method: systems based on preoperative imaging (CT, MRI) and imageless systems.

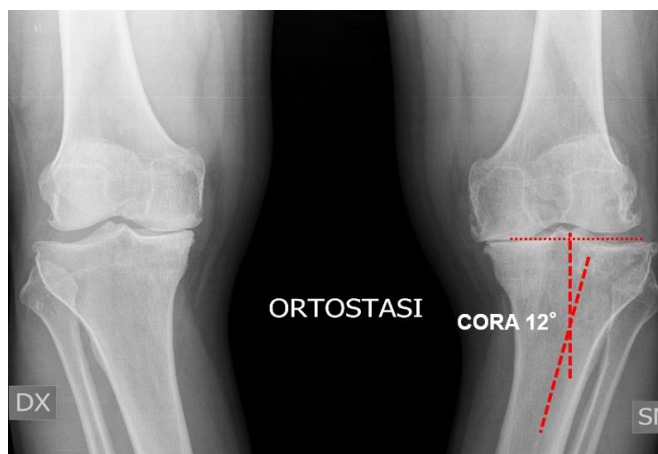
SurgiGATE (Medivision, Oberdorf, Switzerland) for HTO is a fluoroscopy-based system.

OrthoPilot (Aesculap AG, Tuttlingen, Germany) and VectorVision (BrainLab, Heimstetten, Germany) provide HTO software using imageless systems, which have become popular because of the advantages of imageless navigation.



Why no details about cases done in the study and their demographic data and to explain criteria of inclusion in the study. Only mention time period of the study and number of cases as 7 !!!

55-year-old man with medial compartment osteoarthritis, 17° of varus deformity, and a CORA of 12°. Medial open wedge Osteotomy and cemented fixed plateau Uni Aesculap BBraun in the right knee with ORTHOPILOT computer assistance.



Surgical Technique

Two basic techniques are available: medial opening-wedge osteotomy and lateral closing-wedge osteotomy. We will focus on our technique of opening-wedge tibial osteotomy (HTO) combined with

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DOI: [https://doi.org/10.52793/GJSM.2026.5\(2\)-47](https://doi.org/10.52793/GJSM.2026.5(2)-47)

medial unicompartmental arthroplasty using the Orthopilot system.

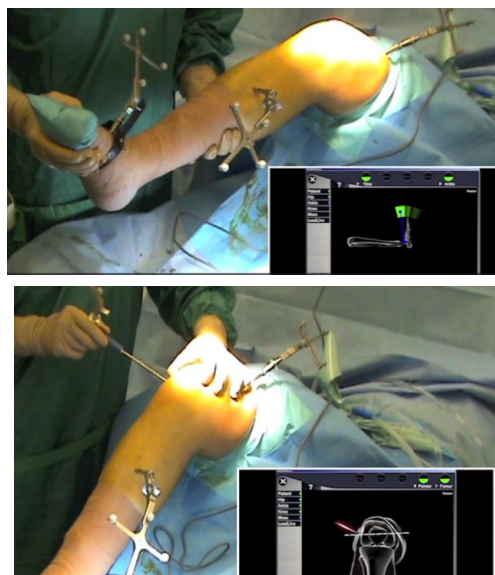
Open-wedge osteotomy

For computer-assisted open-wedge HTO, several factors must be considered, including the determination of the slope (posterior tibial plateau inclination angle) and the use of autologous bone graft or allogeneic bone chips to fill the opening gap and enhance wedge consolidation.

Two reflective sensors are attached—one to the distal femur and one to the mid-shaft of the tibia—each using a pair of 3 mm diameter bicortical threaded metal pins. The hip center is determined using a kinematic reference method, with movements guided by the display.



Other anatomical landmarks of the knee are registered according to the computer's instructions, including the medial and lateral malleoli, medial and lateral tibial plateau points, medial and lateral femoral epicondyles, and anteroposterior tibial rotation.



After a wide skin incision and arthrotomy, the chondral damage is assessed and the compartment is prepared with meniscectomy. Subfascial dissection is then performed, and the superficial medial

collateral ligament and underlying periosteum are reflected with a periosteal retractor. The surgeon places two pins on the tibial plateau for the slope-control sensor.

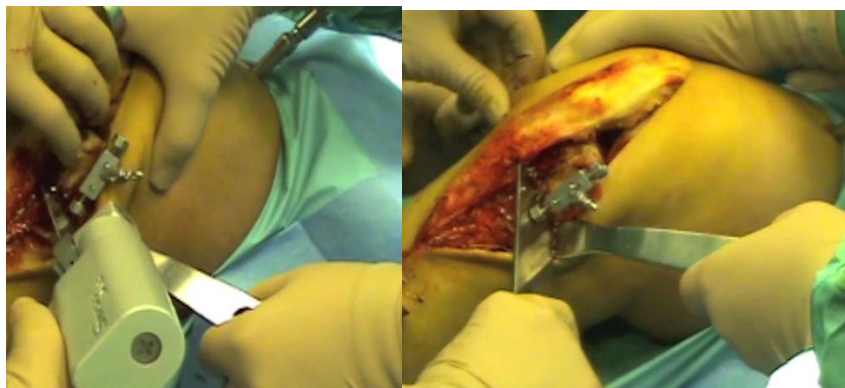


For the optimal degree of correction, the postoperative mechanical axis obtained through navigation should show only a few degrees of undercorrection (1° – 3°) throughout the range of motion. Control of the tibial slope will help achieve this objective.

Two Kirschner wires are inserted into the distal plane of the osteotomy as saw blade guides. The starting point for the K-wires on the medial side of the tibia is positioned at the level of the tibial tuberosity, approximately 3–4 cm from the medial joint line. The endpoint on the lateral side of the tibia is located at the upper part of the fibular head, about 1.5 cm below the joint line. We also perform fluoroscopic monitoring.

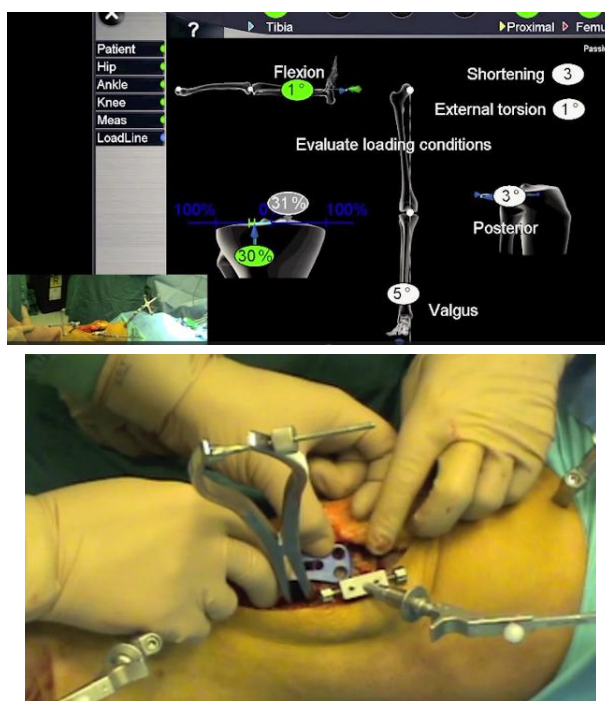
The osteotomy is performed using a power saw, taking care to protect the patellar tendon anteriorly and the neurovascular structures posteriorly with right-angle or Hohmann retractors. A tapered wedge osteotome is inserted into the osteotomy site, and the medial opening is created slowly and carefully, preserving the lateral 5 mm of the posterolateral cortical hinge.





Careful valgus correction is performed by gradually inserting three osteotomies to avoid tibial plateau fractures. Once the desired mechanical axis is achieved (monitored in real-time by navigation) bioactive material, tricortical iliac bone, or nothing at all, is inserted, depending on the surgeon's preference.

The wedge opening is maintained with an appropriate clamp. The size of the metal block of the plate and its positioning, more or less posteriorly according to the desired slope, are selected under computer and radiographic control.



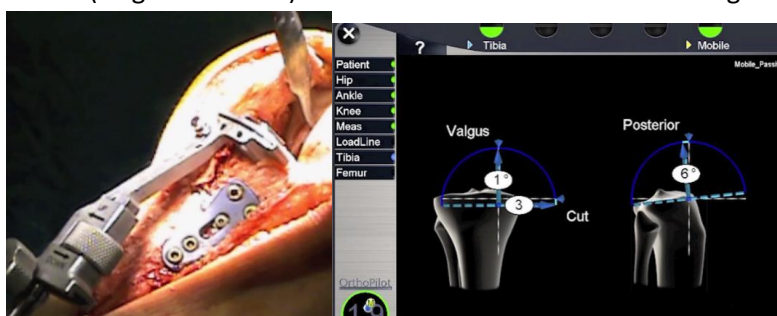


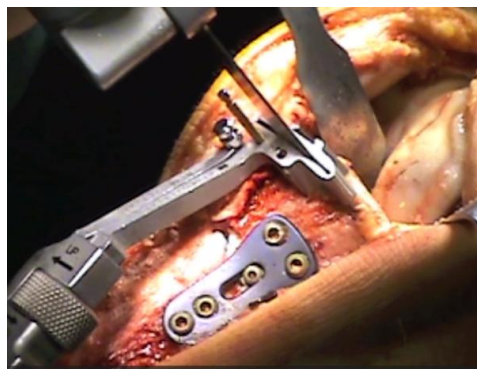
Potential Pitfalls

Registration errors can occur when bony landmarks are inaccurately identified. If landmarks are not precisely located, no computer can compensate for this issue. This limitation must be taken into account, as the navigation system cannot identify features that the surgeon cannot define. In addition to technical errors inherent in the registration process, the navigation system may malfunction if the reflectors or the camera are dirty. In patients with severe osteopenia, the pins placed in the bones to hold the trackers may shift, rendering all subsequent measurements inaccurate. Furthermore, hinge or tibial plateau fractures can occur, and their management may compromise the accuracy of the computer data. In any case, knowledge of axial and flexion-extension corrections, expressed as an objective but verifiable numerical value, is fundamental to achieving an optimal procedure. Computer-assisted medial unicompartmental knee arthroplasty. Using the same skin incision, extended over the knee, arthrotomy, meniscectomy, and compartment preparation are performed.

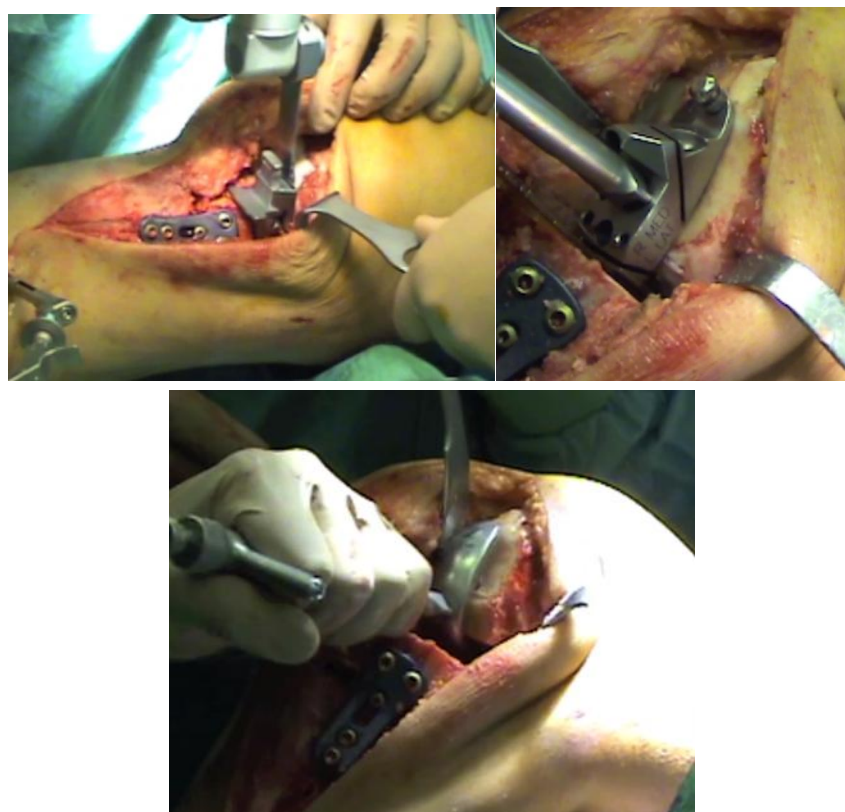
The tibial cutting guide, supported by a metal frame and fitted with a navigation sensor, is positioned. The amount of bone to be removed is determined by a mathematical formula: the minimum thickness of the prosthesis minus the residual arthritic deformity. The guide's orientation is set with a frontal angle close to 0°.

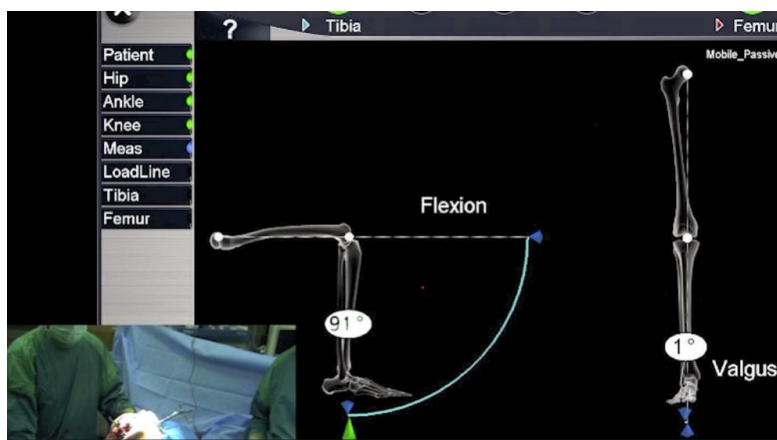
In the lateral plane, the slope is usually the same, although it may be increased if a few degrees of occasional overcorrection (valgus in flexion) need to be recovered after the navigated osteotomy.





The procedure traditionally continues with the distal femoral bone cut and the insertion of spacers to assess flexion and extension gaps—which determine the mechanical axis—all performed using navigation. Next come the femoral chamfer cuts and tibial preparation, using dedicated guides. Finally, trial components are inserted, and the gaps and axis are checked throughout the range of motion.





Cementation of the components and final assessment.

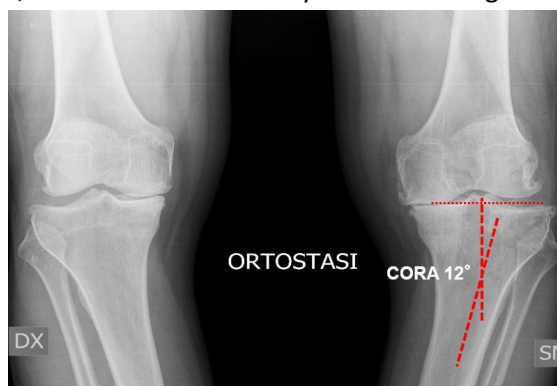


Our Experience

From 2008 to 2014, we operated on seven patients, one of whom underwent bilateral surgery one year apart.

No failure

Bilateral Knee medial arthritis, left knee first and one year later the right knee.



(To mention this one patient who subjected to bilateral surgery, what time elapse after primary surgery as well to clarify the reason why this kind of failure of primary procedure, is it failure or just as natural

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history of original disease ?) We recorded no mechanical or septic failures.

Advantages and Literature Review

There are no published studies in the literature on computer-assisted combined osteotomy and medial unicompartmental arthroplasty.

Regarding isolated osteotomy, the most significant advantage of computer-assisted techniques is improved accuracy and precision in mechanical axis alignment—a benefit consistently demonstrated in both clinical and cadaveric studies (1,2,3,4,5,6,7,8). Computer-assisted HTO provides real-time intraoperative data on coronal, sagittal, and transverse axes, helping to compensate for limitations in preoperative radiographic planning. It can improve postoperative outcomes while reducing radiation exposure (9,10).

Furthermore, navigation systems can serve as educational tools in both laboratory and operating room settings, helping less experienced surgeons shorten their learning curve (11). Computer-assisted navigation can also facilitate more complex procedures, such as combined femoral and tibial osteotomies (double-level osteotomy) performed in conjunction with medial or lateral unicompartmental knee arthroplasty.

Computer-assisted navigation can also serve as a valuable research tool by facilitating precise measurements of overall limb alignment that would normally require additional radiographic procedures, while providing data previously limited to cadaveric studies, such as real-time knee kinematics [1].

Disadvantages and Literature Review

Current barriers to widespread use of computer-assisted navigation include higher costs, increased operating time, and procedural inconveniences [11].

Economic analyses indicate that these high-cost technologies may be cost-effective only in hospitals with high implant volumes [12]. Clinical studies have shown that computer-assisted navigation improves the precision of less experienced surgeons and shortens their learning curve, enabling them to achieve results similar to those of more experienced surgeons [12]. However, the cost of most navigation systems may limit their use in hospitals with low prosthetic implant volumes. Another disadvantage is the additional time required for the registration phase, which ranges from approximately 10 to 30 minutes [6,9]. There are also technique-related drawbacks, such as a long learning curve, registration errors, and mechanical or software malfunctions [13].

Gebhard et al. [3] reported on the influence of surgeon experience and perioperative complications in computer-assisted open-wedge HTO. Seven intraoperative complications were reported among 59 patients (12%); all were related to the navigation system. Issues included loosening of the sensor mount (three knees), system failure (two knees), loss of orientation following reference pin replacement (one knee), and unavailability of the navigation instrument (one knee).

The procedures may appear cumbersome compared with conventional techniques, and several

procedures may be required before the surgeon becomes comfortable with the navigation system [3]. Un'altra complicazione, descritta in letteratura, è l'aumentata incidenza di infezioni profonde dovuta al tempo operatorio più lungo. L'uso dei supporti metallici comporta ferite nel femore distale e nella tibia, il che di conseguenza aumenta il rischio di infezione, frattura e ossificazione eterotopica [14,15]. ENGLISH text?

Another complication described in the literature is the increased incidence of deep infections resulting from longer operative times. The use of metal supports involves creating wounds in the distal femur and tibia, which consequently increases the risk of infection, fracture, and heterotopic ossification [14,15].

Why no mention about healing of steotomy problem which might hinder the post-op physiotherapy program.

Authors' considerations

The main criticism regarding the use of navigation systems in HTO to determine active load-bearing alignment is that data are acquired in the supine position. Therefore, future research should clarify the relationship between alignment assessed in the supine position in the operating room and load-bearing alignment during daily activities.

Previous studies have provided compelling evidence that computer-assisted navigation yields more accurate and precise postoperative alignment [2,11]. However, no long-term clinical study or randomized controlled trial has provided evidence that navigation systems improve clinical outcomes or reduce the rate of conversion to total knee arthroplasty. Doubts remain as to whether reducing alignment outliers would justify the initial cost of the navigation system. Future studies should adhere to high methodological standards, including prospective randomization with control of preoperative, intraoperative, and postoperative variables, and incorporate long-term follow-up to analyze survival rates. Biomechanical studies will also be required to define ideal alignment in the coronal, sagittal, and axial planes. To generate robust evidence regarding the advantages and disadvantages of navigation, it is essential to assess patient kinematic patterns both before and after surgery.

Navigation-system software is expected to evolve toward greater practicality and accuracy. Navigation equipment should ultimately become less expensive, simpler, and easier to use.

Conclusions

The advantage of computer-assisted navigation lies in the improved accuracy and precision of postoperative coronal and sagittal alignment. However, further studies are needed to determine whether improved alignment and axis correction influence long-term outcomes and survival rates sufficiently to offset the increased surgical time, costs, and potential complications associated with computer-assisted surgery. The orthopedic surgeon's experience, adaptability, and knowledge of the technology involved in computer-assisted HTO are crucial for surgical success. Only an orthopedic surgeon with a clear understanding of the technology, objectives, surgical technique, potential pitfalls, advantages, and limitations of the navigation system can appropriately apply the navigated technique in the occasional cases of HTO combined with unicompartmental arthroplasty.

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