ORIGINAL ARTICLE

Employing Conventional Instrumentation with Computer-aided Surgery in Total Knee Replacement – Making it Simple

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ABSTRACT

Our computer-aided surgery (CAS) in total knee replacement (TKR) results in less outliers and accurate implant positioning. The described technique deals with single parameters at a time. Conventional jigs with CAS make an easier transition for surgeons employing standard instrumentation. Conventional jigs also allow greater control and stability compared to free-hand technique and serve as a system check if CAS fails. CAS allows immediate feedback of saw blade resection and application of cutting guides. By employing the hybrid technique, surgeons can perform navigated TKR by following a simple workflow pathway, cutting down the operating time, and saving on inventory costs.

Keywords: Computer-aided surgery, Conventional jigs, Hybrid technique, Total knee replacement

INTRODUCTION

Total knee replacement (TKR) is a highly successful surgery. Despite the best of efforts, hyper-specialist surgeons only achieve optimal implant placement about 70% of the time[1]. The long-term outcome of TKR depends mainly on the restoration of mechanical axis and accurate implant positioning. The introduction of computer-aided surgery (CAS) or navigated TKR, in orthopaedic surgery results in less outliers and accurate implant positioning. CAS has an added advantage in cases with complex intra- and extra-articular deformities, retained hardware where conventional guidance system is impossible, distorted anatomical landmarks[2], or in cases with osteomyelitis with obliterated canals. CAS allows realtime assessment of the mechanical axis, gaps balancing[3–6], and better appreciation of the knee kinematics.

There are different types of knee navigation systems available. The Stryker system with version 3.1 software (Stryker Navigation, Kalamazoo, Michigan, USA) is simple and has an open platform allowing the surgeon to use it for any type of knee implant. One of the major concerns of CAS is prolonged operative time. This may increase the risk of major complications[1,7].

The technique reported in this paper stresses on the use of conventional instrumentation, which is familiar to surgeons, nurses, and assistants. The conventional jigs are superior in providing anchoring stability for the cutting guides. It is challenging to maintain the cutting guide accurately along the three planes in space during surgery amidst blood and soft tissues; this is in addition to pinning the cutting guide down without moving the jigs. The technique described below also allows the surgeon to concentrate on one vector at a time thus aiding those who may have difficulty in hand-eye coordination. Resting the cutting guides on flat surfaces also provides stability to the cutting guides. Marrying this with CAS will help the end user get real time alignment intra-operatively while reducing the operative time, inventory, and cost of purchasing new jigs.

METHODOLOGY

The navigation system used was the Stryker system with software version 3.1 for TKR. This is an open system, with a very simple and logical algorithm that allows the surgeon to personalise his approach to the knee.

SURGICAL TECHNIQUE

We employed CAS in all our TKRs. The trackers are placed percutaneously using the double pin ortholock system. This reduces the risk of stress fractures by using smaller shanz pins placed further apart[8–10]. All varus knees are approached using the midline medial parapatellar quadriceps split approach. After performing the medial release, meniscectomy and excision of the anterior cruciate ligament, the Whiteside line, and epi-condylar axis are marked to help with surface registration and minimise problems of inconsistent femoral rotation registration. The standard Stryker Version 3.1 surface registration is performed and registered.

The required pre-cut anatomical points are registered and pre-operative kinematics are obtained. This will guide the ligamentous balancing and determine the amount of bone resection. We use minimally invasive surgical techniques for most of our patients. As such, the tibia is cut first and patelloplasty done to provide space for subsequent femoral resections.

Tibial Cut

The three parameters to the tibia cut are the tibia slope, mechanical axis alignment, and amount of resection. Using conventional techniques, the tibia extra-medullary (EM) cutting guide is anchored at the proximal third of the tibia tubercle and intermalleolar clamps distally. The stylus (cutting guide to determine a 2 mm cut from the diseased side or 10 mm from the better side) is used to determine the amount of tibia resection. The lateral pin is secured halfway at the level of 0 mm ([A] in Fig. 1). The plane verifying guide (PVG) is now placed in the cutting slot. The navigation system will allow the determination of the varus/valgus cut and the posterior slope. After adjusting the cutting block to the desired cuts in the coronal and sagittal plane, the second pin is driven into the medial hole ([B] in Fig. 1). The lateral pin which was previously inserted halfway is then inserted fully to secure the cutting block. The cutting block can be adjusted vertically to determine the amount of

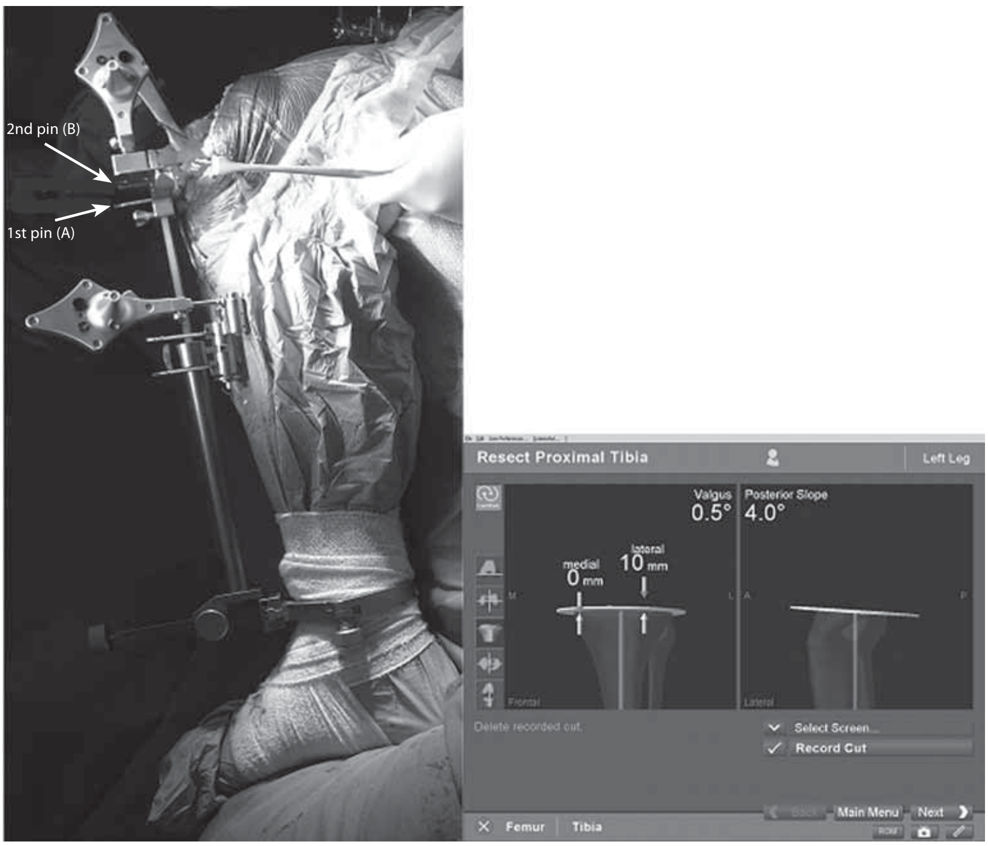

Fig. 1. Planning of tibia resection using the extra-medullary tibia jig with plane verifying guide.

bone resection required using the PVG as a guide with feedback from the screen shots. After the tibia cuts have been made, the PVG can be used to verify whether the desired resection has been made.

The tibia EM jig is certainly more stable, with the anchoring EM rod and intermalleolar clamps compared with the free-hand technique in most navigation systems. The EM guide is a very accurate and consistent tool by itself with CAS, allowing fine tuning and rechecking of the alignment[11]. The lateral pin is placed first, i.e. over the lateral 1/3 of the tibia tubercle as the bone is less dense and flat. This prevents the pin from being forced out of alignment by the denser cortical bone of the medial condyle of the tibia. The pin is placed halfway in order to have a firm anchor yet allowing for fine tuning. The user can choose to use a cutting block with built-in slope or not. The surgeon uses the free floating technique to match the tibia plate rotation placement with the femur component during the trial implant stage.

Femoral Cuts

Parameters for the femoral resection include the mechanical axis, amount of distal cut, flexion, and rotation of the femoral component. The amount of flexion of the femur cut is first determined using the navigation as shown in Fig. 2. The first pin is placed halfway on the lateral femoral condyle ([A] in Fig. 2) to lock in the component in flexion. The block is then rotated to the desired degree with aid of the CAS and the second pin is now placed in the medial femoral condyle ([B] in Fig. 2). Both pins can now be firmly secured in. With this technique, a single vector of the femoral component is dealt with at any time and the block is semi-secured with a pin inserted halfway. A fully navigated system is more difficult technically as adjusting one component in isolation is more difficult compared to this technique. The rotation of the femoral component can be confirmed by referencing the Whiteside line, the epicondylar axis, or the posterior condyles (conventional guide). By employing the AR anterior cutting guide, the platform is then raised to the

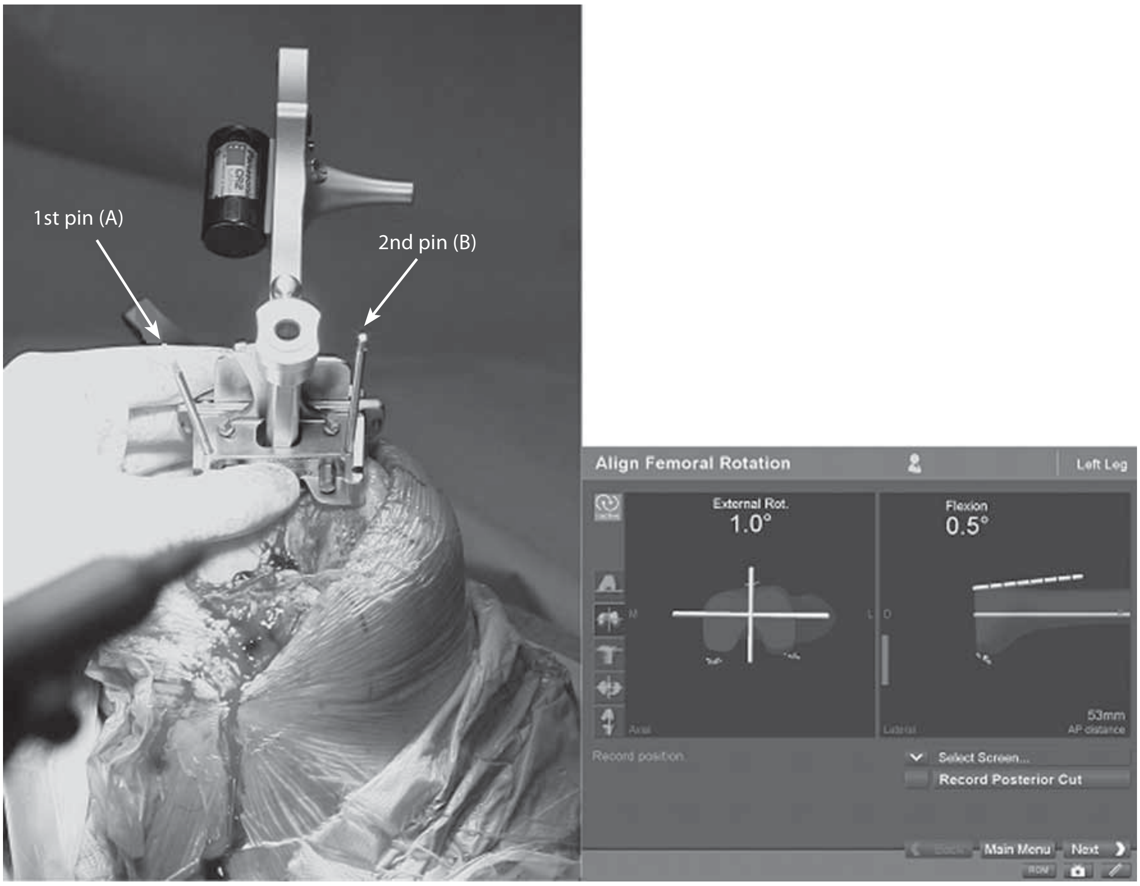

Fig. 2. Positioning of the anterior femoral cutting block with rotation determined by navigation.

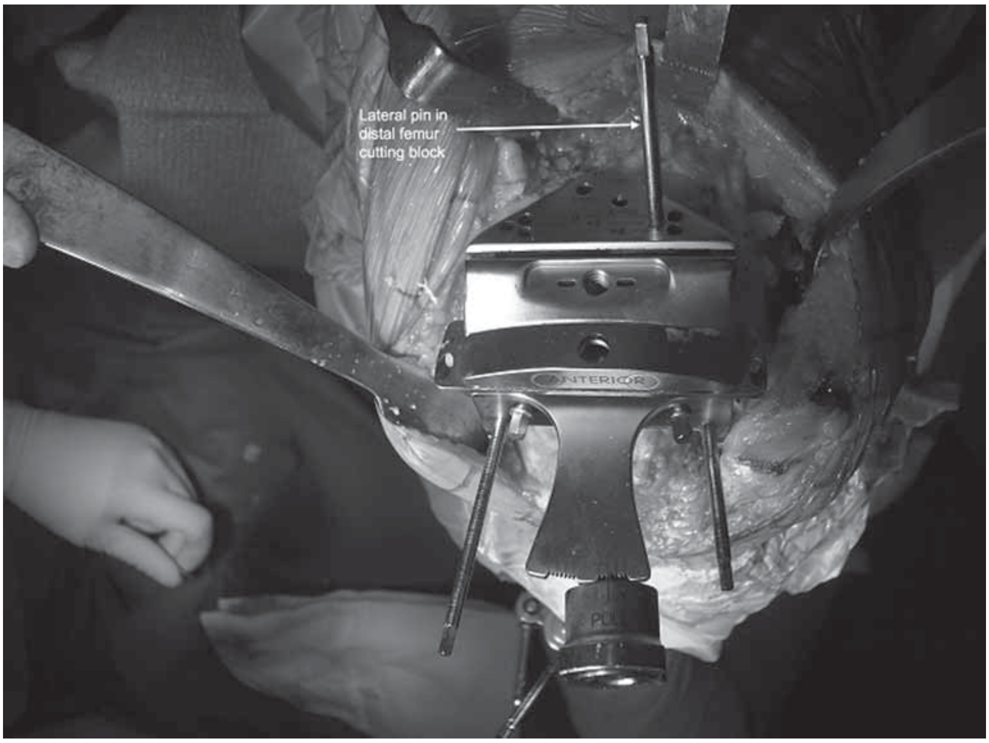

Fig. 3. The anterior cutting block with intra-medullary rod onto which the distal cutting block is added.

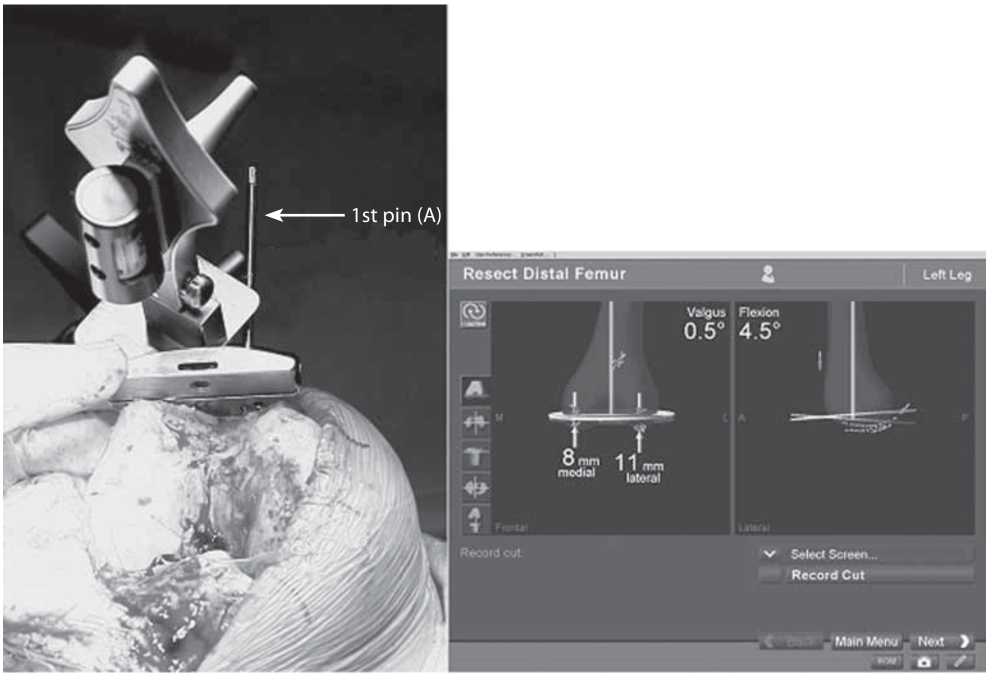

Fig. 4. The distal femoral cutting block after the intra-medullary guide has been removed.

desired anterior chamfer cut of the femur. The PVG and the angel wing are then used to ensure a satisfactory anterior femoral cut without notching. The anterior cut is made and rechecked with the PVG.

The distal femur is cut next. The flat anterior surface (a result of the first cut) makes it easier to control the cutting guide. The distal cutting guide is placed on the intra-medullary (IM) femur guide. This helps to eliminate the need to control the amount of distal cut and a single pin is driven halfway into the lateral hole of the guide in the +2 mm hole (Fig. 3). The IM femur guide is removed and the distal cutting guide is aligned using CAS (Fig. 4 and [A] in Fig. 5) to the desired valgus cut and the block is then secured with the second pin in the medial hole ([B] in Fig. 5). The IM femur guide adds additional stability to the cutting block system and makes it easier to make fine adjustments to the cut. The amount of distal cuts is then checked. Occasionally, there may be a need to shift the guide proximally or distally. As such, it would be advisable to pin the "+2 mm" hole at the beginning.

By now, the distal femur cut, rotation, and anterior chamfer have been completed. The femur size is measured and the four-in-one chamfer cutting block is placed and used as in a routine conventional TKR. For a posterior stabilised knee, the box cut is performed as in a normal conventional technique. Unfortunately this CAS system does not guide us in the medial/lateral placement of the box cut, thus affecting the final component placement. We prefer to lateralise the component without overhanging solely for better patella tracking[12].

The femoral osteotomy is the most challenging due to the multiple vectors at play. The concept of concentrating on one vector at a time and adjusting cutting guides on flat surfaces and using cutting guides like the AR cutting stylus or 8/10 mm distal cutting block is less challenging for those with difficulty in hand-eye coordination.

Trial of Components

The trial components are now placed *in situ*. The trial alignment ensures that the knee is aligned to the mechanical axis. Fine adjustments can be made through ligamentous releases or osteophytectomy. The knee is ranged taking note of the patella tracking and tibia base plate rotation. The base plate rotation is recorded using CAS and the final tibial keel cuts are made. The exact external rotation of the tibial component is less critical when using a rotating platform. The implants are cemented as in the normal conventional technique. CAS is superior in providing feedback on the ligamentous balancing and component rotational matching[13].

Proposed Classification of Navigation Systems

We propose a modification of the classification first described by Cinquin and Picard, which classified systems into active, semi-active, and passive systems[14]. Active systems are systems where robots can perform some surgical tasks such as drilling and milling independently. Semi-active robotic systems increase the surgeon's control of the operation by allowing the surgeon to operate in a safe zone. Passive systems allow the surgeon full control of

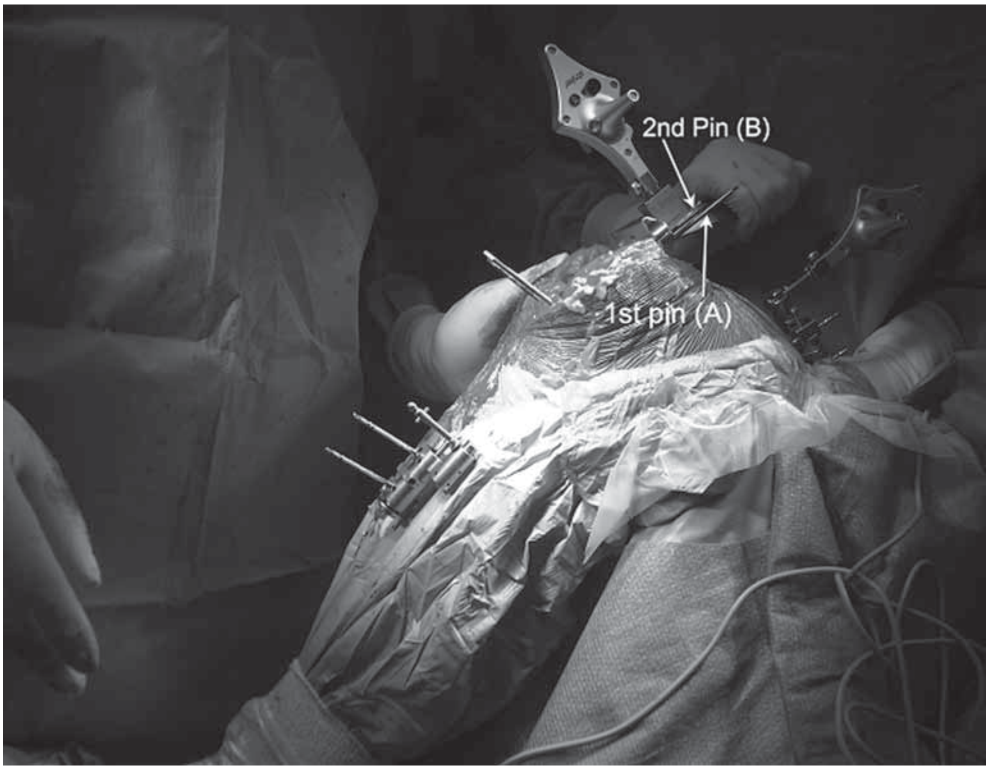

Fig. 5. Final position of the distal femoral cutting guide with both the pins in place.

the operation. Passive systems can be divided into image-based or surface-registration-based system. An image-based system involves pre-operative imaging, which can be a computed tomography scan or magnetic resonance imaging, with patient specific instrumentation to match the patient's bony anatomy to make desired bone cuts. Surface registration based systems involve registering the bony landmarks intra-operatively using active (usually light emitting diodes) or passive (using tracker balls or markers) trackers or even electromagnetic (EM) technology. EM technology does not need a line of sight as compared to active/passive trackers. However, EM signals can be affected by surrounding ferrous materials.

Our modification divides the passive system into either image-based patient specific instrumentation or intra-operative surface registration based system. This modification will allow for an easier understanding of different systems available so that comparisons can be made between various systems employing similar technologies. It will also help the surgeon understand and appreciate advantages and limitations of different systems. Table 1 shows our proposed classification with modifications underlined.

CONCLUSION

TKR using CAS techniques can be simple. Dealing with a single parameter at a time is technically easier to achieve, especially for beginners. Conventional jigs with CAS also make it easier for the surgeon to switch between navigation and conventional techniques. This allows the surgeon to have more control as compared to using the free-hand technique and also serves as a check if the CAS fails due to system registration errors or loose probes. Residents will be able to compare and contrast interactively between conventional guide techniques and CAS. CAS allows immediate feedback on their saw blade control and application of cutting guides. We hope we can make it easier for surgeons to perform navigated TKR by employing

Table 1. Classification for computer-aided surgery for total knee replacement (Mash and Chin).

Active systems (Robotic) • Robodoc
Semi-active systems (Robotic arm assisted with navigation) • Robotic arms e.g. PUMA • Mini robotic cutting guides with passive trackers Praxim • Mini robotic arm with passive trackers e.g. Makoplasty

Passive systems
• Image based patient specific instrumentaion/ implants
  ○ magnetic resonance imaging-based
  ○ computed tomography-based
• Surface registration (intra-operative)
  ○ active trackers
    ▪ battery powered - e.g. Stryker system
    ▪ wire/cables e.g. Orthopilot
  ○ passive trackers
    ▪ ball spheres e.g. BrainLab, Orthopilot
    ▪ Orthosoft Navitrack
  ○ trackers which do not require line of sight
    ▪ electromagnetic technology
    ▪ bluetooth technology

this hybrid technique described above, which follows a simple workflow pathway, cuts down the operating time, and saves on inventory costs. We also propose an easily understandable and applicable classification of CAS for TKR.

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