Introduction

While the goal of total knee arthroplasty is the restoration of a quality of life by eliminating pain and improving function, it is clear to most knee-replacement surgeons that this goal is not always achieved. Sharkey et al. [1] reviewed 203 consecutive total knee revisions and found that greater than one-half of these revisions were performed within 2 years of index arthroplasty and one third of these were due to instability, mal-alignment or mal-position (usually avoidable problems). Similarly, Fehring et al. [2] reported on 440 patients who underwent revision total knee arthroplasty and found that 63% of patients required revision surgery within 5 years of their index arthroplasty, 27% were due to instability. It is quite evident that current instrumentation systems leave room for improvement. Stulberg [3] used navigation to assess the position of knee components implanted with traditional methods and found that only 4 of 20 knees were implanted within 3° of ideal component position in all planes. Conversely, occasionally a surgeon performs an operation in which the patient has a near perfect result. Unfortunately, using traditional techniques there is no tangible information or objective data that allows us to reproduce that result in the next patient.

Navigation systems provide us with the potential to quantify data, to have dynamic intra-operative feedback and to obtain more reproducible results. Errors in component positioning and limb alignment that continue to occur using the conventional mechanical alignment jigs can be minimized through navigation instrumentation [4–8]. Another important attribute of navigation system is its ability to provide instant feedback regarding in vivo kinematics of the joint. Alignment and ligament stability can be assessed with the trials in place to ensure proper function. Coronal deformity, alignment, rotation, and translation can be measured for any specified degree of flexion. This characteristic of the navigation system provides the unique opportunity to assess in vivo kinematics of the knee during surgery and implement beneficial changes such as refinements in soft-tissue tensioning, rotational adjustment of components, or alterations in component selection. Phillips and Krackow [9] reported on thirty patients undergoing total knee replacement with a computer-assisted surgical system and found that range of motion, alignment and knee scores were equal to or better than patients undergoing standard total knee replacement. Surgeons can now take the “subjective feel” of standard knee arthroplasty and translate it into more “objective data” provided by the navigation system. This creates the potential for more consistent reproducibility of the surgeon's clinical result.

Surgical Technique

The following technique is for the Stryker Knee Navigation System using the Stryker Orthopedics Scorpio Total Knee System. During surgical approach the scrub technician/nurse should be setting up the specialized navigation instruments. During the system setup dialog, the trackers are initialized and the Smart Tools are registered. While a medial parapatellar exposure is used to enter the knee joint, it is done so with the knee in 90° of flexion so as to minimize the total length of the incision. During the procedure, the patella is not everted so as to minimize the soft-tissue trauma to the quadriceps mechanism. Bicortical 4.0 mm anchoring pins, which consist of a self-tapping screw design with anti-rotation and tracker attachment features built-into ensure the trackers remain rigidly fixed throughout the surgical procedure,
are affixed to proximal tibia and the distal femur. The trackers are then attached to the anchoring pins.

**Registration**

Registration of the navigation system includes determining the centers of the femoral head, knee and ankle joints as well as surface mapping of particular bony landmarks of the knee. This procedure allows the navigation system to determine the mechanical axis of the extremity. The determination of the mechanical axis involves direct measurement of specific landmarks except for determining the center of the femoral head, which is a calculated value. No imaging studies are necessary when performing this procedure, again minimizing the overall invasiveness of the procedure to the patient.

The first step of registration involves calculating the center of femoral head. The rotational center of the femoral head is determined using motion analysis. As the leg is gently rotated, the femoral LED location yields a set of data points that lie on a sphere with the femoral head theoretically at its center. Feedback is provided to the surgeon through visualization of the digitized data points on the computer screen, seen as 3D tiny spheres (Fig. 14.1).

The distal femur is registered next. The navigation system will guide the surgeon through each component of the femoral registration to pick the medial and lateral epicondyles, center of knee, and anteroposterior axis of knee (Fig. 14.2). After key landmarks are identified, the surgeon will digitize the medial and lateral condyles. This is done by tracing the surface of the bone with the pointer for both of the distal articulating portions of the condyles. It is important to identify the most distal portion of the condyles as this will be the basis for the resection levels.

The proximal tibia is registered next. Using the navigation screen as a guide, the center of tibia and anteroposterior axis of the tibia (i.e. rotation) are selected. The medial (Fig. 14.3) and lateral tibial plateaus are then digitized in similar fashion to the femoral condyles. Here it is important to identify the most proximal portions of the articulating surface of the proximal tibia. The last step of the registration process involves the ankle. The medial and lateral malleoli as well as the center of the ankle are identified with the pointer.

**Fig. 14.1.** Navigation system screen shot of digitized points during center of femoral head calculation  
**Fig. 14.2.** a Surgeon-positioned navigation system pointer indicating the anteroposterior axis of femur. b Corresponding navigation-system screen shot
Initial Kinematics

After the registration is performed, the initial kinematics of the pathological knee is performed. Data such as maximal extension, flexion and alignment is recorded in table form by the navigation unit. Soft-tissue releases are performed based on this initial pre-operative data. Initial kinematic curves, which give an indication of the initial balance of the knee, are then assessed. This process involves bringing the knee through a range of motion while exerting sequentially a varus and then a valgus stress. It is important to note that the noise (i.e. widening of band) in the curves indicates either bone deficiency or soft-tissue laxity. The absolute values of the curves reflect the distance of the digitized femoral epicondyles to the transverse axis of the tibial plateau.

Overall, the initial registration and kinematic measurements take less than 5 min of time.

Navigated Tibial Preparation

It is the authors' preference to approach the tibia first. However, the Stryker software is flexible and allows surgeon preference. Using the navigation-system computer screen, the surgeon is able to micro-manipulate the depth of tibial resection, amount of posterior slope, and varus/valgus orientation of the cut (Fig. 14.4). The initial tibial cut is checked with a navigated flat-plate guide and, if needed, modifications to the cut may be made. The rota-
tional alignment of the tibial component (as determined by the initial registration of the anteroposterior axis during the tibial registration) is then set, using navigated instruments, thus completing the preparation of the tibia.

**Navigated Femoral Preparation**

Navigated femoral preparation occurs in two steps. First, the sagittal and coronal alignment of the distal cut as well as the depth of distal cut is performed, and then the rotational alignment is set. During the first step (Fig. 14.5), we generally cut 10 mm of distal femur (11–12 mm with a large flexion contracture) and prefer to orient the varus/valgus position to 0° and the flexion/extension position to 0° with respect to the mechanical axis of the limb. After the initial distal femoral preparation is performed, the surgeon should check the cut using the navigated flat plate, with modifications being made as necessary.

Navigated anterior referencing instrumentation is used to set the rotational alignment of the femoral component (a posterior referencing software package is available if preferred). The navigation system gives the option to set rotation in reference to the pre-registered Whiteside's line or epicondylar axis. We prefer to set rotation to 0° in reference to the epicondylar axis which in most cases corresponds to Whiteside's line within a few degrees (Fig. 14.6).

![Fig. 14.5](image1.png) a Navigated distal femoral resection guide. b Corresponding navigation-system screen shot. The surgeon has the ability to set the amount of femoral resection, flexion/extension and varus-valgus orientation. It should be noted that there is not an intra-medullary extension to this guide.

![Fig. 14.6](image2.png) a Navigated anterior skim-cut instrumentation. b Corresponding navigation-system screen shot. Note rotation is indicated in reference to the epicondylar axis as well as Whiteside's line.
The remainder of the femoral preparation does not involve the use of navigation. Trial components are now placed and patellar resurfacing, if desired, may be performed at this time.

**Final Kinematics**

At this point, data, such as maximal extension, flexion and alignment, is re-assessed by the navigation unit (Fig. 14.7). With the trials in place, new kinematic curves are created, which give an indication of the soft-tissue balance of the replaced knee. The goal during the soft-tissue balancing stage is to achieve relatively horizontal, smooth parallel curves for both the medial and lateral compartments throughout the entire range of motion. In general, the wider the curves the more instability is present. If the curves show a poorly balanced knee, soft-tissue- or bony corrections may be made at this point and a new kinematic curve may be generated to evaluate if the changes helped to balance the knee (Fig. 14.8). Based on the information obtained from the navigation software, the surgeon can implement changes in selection of the knee components with beneficial effects in knee kinematics and function.

**Navigation and Minimal Invasiveness**

At several levels, computer-assisted total knee replacement as described above is already minimally invasive in nature. The Stryker system requires no special radiographic techniques, thereby minimizing radiation exposure for the patient. Exposing the knee in flexion minimizes the total length of the incision. Performing the surgery without evertting the patella minimizes the trauma to the quadriceps mechanism. Strict standardization of surgical technique and sequence of steps has lead to an imperceptible change in the total operative...
time (and tourniquet time). Review of the most recently performed knee replacements (20 knees), the total surgical time averaged 57 min (range 46 to 63 min). However there is an initial learning-curve period. In the senior authors’ experience, the average operative time was 61 min (range 51–84 min) based on the tourniquet times (skin incision to application of dressings) for the first 30 surgeries. However, when critically analyzed, the operative time for the first five knees performed with the navigation system averaged 70 min and the remaining 32 knees averaged 60 min. This result was statistically different (p=0.02).

An important minimally invasive benefit of navigation is the lower chance of emboli related to the use of dedicated extra-medullary instrumentation. During “classic” total knee replacement with intra-medullary instrumentation, numerous studies have documented the release of fat-embolic particles to the lungs and brains of patients. Using trans-esophageal ultrasound, multiple studies have shown the persistence of echogenic material when intra-medullary alignment was used [10, 11]. These studies have attributed the intra-medullary rod as the cause of the fat embolus [12–15]. These particles may lead to pulmonary compromise such as fat embolism or adult respiratory distress syndrome and neurologic changes related to fat in the cerebral circulation [16]. Morawa et al. [17] compared patients undergoing total knee arthroplasty with intra-medullary and extra-medullary instrumentation and found that the risk of embolic events was substantially reduced with the extra-medullary instrumentation. True to the minimally invasive terminology, navigation eliminates a serious risk factor – the use of intra-medullary alignment rods – and thus may decrease the risks of embolic events to the patient. This may result in less pulmonary effects as well and less postoperative mental status changes.

Navigation also has the potential to expand the realm of minimally invasive arthroplasty. Questions about visualization and component orientation can now be overcome by using navigation. In smaller incision surgery, specific landmarks and orientations may be hard to visualize; however, navigation has the ability to solve these problems. Newer and smaller instrumentation is currently being used in preliminary clinical evaluations to couple the fascinating worlds of computer-assisted surgery and minimally invasive surgery.

References