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Total knee arthroplasty using computer-assisted navigation in patients with deformities of the femur and tibia: A report of 5 cases

Klein GR, Austin MS, Smith EB, Hozack WJ.

ABSTRACT

Anatomical aberrations of the femur and tibia secondary to trauma, congenital defects, and prior surgery present challenges for the reconstructive knee surgeon because of an altered mechanical axis and distorted anatomic landmarks. Five patients with arthritis of the knee and extra-articular femoral and/or tibial deformity, retained hardware or intramedullary implants underwent total knee arthroplasty using a computer navigation system. The navigation system obviated the need for an intramedullary guide and the normal mechanical axis of the patients was restored. Extensive dissection for hardware removal or osteotomy was not necessary in these patients. In these 5 cases, a navigation system proved to be an effective tool for restoration of limb alignment in the presence of significant extra-articular deformities and/or intramedullary hardware. It thus provides an alternative approach to the traditional intramedullary instrumentation for treating these patients in an effective manner.

Keywords: Navigation, Computer assisted surgery, total knee arthroplasty, extrarticular deformity, retained hardware

Introduction

Patients with distorted anatomy of the femur and tibia (secondary to trauma, congenital defects, prior surgery, etc.) present significant challenges for the reconstructive knee surgeon. Femoral and/or tibial deformities may make implantation of total knee components difficult because of an altered mechanical axis and distorted anatomic landmarks. Achieving optimal femoral-tibial alignment can be made more difficult due to retained hardware. Staged surgical procedures, including osteotomy or hardware removal, can be used to restore alignment. However, the benefits of these multiple procedures must be weighed against the increased risk of complications. In addition, the screw holes that remain after hardware removal are stress-risers, possibly increasing the risk of fracture. In addition, long stemmed hip implants makes instrumentation of the femoral canal for total knee arthroplasty difficult. Traditional intramedullary based knee instrumentation systems may be suboptimal in the setting of angular deformities, intramedullary sclerosis, long stemmed hip implants, or hardware within the femoral or tibial canals.

Computer-assisted navigation total knee arthroplasty does not require intramedullary instrumentation and is particularly appealing for these situations. We present five cases in which ideal mechanical and prosthetic alignment was achieved with an image-free computer-assisted navigation system.

Methods

Five patients (three men and two women) with an average age of sixty years (range fifty to seventy-five years) with arthritis of the knee and extra-articular femoral and/or tibial deformity(s), retained hardware, or intramedullary implants underwent total

knee arthroplasty using the Stryker Navigation™ system. The patients were an average height of sixty-seven inches (range sixty to seventy-two inches) and were an average weight of 175 pounds (range 130-220 pounds). On the femoral side, retained hardware or implants from previous surgeries ranged 2 to 10 cm from the intercondylar notch. One patient who did not have retained hardware had significant residual deformities of both his femur and tibia secondary to longstanding malunions.

The navigation system utilized is a PC-based extra-medullary guidance system in which pre-operative studies are not required. All of the patients presented with pain and a history of multiple surgical procedures including open reduction and internal fixation, osteotomy, or hip replacement with a long-stemmed component. Four of the five patients had metal plates or long-stemmed hip implants which would have made the use of intramedullary instrumentation impractical.

A standard medial parapatellar arthrotomy was used in all patients. The navigation system was used to assist the surgeon in making accurate bony cuts, orient the implants, and assess the soft tissue balancing. During surgery, an infrared intraoperative device is used to send data pertaining to knee anatomy to the computer. The information obtained includes the center of the hip, knee, and ankle; slope of the knee; femoral rotation; and contour of the distal femur and proximal tibia. These data points are used by the computer system to calculate the mechanical axis of the lower extremity. The surgeon makes the bone cuts based on the mechanical axis. Using navigation, adjustments may be made to approximate the best possible alignment of the prosthesis in relation to the mechanical axis of the limb. A posterior cruciate-substituting Scorpio® knee (Stryker Orthopedics, Mahwah, NJ) was then trialed. An intra-operative assessment

of range of motion, anterior drawer, and ligament tension was performed. Adjustments were made using this data to improve alignment, ligament tension, and range of motion if necessary. Once a satisfactory result was recorded (as evaluated by the navigation system and clinically by the surgeon) the final components were cemented in place. A standard postoperative protocol was instituted in all patients, including immediate full weight bearing with crutches or a walker and continuous passive motion (CPM).

Standing full-length radiographs were obtained postoperatively on all patients. The mechanical axis of the limb was analyzed in these patients as described by Moreland[1]. The center of the femoral head was determined using Mose circles and a line was drawn connecting this point to the center of the knee (the mechanical axis of the femur). A line was then drawn connecting the center of the knee with the center of the ankle (the mechanical axis of the tibia). The angle between these two lines was measured and recorded as relative varus, relative valgus or neutral (0 degrees). Orthoview™ Orthopaedic Digital Imaging (Meridian Technique Ltd, Basingstoke, Hampshire UK) and Adobe Photoshop 4.0LE (Adobe Systems Incorporated, San Jose, CA) software was utilized to draw the lines and measure the mechanical axis and knee alignment for each radiograph.

Case Reports

Illustrative Case 1--Intramedullary Hardware

A fifty-eight year-old active homemaker presented with activity related knee pain and instability of the left knee. Thirty years prior to presentation, she had undergone open reduction and internal fixation of ipsilateral femur and tibial shaft fractures. These injuries were sustained in a motor vehicle accident. Radiographs (Figure 1 A-B)

confirmed the varus deformity of 12° and showed tri-compartmental arthritis of the knee with plates on both the femur and the tibia. The distal femoral hardware was 5.5 cm from the intercondylar notch. Both fractures were healed. There was a tibial shaft malunion that measured 16 degrees of flexion and 8 degrees of varus.

In this circumstance it was not necessary to remove the hardware that traditionally would interfere with intramedullary instrumentation during total knee arthroplasty, since the navigation system does not rely on intramedullary instrumentation. An additional incision was not needed, because hardware removal was not necessary..

The tibial malunion may have presented a challenge with classic instruments, however, the system calculated the overall limb alignment, and accommodated both the deformity and the hardware.

Postoperatively, the patient reported excellent functional recovery with no pain in the operated knee. Radiographic follow-up (Figure 1 C-D) demonstrated good positioning and fixation of the components with a valgus knee alignment of 6°. The mechanical axis was 0°

Illustrative Case 2-Extrarticular Deformity

A sixty-two year-old train conductor presented with left knee pain resulting in declining function. Thirty-four years ago he was involved in a motor vehicle accident, which resulted in fracture of left femur and tibia. Radiographs (Figure 2 A-B) revealed significant degenerative joint disease with a valgus deformity of 16°. There was a

malunion of both the femur and tibia. The distal femur healed with 1cm lateral displacement and the proximal tibia malunion measured 12° recurvatum and 6° valgus.

In this patient classic instrumentation would have been difficult because of the deformity of the femur and tibia. It would have been difficult to instrument the femoral canal secondarily to the fracture callus and deformity. The tibial deformity would have proven troublesome for either extramedullary or intramedullary instrumentation. Postoperatively, the patient reported excellent functional recovery with no pain in the operated knee. Radiographic follow-up (Figure 2 C-D) demonstrated good positioning and fixation of the components with a valgus knee alignment of 4 °. The mechanical axis was 1° of varus.

Results

Using this navigation system, the mechanical axis (Table 1) was restored to within 1 degree of the desired mechanical axis in four of five patients In the fifth patient, the mechanical axis was restored to within two degrees of desired alignment. A primary, posterior-stabilized prosthesis was utilized in all of the cases.

Preoperative coronal alignment averaged 2.7° varus (range of 13.6° varus to 16.2° valgus). Postoperative coronal alignment averaged 5.8° valgus (range of 3.7° to 10.1° valgus). The average overall mechanical axis of the five patients was 0.6°of varus (range 1.8° varus to 0.4° valgus). All knees were well balanced. Perioperatively, there were no complications related to the procedure.

Discussion

The usefulness of a computer-assisted navigation system in achieving accurate bony cuts and reestablishing the mechanical axis during routine total knee arthroplasty has been well established [2-6]. It enables the surgeon to make accurate bony cuts, orient the implants correctly, and provide a good qualitative intra-operative assessment of ligament balance and kinematics. Computer-assisted navigation systems are an excellent choice for total knee arthroplasty in the presence of femoral and/or tibial bone deformity or when femoral or tibial hardware make traditional intramedullary instrumentation impractical. In the cases presented, instrumentation of the medullary canal of the femur would have been extremely difficult, if not impossible, due to either the presence of hardware, significant deformity of the canal, or sclerosis in the canal which precluded use of a standard rod.

Extra-articular deformity creates an altered mechanical axis, thus making component positioning and alignment difficult. Restoration of the mechanical axis in these patients may be more reliably achieved with the use of computer-assisted techniques. The navigation system uses the center of the femoral head, the center of the knee and the center of the ankle to calculate the patient's mechanical axis. By using these landmarks, the navigation system helps the surgeon overcome the complicated task of figuring out the mechanical axis in a patient with distorted anatomy. Using the mechanical axis as determined by the navigation system, not the intramedullary canal, the surgeon can implant the prosthesis in a position consistent with the true mechanical axis for that patient.

Navigation for Deformity

The limits of intra-articular correction of an extra-articular deformity have been elucidated by Wang and Wang [7]. They concluded that an extra-articular coronal femoral varus deformity of less than twenty degrees and a tibial coronal deformity of thirty degrees or less may be corrected without the need for extra-articular osteotomy. . It would be reasonable to assume that any computer-aided system would be limited by the same criteria. The authors are not aware of any articles regarding sagittal plane deformities

As far as we are aware, this is the first report in the literature on the use of a navigation system to aid the surgeon in total knee arthroplasty for extra-articular deformity or retained hardware. Navigation aids the surgeon with accurate positioning of the implants. In addition, the navigation system avoids the need to remove some or all of the hardware in a patient with previous surgery. Plate removal and total knee arthroplasty is usually performed as a staged procedure. Simultaneous arthroplasty and removal of hardware usually requires either two incisions or the use of a skin flap to expose both the hardware and the knee. These approaches may compromise the viability of the skin, especially in a patient with poor circulation [8]. In addition, multiple surgical procedures may leave the post-traumatic patient prone to arthrofibrosis [9,10]. In addition, the screw holes from hardware may prove to be stress-risers, limiting postoperative weight-bearing or requiring additional support such as stems, strut allograft, or intramedullary rods during the procedure [11-13]. In our series, we noted that these obstacles could be circumvented with the use of a navigation system. The system also assesses mechanical alignment and soft-tissue balancing.

We acknowledge the evident shortcomings with any case series. The weakest portion of such a report is the inability to demonstrate a statistically improved radiological and clinical performance of a PC-based navigation system over traditional intramedullary instrumentation or tensor systems. However, due to the relative rarity of these situations, these five cases were collected from a single-surgeon experience of more than 500 primary and revision knee replacements over the last two years.

Despite these limitations, this case series shows that the navigation system is a very effective and useful tool for accurate intra-operative restoration of alignment in the face of significant deformity and/or intramedullary hardware. Based on the information obtained from the navigation software, the surgeon can implement changes in surgical technique, component sizing and positioning with potential favorable effects on eventual knee function. It also supplies objective information regarding positioning of the components and ligament balance that may help improve the results of total knee replacement in the future. In addition, the intramedullary canal is not violated which may reduce the chance of fat emboli [14-17]. It thus provides an alternative approach to the traditional intramedullary instrumentation for treating these patients in an effective manner.

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