How Does Electromagnetic Navigation Stack Up Against Infrared Navigation in Minimally Invasive Total Knee Arthroplasties?

David R. Lionberger, MD,* Jennifer Weise, BS,*
David M. Ho, MS,* and John L. Haddad, MD†

Abstract: Forty-six primary total knee arthroplasties were performed using either an electromagnetic (EM) or infrared (IR) navigation system. In this IRB-approved study, patients were evaluated clinically and for accuracy using spiral computed tomographic imaging and 36-in standing radiographs. Although EM navigation was subject to metal interference, it was not as drastic as line-of-sight interference with IR navigation. Mechanical alignment was ideal in 92.9% of EM and 90.0% of IR cases based on spiral computed tomographic imaging and 100% of EM and 95% of IR cases based on x-ray. Individual measurements of component varus/valgus and sagittal measurements showed EM to be equivalent to IR, with both systems producing subdegree accuracy in 95% of the readings. **Key words:** total knee arthroplasty, electromagnetic navigation, mechanical alignment, minimally invasive, surgery, computer-assisted orthopedic surgery.

Electromagnetic (EM) navigation is a recently developed variant of traditionally used imageless infrared (IR) navigation systems that uses a magnetic field generator to attain positional awareness rather than an optical system that requires line of sight. An operating room is subject to a variety of EM and ferric interference. As such, skepticism is rightfully justified in the EM navigation system, which relies on magnetic field generation for guidance in the operating room. The goal of this study was to ascertain the accuracy in such a system.

Because accuracy is the primary end point of this study, it was felt that spiral computed tomographic (CT) imaging, which has long been regarded as the gold standard of anatomical morphology, would provide the most precise measurements and would be subject to fewer errors than traditional 36-in films [1-5]. Each measurement in the CT evaluation was taken segmentally (ie, femur then tibia) rather than compiled as mean of hip-knee-ankle centers as with standing 36-in anteroposterior AP films, allowing for specific computer-assisted surgery (CAS) individual measurements rather than a summation of mechanical alignment. Although most articles use x-ray instead of spiral CT because of its lower cost, one way or the other, this study used both sets of imaging to be more stringent in measuring postoperative alignment from both navigation systems.

The purpose of this study was to compare a minimally invasive surgical (MIS) application of EM-CAS with an existing and widely-used IR-CAS

*From the *Southwest Orthopedic Group, LLP, Houston, Texas; and †Department of Radiology, The Methodist Hospital, Weill Medical College of Cornell University, Houston, Texas.*
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Reprint requests: David R. Lionberger, MD, Southwest Orthopedic Group, LLP, Suite 1016, 6560 Fannin, Houston, TX 77030.

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system on 2 sets of parameters. The primary end point was accuracy. To our knowledge, no head-to-head comparisons of one system with another have been published, but only studies comparing traditional instruments to navigation [6-9].

Materials and Methods

This investigation was a prospective, randomized trial approved by the institutional review board and performed by the principal investigator at a single hospital. Forty-six patients were enrolled in this investigation comparing MIS total knee arthroplasty (TKA) using either an EM-CAS or IR-CAS navigation system. Of the 46 patients, 7 were bilateral. Inclusion criteria were patients preselected for knee arthroplasties to correct osteoarthritis or rheumatoid arthritic conditions of the knee. Patients were excluded if there was any previous infection or preexisting hardware. Patients with a body mass index (BMI) of more than 35 kg/m^2 were also excluded because of recent literature citing up to 6 times the infection rate in such patients. The EM study population consisted of 27 knees, 9 males and 18 females (1 female with bilateral TKAs using EM), with a mean age of 71.3 years and a mean BMI of 27.5 kg/m^2. The IR study population consisted of 19 knees, 9 males and 10 females (1 female with bilateral TKAs using IR), with a mean age of 65.2 and a mean BMI of 29 kg/m^2. Among these 47 knees were 3 males and 3 females who had bilateral knee arthroplasties, which were randomized into IR navigation on 1 knee and EM on the other.

All patients received the same preoperative instructions and were enrolled in the same clinical pathway. This included preoperative COX-2 inhibitors and hydrocodone with epidural anesthesia along with intraoperative capsular injections of morphine and Marcaine. The implant used in all patients was a Zimmer Nex-Gen high-flexed femoral component with a posterior cruciate-sacrificing, stemmed tibial tray (Warsaw, Ind). A Medtronic StealthStation IR navigational system or a Medtronic AxiEM for EM navigational guidance platform was used (Louisville, Colo).

Because both of these cohorts involved minimally invasive surgery exposures, identification of epicondyles could not be accurately done. Although functional axis and posterior condyles could be used during landmarking, Whiteside's line appeared to be the easiest to attain in the limited-exposure situation. Numerous authors have debated the accuracy of epicondyles vs Whiteside's line, especially in limited exposures [3,4], yet this similarly compromises view of the posterior joint for reference. Because Whiteside's line has been validated in use, we chose this in both cohorts to evaluate its legitimacy.

Intraoperative data collection included measurements of the distal femur before and after resection, rotation (varus and valgus), flexion and extension, and size prediction with anterior notch resection accuracy. Tibial measurements included slope and angulation along with final mechanical alignment. Gap distance measurements of femoral to tibial displacement measurements taken at 0°, 45°, 60°, and 90° flexion for soft tissue balance and final postoperative extension and flexion kinematics were recorded. These measurements were not analyzed because algorithms to measure distance separation under dynamic stress with CT imaging have not been developed. All cuts were rechecked both mechanically and electronically and recorded in archives before proceeding to the next step. However, if the mechanical and navigation system measurements did not agree, the navigation system measurement was recorded as the true value in computer files so as to validate accuracy of the system in question.

Electromagnetic Procedure

Through an MIS incision for TKA, the dynamic reference frames (DRFs) were attached to the medial flare of the anterior distal femur at the adductor magnus insertion and on the proximal medial tibia, anterior and superior to the pes insertion (Fig. 1). The EM trackers were rigidly affixed unicortically by cortical screws. Acquisition of landmarks or waypoints was similar in both groups except the posterior femoral condyle

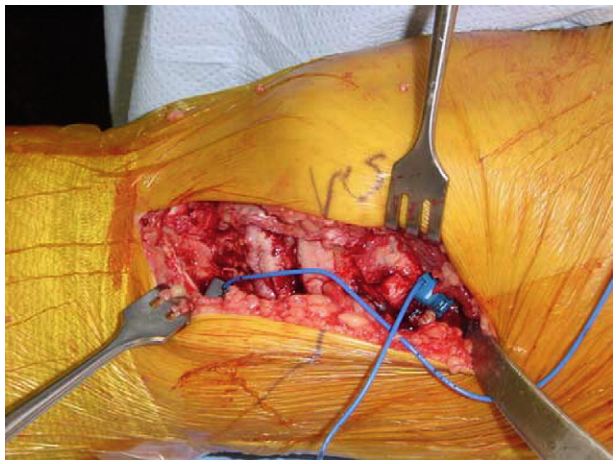

Fig. 1. Tibial tracker (left) and femoral tracker (right) in place.