ACS 2026 Surgeons and Engineers: A Dialogue on Surgical Simulation

P-B-04

Research Abstracts

A Novel IMU-Based System for Tracking Surgical Device Orientations During Simulated Bicortical Screw Fixation: Foundation for More Effective Training of Foundational Orthopaedic Surgical Skills

Seung-Ho Bae, BS; Louis Grodman, MD, Meng; Colin Brady, MEng; Daniel S. Yang, MD; Mark Hake, MD; and Adam Abraham, PhD

University of Michigan Medical School, Ann Arbor, MI; University of California, San Diego Jacobs School of Engineering, San Diego, CA; University of Michigan, Ann Arbor, MI; Trinity Health IHA Medical Group - Ann Arbor Campus, Ypsilanti, MI

Introduction: Bicortical screw fixation is a fundamental component of orthopedic surgery resident training, and it is imperative that the same trajectory of surgical instruments and implants is applied in screw insertion to ensure a stable fixation construct. Simulation-based training can help trainees improve their sensorimotor skills, and no simulator exists that gives objective real-time feedback on trajectory of the drill, depth gauge, and screwdriver, which all must be in exact orientation for successful screw insertion in fracture fixation.. We present a novel motion-tracking system (Fig. 1) and its internal validation designed to measure the relative orientation of these surgical devices.

Methods: The Adafruit BNO085 9-DOF Inertial Measurement Device (IMU) and Adafruit Metro M4 microcontroller were interfaced with the Arduino/Python integrated development environment. An internal-validation rig was designed to measure standard 15-degree intervals from 0° to 90°. For each primary axis (yaw, pitch, roll), ten randomized sequences of 20 angular steps were generated. Angular changes during isolated motion of the IMU along each primary axis were recorded using the IMU's quaternion system and displayed as Euler angles. Movement in the remaining two secondary axes was measured during isolated movement along the primary axis.

Results: Root mean squared error and mean absolute error for yaw, pitch, and roll were (1.78°, 0.83°), (1.61°, 0.66°), (0.45°, 0.34°) respectively. Mean angle estimates for angular change closely approximated known values, with coefficients of variation less than 10%. 95% confidence intervals for secondary axis measurements showed deviations of no more than 0.5°, indicating minimal off-axis changes with isolated movement around the primary axis.

Conclusions: Our results suggest consistent IMU behavior across trials, low relative error, and acceptable motion-tracking. Future external-validation studies are planned to assess the system's sensitivity in differentiating alignment accuracy of surgical instruments across years of surgical experience in a simulated bicortical screw fixation exercise.

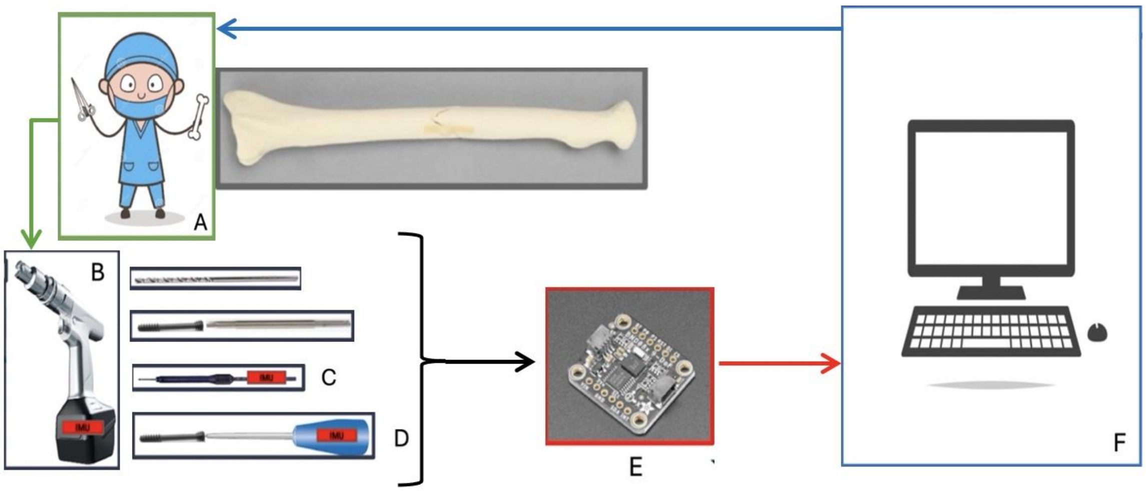

Figure 1. Conceptual diagram showing the sensor system for our proposed external validation experiment and future training use. The operator (A) is practicing bicortical screw fixation on a SawBones fracture model. The operator will use surgical instruments (B–Drill , C–Depth Gauge, D-Screw) affixed with the IMU (E) parallel to the instruments' operative axes. Proper technique emphasizes collinear trajectory of these three instruments. To assess instrument collinearity between surgical steps, the IMU will track the operative axis of the instrument being used at each step of the procedure. This data will be sent to a computer (F) running software to analyze, manipulate, and report this data. For training purposes, this data can be used by the operator to make appropriate adjustments and develop their "feel".