A NOVEL AUGMENTED REALITY SIMULATOR FOR TEACHING WIRE NAVIGATION SKILLS IN TREATING INTERTROCHANTERIC HIP FRACTURES

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INTRODUCTION

Standard surgical repair of an intertrochanteric fracture, the most common hip fracture, requires accurate placement of a wire across the fracture using static fluoroscopic images. Wire navigation is fundamental to a number of orthopedic procedures. Directing and advancing the wire in the correct plane relies on both visual-spatial and psychomotor dexterity skills [1]. Underdeveloped skills cause substandard wire positioning increasing fracture fixation failure rates [2].

Few practice methods exist for perfecting wire navigation skills outside the operating room. Completing the task in an artificial hip model, with radiopaque surrogate bone models and a C-arm fluoroscopy unit is the most common practice. Unfortunately, C-arm fluoroscopes are expensive, difficult to schedule, and expose trainees to potentially avoidable radiation. The few virtual orthopaedic simulators in existence use force-feedback devices in an attempt to simulate realistic drilling [3-5].

The augmented reality wire-navigation simulator (Fig. 1) combines real drills, wires, and surrogate bone models with virtually generated, radiation-free
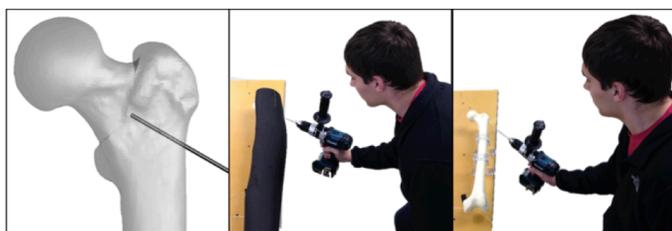

Figure 1: Trainees use virtual fluoroscopy (left) to complete wire navigation with (middle) and without (right) a visually obstructed view of the artificial femur.

fluoroscopic images. Trainees navigate a wire from the lateral femoral cortex, through the femoral neck, in order to end within 5mm of the articular surface within the femoral head. The simulator exercises drilling dexterity, fluoroscopic interpretation, and visual-spatial wire navigation skills.

METHODS

The simulator hardware consists of four major components: a personal computer, an artificial left femur (Sawbones Part No. 1129), a battery-powered portable electric drill, and two Ascension 3D Guidance trakSTAR 6-DOF electromagnetic tracking sensors. One sensor, attached to the bone, tracks the position and orientation of the femur. Simultaneously, the sensor connected to the drill tracks the advancement of the wire into the artificial femur.
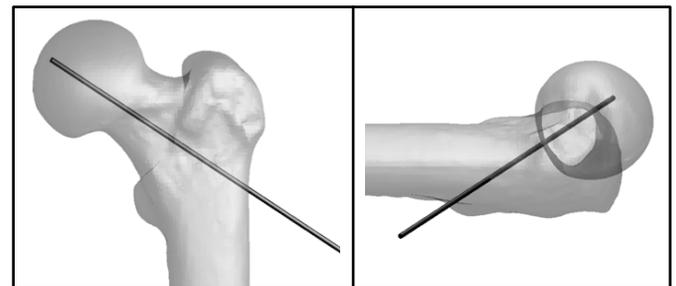

Figure 2: Sample views of virtual fluoroscopy showing AP (left) and lateral (right) views.

The computer generates virtual fluoroscopic images from two standard views used in this procedure: the anteroposterior (AP) and lateral view (Fig. 2). The software produces an AP or lateral view upon the trainee's request. Calibration techniques map the real-world environment to simulated fluoroscopy; ensuring actual movements of the wire correspond to the simulated images. The simulator saves and timestamps each image, while recording a continuous record of the wire positions throughout the exercise. Trainees review the accuracy of their entry and tip locations by rotating a 3D model of the wire and bone, augmented with an overlay of the optimal entry and ending positions (Fig. 3).
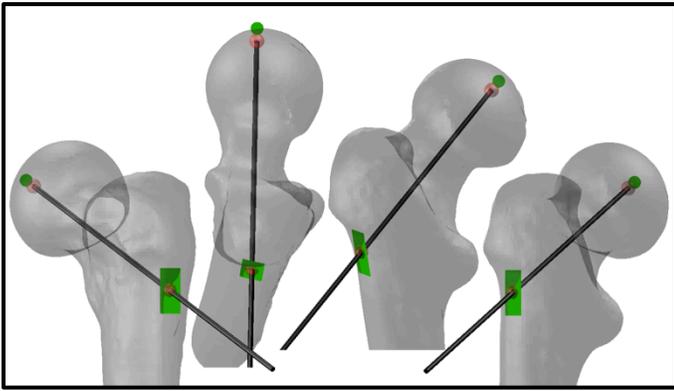
Figure 3: Geometric representation demonstrating the 3D model feedback to the trainees.

Six first-year orthopaedic residents, one third-year orthopaedic resident, and one expert surgeon completed three consecutive trials on the wire-navigation simulator. Before and after, the six first-year residents also completed a wire-guided training task with a C-arm and radiopaque surrogate bone models. Participants completed a survey pertaining to their individual experience.

The experiment tested three hypotheses:

1. Construct validity: The simulator can discriminate between levels of expertise.
2. Face validity: Subjects will report the simulator is realistic.
3. Trainees will report practicing on the simulator would improve their intraoperative skills.

RESULTS AND DISCUSSION

The team summed the standardized tip-apex distance (i.e. wire tip accuracy), number of fluoroscopic images, and accuracy of the entry point in the lateral cortex to create a composite final score. The entry location of one of the 24 trials was not in the lateral femoral cortex resulting in omission from the overall composite calculation.

The expert orthopaedic surgeon earned three out of the four top composite scores, exceeding the participant pool by an average of 1.00 standard deviations on each subcategory. Two out of the three trials for the third-year orthopaedic resident landed in the top five of all trials. The third trial ranked eighth out of the 23 trials. The worst resident trial averaged 1.06 standard deviations below the mean on each of the

three scoring metrics. This preliminary data shows the simulator discriminates experienced surgeons from inexperienced residents, thus establishing grounds for construct validity.

The questionnaire contained three questions involving the realism of the simulator. Scores for realism ranged from one to five, with five being the most realistic. Questions concerned the realism of the virtual fluoroscopy, the realism of drilling of the artificial bone, and the overall simulator realism. Overall, subjects rated the simulator realistic (mean = 3.83), with the virtual fluoroscopy being slightly more realistic (mean = 4.17) than the drilling of artificial bone (mean = 3.67). Furthermore, 100% of participants agreed simulator practice would improve intraoperative skills for placing a wire in the femoral head during hip fracture surgery.

CONCLUSIONS

The composite scores of the experts and novices support the simulator has construct validity; though establishing the generality of this finding requires more participants. The experiment also supports the face validity of the simulator, with the same limitation on generality. These initial positive results forecast a worthy future and merits more trials to further the validation of the simulator.

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