Simulator and Distal Targeting Device for In-Vitro Training and Experimentation in Computer-Aided Closed Medullary Nailing

L. Joskowicz[1], C. Milgrom[2], A. Simkin[3], S. Kimchi[4], Z. Yaniv[1], O. Sadowsky[1]

[1] School of Computer Science, The Hebrew University of Jerusalem, Israel.
[2] Dept. of Orthopaedic Surgery, Hadassah Univ. Hospital, Jerusalem, Israel.
[3] Dept. Experimental Surgery, Hadassah Univ. Hospital, Jerusalem, Israel.
[4] Precision Machining Workshop, The Hebrew University of Jerusalem, Israel
E-mail: josko@cs.huji.ac.il, WWW site: http://www.cs.huji.ac.il/~josko

Reducing the surgeon cumulative radiation exposure and improving the positioning accuracy are key issues in computer-assisted orthopaedic surgery. We have developed FRACAS, a computer-integrated system for closed long bone fracture reduction. The system replaces uncorrelated static fluoroscopic images with a virtual reality display of 3D bone models created from preoperative CT and tracked intraoperatively in real time. Two important issues for system acceptance are distal locking and training. Because the nail bends when insterted, distal locking requires automatic recognition of nail holes and an adjustable drill guide to ensure that the holes are drilled in the right position. Training devices help familiarize surgeons with computer-generated real-time multiple view displays, with the requirements of optical tracking, and to study system ergonomy.

We have developed two devices and software for in-vitro experimentation and training for computer-aided closed medullary nailing: a fracture reduction simulator and an adjustable drill guide for distal locking. The simulator consists of two adjustable bone fragment holders mounted on a radio-lucent basis, whose positions are followed by optical tracking. Each bone fragment holder is a spring-loaded lockable spherical joint to which distal and proximal bone fragments are attached. The distal fragment holder also translates, simulating the action of the muscles on the bones. The device allows surgeons to practice bone alignment and distal nailing based on computer-generated images. It also serves as a platform to evaluate the ergonomy and accuracy of the system.

The adjustable drill guide is a radio-lucent, 5dof device for assisting the surgeon in drilling the holes for distal locking screws. The guide attaches to the nail's head like the proximal targeting fixture. The drill is tracked in real time, and its position with respect to the nail holes is determined by image processing and registration software. The axes of the nail holes are automatically identified in the fluoroscopic images, and registered to the bone model. The surgeon can then adjust the position and orientation of the drill guide until its axis and the axis of the nail are identical. The guide, whose position and orientation is tracked in real time, can also be used independently as a targeting device.

Both devices have been integrated to the current FRACAS system. Preliminary experiments show improvement in the acceptance of the computer-aided system and allow for accuracy evaluation of image-based methods.