COMPUTER-ASSISTED FREEHAND NAVIGATION FOR TKR

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Introduction:

Current surgical technique for TKR surgery:

- Numerous jigs and fixtures and a complex sequence of steps often compromise accuracy of bone cuts [1].
- Bone cutting using jigs and fixtures can produce error due to a non-central intramedullary rod, jig placement, movement of the jig during cutting, and bending of the saw blade [2].
- Navigation techniques have improved consistency and facilitated ligament balancing, but jigs and fixtures are still required [3].

In this study we proposed ***freehand cutting***:

- This bone cutting technique utilizes direct visualization without requiring jigs or fixtures.
- By eliminating jigs it may be possible to achieve accurate cuts with reduced time and complexity.
- Freehand cutting may result in less invasive surgery.

Materials and Methods:

Our experiment simulated resection of the proximal tibia, represented by a block of solid rigid polyurethane foam (0.32 g/cm^3).

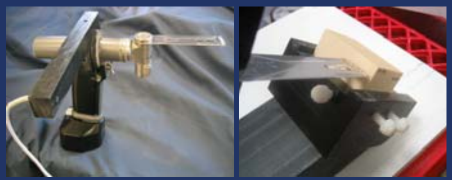

Figure 1. The MiniBIRD sensor was mounted away from the saw (left), and a plastic vice was used (right) to minimize interference.

Blocks were cut freehand (Figure 1) while the saw was guided with the MiniBIRD (Ascension Technology), an electromagnetic tracking system. A computer displayed images of the surgeon's saw in motion, the block, and the target cutting plane (Figure2).

The visualization software was written in C++ using Microsoft Visual C++ on a Windows XP platform with OpenGL graphics API. It was run on a PC with a Pentium 4 Intel Processor, 256 MB RAM at 2.59 GHz.

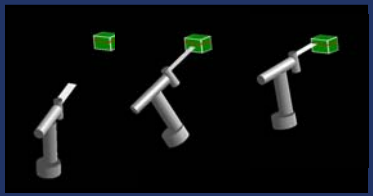

Figure 2. The saw image moves in real time on the computer screen as the surgeon cuts the block.

To measure the accuracy of the cuts, a Microscribe G2X (Immersion Corp.) input points from the cut surface to the computer (Figure 3). A metal plate was placed on the cut surface and digitized to simulate the placement of a tibial component. Rhinoceros 3.0 was used for the data analysis.

Figure 3. Digitizing with a Microscribe G2X.

Work in Progress:

Shell Morphing: Accurate patient-specific 3D bone models will be created without a preoperative CT scan (Figure 4).

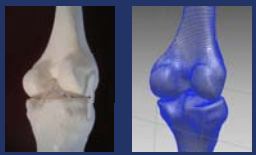

Figure 4. Sawbone (left) and polygon mesh of the sawbone (right).

Surgical Simulation: A test set-up will be assembled to closely replicate the conditions of surgery. Cadaver knee replacement surgery will be performed here using the freehand technique.

Results:

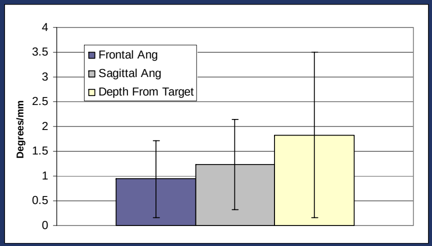

Figure 5. Block cutting tests (n=39) showed that surgeons cutting freehand with the MiniBIRD were able to cut blocks on average within 2 mm and 1.5 degrees of the target thickness and angle.

Discussion:

- Freehand cutting with computer guidance appeared to produce sufficiently accurate results for knee replacement, at least comparable with the accuracy produced using jigs and fixtures. Average errors were less than 1.5° in alignments (Figure 5).

- Preliminary tests with the system we have developed suggest that these results can improve further with a more accurate guidance system.

- The tolerance associated with the MiniBIRD, 1.8 mm RMS, may have affected results. Any metal or electrical devices in the area may have interfered with the electromagnetic signal, although measures were taken to reduce this interference as much as possible.

- Freehand cutting using an oscillating saw is still subject to errors such as blade bending and imprecise control by the surgeon.

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