ACCURACY OF FREEHAND CUTTING IN SIMULATED TOTAL KNEE SURGERY

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Introduction:

Current surgical technique for TKR surgery:

- Numerous jigs and fixtures and a complex sequence of steps often compromise accuracy [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:

- Three different methods were investigated:

WITHOUT COMPUTER GUIDANCE

1. Blocks were cut:
   - Freehand.
   - Freehand with a stationary armrest (Figure 1).
   - Freehand with a slotted jig which was perfectly aligned with the target cutting plane before cutting.

COMPUTER GUIDANCE

2. Electromagnetic navigation: Blocks were cut freehand using a MiniBIRD navigation system (Figure 2). The computer display guided the surgeon's saw along the target cutting plane (Figure 3).

3. Spatial linkage navigation: Blocks were cut freehand using a Microscribe arm as a navigation tool (Figure 4). The same computer display was used (Figure 3).

- All experiments simulated resection of the proximal tibia, represented by a block of solid rigid polyurethane foam (0.32 g/cm^3).
- To measure the accuracy of the cuts, the Microscribe G2X was used to input points from the cut surface to the computer. Rhinoceros 3.0 was used for the analysis.

Figure 1. Freehand cutting of blocks.

Figure 2. Freehand cutting navigated with a MiniBIRD navigation system.

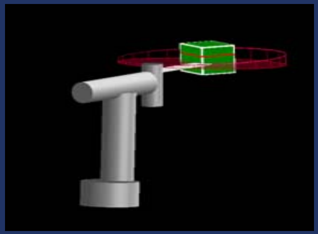

Figure 3. When the aiming ellipse is matched to the target circle, the cutting blade has reached the target cutting plane.

Figure 4. Freehand cutting navigated with a Microscribe G2X arm.

Results:

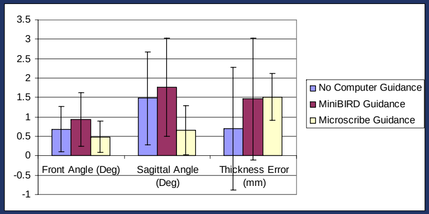

Figure5. Results for all blocks cut freehand.

	FRONT ANGLE (DEG)	SAGITTAL ANGLE (DEG)	THICKNESS ERROR (MM)
FREEHAND	0.68 ± (0.59)	1.5 ± (1.2)	0.70 ± (1.6)
ARMREST	0.66 ± (0.63)	1.2 ± (1.1)	0.69 ± (1.5)
JIG	0.34 ± (0.23)	0.68 ± (0.50)	-0.18 ± (0.17)

Figure 6. Data from non-computer guided tests.

Discussion:

- Freehand cutting with and without computer guidance appeared to produce sufficiently accurate results for knee replacement, at least comparable with the accuracy produced using jigs and fixtures.
- Spatial linkage navigation with computer guidance gave the most accurate results of the three methods, with average alignment errors of only about 0.5° (Figure 5).
- The armrest did not significantly improve accuracy. Cuts made with a jig appeared highly accurate as a result of the perfect jig placement before cutting (Figure 6).
- The tolerance associated with the MiniBIRD, 1.8 mm RMS, may have affected results. Alternately, the Microscribe G2X has a tolerance of only 0.23 mm.
- Freehand cutting using an oscillating saw is still subject to errors of blade bending. To address this we are investigating the possibilities of using rigid burrs and other tools for many of the cuts.
- One drawback of the current system is that the computer screen is not directly in the surgeon's field of view during surgery. An LED display pad to mount on the saw is being developed to address this problem.

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