A 3D ACCURACY ANALYSIS OF COMPUTER-ASSISTED DISTAL RADIUS OSTEOTOMY

INTRODUCTION

Fractures of the distal radius fractures that heal in malalignment frequently require surgical correction. Traditional technique uses fluoroscopic imaging, which is difficult to perform and which can produce substantial radiation exposure to the surgeon. As an alternative, we have developed a computer-assisted planning and guidance system that has three stages:

1. 3D isosurface bone models are constructed from a CT scan of both wrists. A mirror image of the healthy wrist acts as a template.
2. The bone models, and a scale model of a fixation plate, are imported into a graphics-based system that is used to plan the procedure.
3. Intraoperatively, an image-guided system optically tracks the surgical instruments to assist the surgeon in performing the surgery.

METHODS

Computer-assisted preoperative planning is performed in four steps:

a. Align the ulna of the affected and healthy wrists.
b. Cut the deformed radius ("virtual surgery").
c. Align the deformed distal radius with the healthy distal radius.
d. Place the fixation plate on the deformed radius.

The image-guided intraoperative technique has four steps:

1. Register the patient's anatomy to the CT scan and preoperative plan, to find a rigid-body transform between patient coordinates and CT coordinates.
2. Track a surgical drill, relative to patient coordinates, and superimpose a virtual instrument on the CT scans and the plan. The surgeon drills pilot holes in the planned locations by watching the computer-generated images.
3. Resect the radius at the planned position.
4. Screw the fixation plate to the deformed radius.

RESULTS

Laboratory Validation

Translation errors were measured in millimeters, rotation errors in degrees.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Traditional Technique</th>
<th>Computer-Assisted Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>X trans</td>
<td>1.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Y trans</td>
<td>-1.7</td>
<td>-1.0</td>
</tr>
<tr>
<td>Z trans</td>
<td>-0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>X rot</td>
<td>-10.3</td>
<td>-1.1</td>
</tr>
<tr>
<td>Y rot</td>
<td>-0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Z rot</td>
<td>7.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Net rot</td>
<td>14.0</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Translation errors were nearly zero-mean, except for dorsal rotations. There were high standard deviations for all rotations and for X/Y translations. The translation that produced lengthening of the radius was highly repeatable.

Computer-Assisted Technique: All errors were nearly zero-mean. Mean dorsal rotation (about X) was reduced by 90% (p<0.01), and the standard deviation in dorsal rotation was reduced by 50% (p<0.01). Standard deviations in X/Y translations were reduced by 50% (p<0.01). Differences in Z translations and rotations were not significantly different.

Pilot Clinical Study: Both cases produced results that were evaluated as “excellent” (author DP operating). No fluoroscopic images were taken during the procedure. The preoperative plans were nearly identical to the postoperative fluoroscopic images.

DISCUSSION

We report the first published use of computer-assisted wrist surgery. The computer-enhanced planning and guidance system has been shown, in laboratory trials, to significantly improve most of the geometric variables in a corrective wrist surgery. One important part of the system is that it is fixation-based: the plate placement determines the joint alignment in addition to promoting correct bone union. This represents a significant departure from conventional technique, and is facilitated by computer planning and guidance.

The system has been used in two clinical cases, with no complications arising from the system’s use. After a brief learning period, the two surgeons (RP and DP) who participated in the system’s development found it easy to use. Because diagnostic CT scans are routinely taken of wrist malunions, this system does not add extra cost or time to treatment. The guidance system also reduces X-ray exposure to the surgical team during the operative procedure, because fluoroscopy is used only for the final confirmation of the correction.

Limitations of the study include a relatively small sample size and an inability to reduce rotational errors in pronation/supination. We are currently refining the surgical instrumentation and computer programs to improve accuracy in all six of the rotational and translational degrees of freedom.