INTRODUCTION

Navigation systems are becoming increasingly important to the orthopedic community for both surgery and research. While most current systems are optically based, magnetic systems are beginning to appear for clinical use. Users of these systems trust them to be sufficiently accurate, but unfortunately there is little data in current literature where the absolute accuracy of either of these types of systems has been defined or reported.

The aim of this study was to evaluate the accuracy of both optical and magnetic systems by comparing them to a gold standard. It is hoped that these results will lead to a further definition of the range of accuracy of these orthopedic systems.

METHODS

A study was performed to evaluate the accuracy of optical and magnetic navigation systems using the Stinger II Coordinate Measuring Machine (CMM) (Romer CimCore, Wixom, MI) as a gold standard. This particular CMM has a traceable accuracy of ±0.02 mm. A three dimensional phantom was constructed from white nylon 6/6. Five conical divots were machined on the surfaces of the phantom. The CMM was used to paired the relevant geometry of the phantom to determine the baseline measurements. The phantom was then measured using each navigation system to determine the relative accuracies of these systems.

The tip of the surgical navigation pointers were repeatedly placed in each of the divots. For the optically based system the pointer had 4 infrared LEDs oriented parallel to each other. For initial measurements the front of the pointer was oriented so that the LEDs were directed forward, back, left and right until the tool was no longer visible to the system. Data on the pointer orientation were recorded at these extremes. The phantom was then placed at the center of visibility. The system was then rotated clockwise and counter-clockwise about the pointer axis, as well as tilted forward, back, left and right until the tool was no longer visible to the system. Data on the pointer orientation were recorded at these extremes. The phantom was then placed at different locations within the defined measurement volume stated by each company, including the middle, the front, the back, and the right and left sides of the volume. Each of these positions was then measured again at the bottom, middle, and top of the defined volume.

Distances between points were calculated based on the data from each of the three devices. Using the distance calculated from the points measured using the CMM as an absolute, the other two systems were evaluated by calculating the deviation of each system from the CMM. Using a significance value of 0.05, a paired t-test was used to determine the statistical significance of the results.

RESULTS

The mean of the differences between the distances measured with the optical system and the CMM was found to be -0.38mm. The mean of the absolute values of these differences was found to be 1.37mm. These averages included all angles and rotations of the tracking device. The average of the differences between the distances measured with the magnetic system and the CMM was found to be 1.77mm. The average of the absolute value of these differences was found to be 1.96mm. Data for the optimal orientation of the pointer with the optical system (LEDs oriented towards the cameras), as well as for the magnetic system are presented in Table 1. The data in Table 2 is for the optical system only and represents the distances measured when the pointer was rotated to the extremes of visibility: clockwise - Left and counterclockwise - Right. The paired t-test failed to reveal significant differences between the distances found using the optical and magnetic systems relative to the CMM.

DISCUSSION

These results suggest that under ideal conditions, both optical and magnetic navigation systems are relatively precise in terms of absolute accuracy. The magnetic system had an average error of 1.96 mm whereas the optical system had an average error of 1.37 mm. Under less ideal conditions (Table 2) it is apparent that the optical system can be off by 4.08mm or more. In the very center, a rotation of 40 degrees of the optical pointer can produce inaccurate data. Towards the edge of the volume on the Left or Right, a rotation of 20 degrees can produce moderate inaccuracies. These results reinforce the importance of proper setup and operation of optically-based systems. It should be noted that magnetic systems are susceptible to interference from metal objects within the measurement field. No attempts to evaluate this effect were made in this current study; the field was kept free of foreign objects.

While the paired t-test failed to show statistically significant differences between the systems, it is up to the end-user to determine if 1.4 to 4.1 mm accuracy is adequate for a given surgical task. Since these systems are being used increasingly by the orthopedic community, it is essential to have an understanding of the absolute accuracy of the system in use.