Registration and tracking accuracy of the HipSextant™ navigation system

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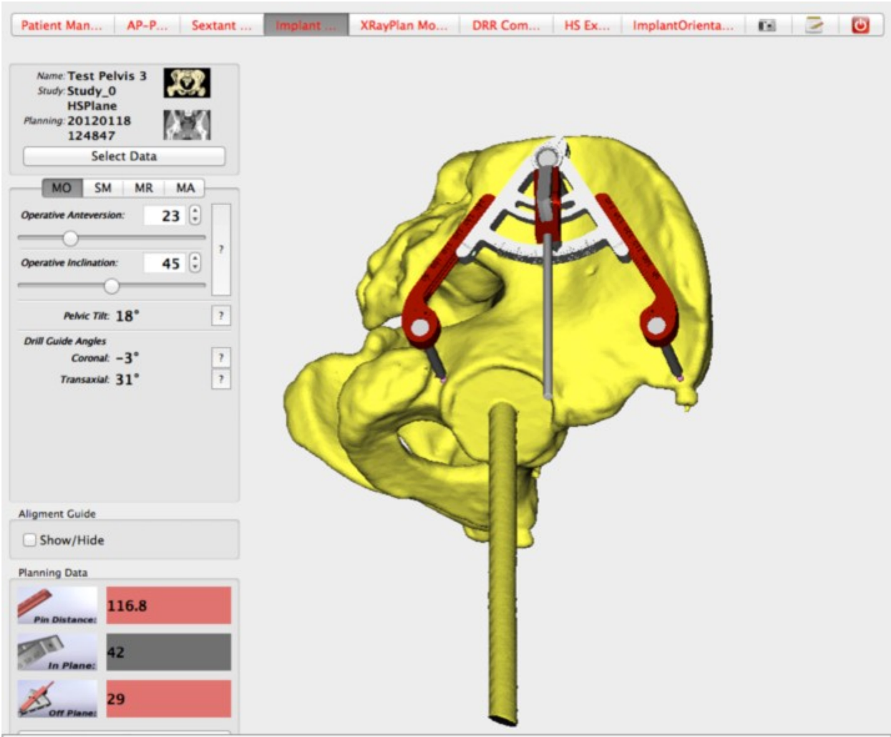
Introduction: Half of all acetabular components placed using conventional methods are malpositioned[1]. Malpositioned cups are associated with instability, wear, impingement, osteolysis, and pseudotumor. While traditional navigation techniques have proven to improve the accuracy of cup position, their use has been restricted to a small percentage of surgeons, possibly due to expense, complexity, the time required to perform. The HipSextant™ Navigation System (Surgical Planning Associates, Boston, MA) is a mechanical navigation system, adjusted on a patient-specific basis, designed to achieve appropriate cup alignment as simply and rapidly as possible. The current study assesses the surgeon's ability to register and track the pelvis and align the cup using the system.

Methods: A bioskills model pelvis (Pacific Research Laboratories, Inc., Vashon, WA) was prepared by placing screws to mark the anterior pelvic plane points and by inserting a long cup alignment pin, simulating a cup insertion handle, into the acetabulum. The cup alignment pin was secured the methyl methacrylate. The bone model was then scanned using CT. The HipSextantTM Navigation System Planning Application was then used to plan the use of the HipSextant for the surgery. This is accomplished by creating a 3D model, designating the AP plane (marked by the screws), and then determining the HipSextant docking points. One of these three points is behind the posterior wall of the acetabulum (the basepoint). The second of these three points is on the lateral aspect of the anterior superior iliac spine. The third point, the landing point, is located on the surface of the ilium and equally distant from the other two points (Figure 1a). The two protractors on the HipSextant planning application were then adjusted to be parallel with the cup alignment pin on the bone model.

A surgeon and assistant were then asked to dock the HipSextant on the bone model and to visually align the direction indicator to be parallel with the cup alignment pin. The two protractor angles on the instrument were recorded. This allowed for calculation of error in operative anteversion and operative inclination between the plan and the actual alignment that was accomplished. Four pairs of surgeon and assistant each performed the docking and alignment procedure 10 times for a total of 40 measurements. The pairs included a joint replacement fellow and a surgical technologist, a second joint replacement fellow and an undergraduate student, a third joint replacement fellow and orthopedic resident, an attending orthopedic surgeon and physician's assistant.

Results: The results of the 40 tests demonstrated a mean error of operative anteversion of -0.06 degrees with a standard deviation of 0.65 degrees and a range of 0 to 2 degrees. The mean error of operative inclination was -0.34 degrees with a standard deviation of 0.65 degrees and a range of 0 to 2 degrees. The ANOVA test demonstrated no statistical difference in the means of the four groups. The results are depicted in a scatter plot in figure 1B.

Conclusion: The current study demonstrates the ability of a pair of surgeons of varying experience to use the patient-specific mechanical navigation system to align the acetabular component with a high degree of accuracy with a very small range of error (maximum 2 degrees in both anteversion and inclination). The method takes advantage of the human eye's ability to discern if objects are in parallel alignment. Such mechanical navigation methods have several advantages over traditional navigation methods. Traditional navigation involves the attachment of reference frames and subsequent registration steps which can be time-consuming and can also result in registration errors. Reference



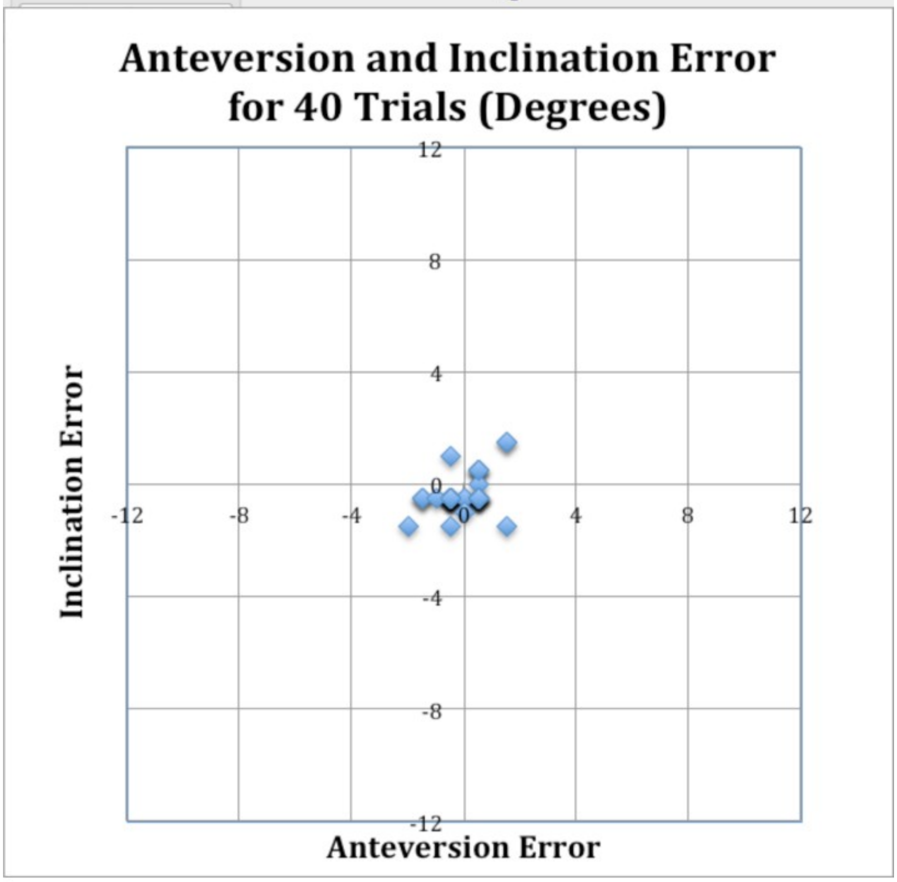


Figure 1A shows the three dimensional reconstruction of a bioskills test model with screws marking the locations of the AP plane points and a direction rod marking the desired orientation of the cup. The surgeon pairs docked the HipSextant according to the docking locations on the plan and then adjusted the direction indicator to be parallel to the direction rod. The angles on the instrument protractors were then used to calculate the error in anteversion and inclination compared to the known orientation of the direction rod. Figure 1B shows a scatter plot of error in Operative Anteversion and Operative Inclination.

frame loosening can go unrecognized and lead to significant errors. Further, tracking technologies can be expensive and have inherent cumulative tracking errors which are typically 1 degree and 1mm for each tracked object in addition to the error of registration. While the mechanical navigation device studied can also be used as a pelvis registration device and combined with any tracking technology, the use of the instrument as a stand-alone, self-contained registration, tracking, and navigation device has advantages not only of simplicity and speed, but also of accuracy.

References

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