Can patient-specific mechanical navigation of cup implantation be performed based only on plain radiographs?

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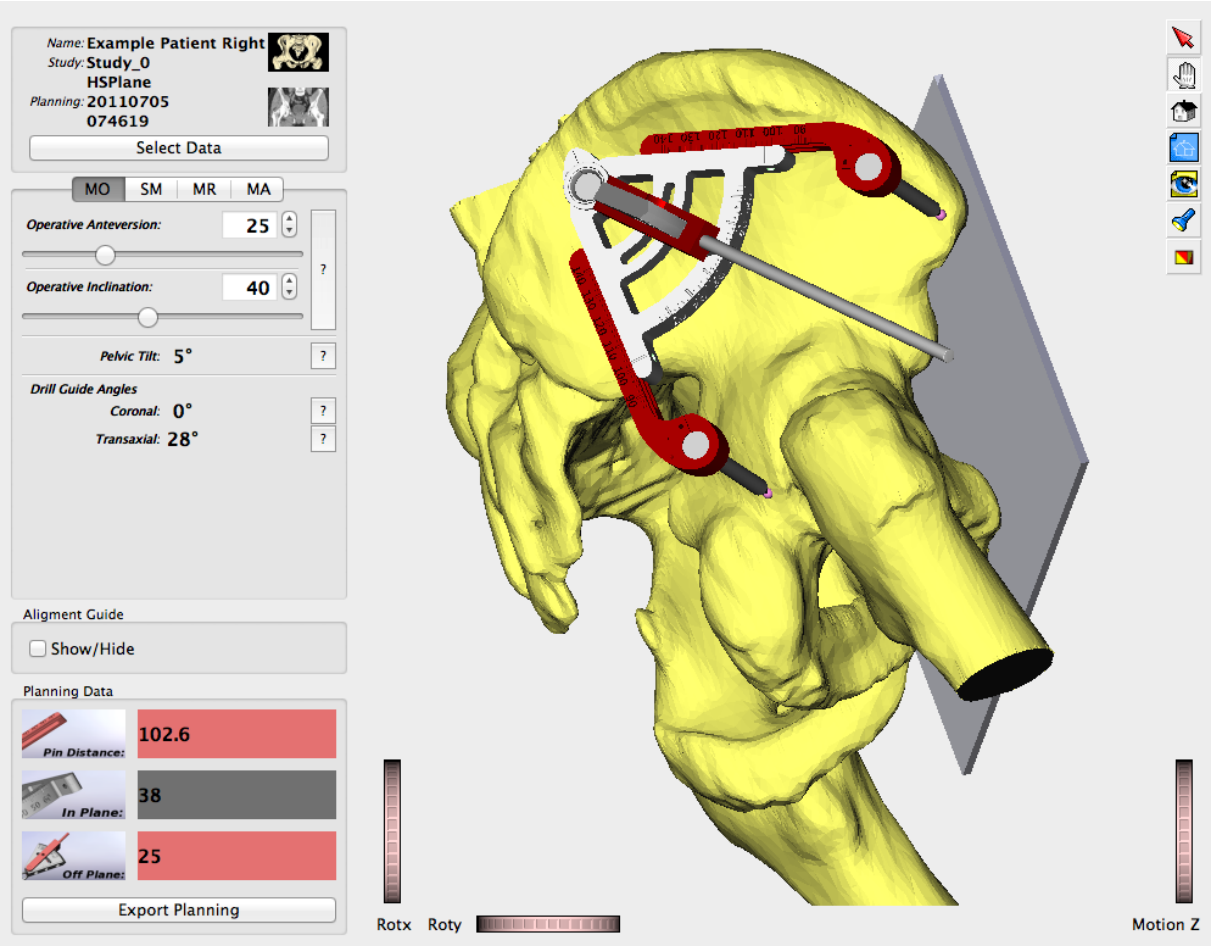
Introduction: At least half of all conventionally placed acetabular components are poorly positioned[1]. Acetabular component malposition is associated with wear-induced loosening and instability, the two most common reasons for revision THA[2]. The HipSextant™ Navigation System (Surgical Planning Associates, Boston, MA) is an adjustable mechanical navigation device designed to indicate appropriate cup orientation during surgery. The instrument docks to the pelvis with three legs; one through the incision behind the posterior wall, one on the lateral side of the anterior spine, and one on the surface of the ilium. A study of its use based on 3D surface models from preoperative CT imaging demonstrated that 70 of 70 patients had the cup placed within the safe zone of +/- 10 degrees of abduction and anteversion[3]. However, pre-operative CT imaging is not always practical or available on a routine basis. It may be possible to predict the three-dimensional structure of the pelvis based on plain radiographs. The current study compares the accuracy of statistical models based on AP and lateral radiographs to 3D models from CT imaging.



Methods: 402 hips were used for this study (101 left female, 96 left male, 94 right female, 111 right male). The material was derived from patients undergoing total hip arthroplasty who had both a preoperative CT study and plain radiographs. Inclusion criteria were the absence of prior surgery or gross pelvic asymmetry. Surgery using the HipSextant was planned for each hip using CT imaging as previously described[3,] Figure 1. The CT plan was considered the ground truth. Surgery using the HipSextant was also planned using the statistical models derived from AP and Lateral pelvic radiographic images. The plain radiographs had simple, specific criteria for acceptance that can easily be met by radiology technologists. No magnification markers are required. The cup abduction, flexion, and anteversion errors that would result from planning the surgery using radiographs instead of CT were calculated for a cup that was aimed for 40 degrees of abduction and 25 degrees of flexion.

Results: The error resulting from planning the HipSextant using plain radiographs instead of planning on a 3D model from CT imaging is listed in the four tables below.

Men	Right	N=111
Abduction	Flexion	Anteversion
Mean Error: 1.6^0	Mean Error: 1.8^0	Mean Error: 2.6^0
SD: 1.1^0	SD: 1.4^0	SD: 1.7^0
Max Error: 4.9^0	Max Error: 6.7^0	Max Error: 6.7^0
Women	Right	N=94
Abduction	Flexion	Anteversion
Mean Error: 1.3^0	Mean Error: 1.5^0	Mean Error: 2.0^0
SD: 0.8^0	SD: 1.1^0	SD: 1.4^0
Max Error: 3.7^0	Max Error: 4.8^0	Max Error: 5.6^0
Men	Left	N=96
Abduction	Flexion	Anteversion
Mean Error: 1.5^0	Mean Error: 1.5^0	Mean Error: 2.0^0
SD: 1.0^0	SD: 1.0^0	SD: 1.5^0
Max Error: 4.3^0	Max Error: 4.3^0	Max Error: 5.6^0
Women	Left	N=101
Abduction	Flexion	Anteversion
Mean Error: 1.4^0	Mean Error: 1.7^0	Mean Error: 2.3^0
SD: 1.1^0	SD: 1.2^0	SD: 1.7^0
Max Error: 5.3^0	Max Error: 4.8^0	Max Error: 6.3^0

Summary & Conclusion: Cup malposition following total hip replacement and hip resurfacing is a critical surgical technique factor that affects outcome. The HipSextant is a simple mechanical navigation device that can be uniquely adjusted for each patient according to the surgeon's cup orientation goal with results that are equivalent to traditional navigation, when based on CT imaging[3]. While CT imaging may be prudent for hips with prior surgery, trauma, or gross pelvic asymmetry, planning the surgery based on plain radiographs is simpler and more practical. The current study demonstrates that simple plain radiographs may be used for pre-operative planning in routine circumstances with small additional errors when compared to CT. These findings suggest that better cup positioning can be routinely achieved using simple plain radiographs, without the need for complex intraoperative navigation systems, and with minimal additional OR time.

References

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