Proof-of-Concept Study: Evaluation of A Novel Augmented Reality Overlay for Cervical Screw Placement in Phantom Spine Models

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Background:

The anatomy of the spine presents surgeons with unique challenges making image guidance technologies an attractive option for enhancing the safety and accuracy of procedures. Over the past several years, AR has emerged as a promising technology, gaining considerable traction in the fields of neurosurgery and orthopaedic surgery. Unlike VR, in which views of the real-world environment are lost, AR enables users to experience computer-generated content (i.e., holograms) in the real-world by merging virtual data such as 3D anatomy or virtual tools with the real environment. The AR system described in this poster uses a rapid, markerless registration process to superimpose 3D reconstructed spinal anatomy onto the corresponding physical object (i.e., spinal model) to allow for visualization and optimization of screw placement. The goal of this study is to evaluate the feasibility of this technology as a potential navigation system in the setting of spinal surgery

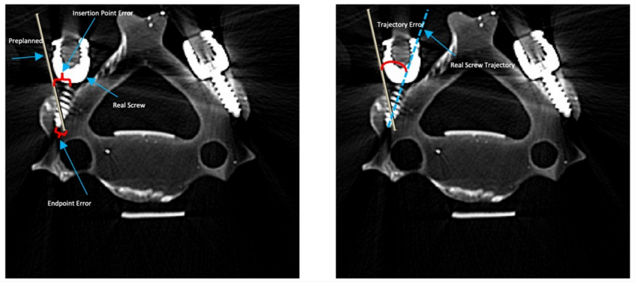

Figure 2 Pre-insertion and post insertion CT images were fused. A) The insertion point and endpoint distance error was measured as the Euclidian distance between the corresponding points of the preplanned trajectory and real screw. Multiple views of the reconstructed 3D digital spine model with preplanned trajectories. B) The trajectory angle error was measured as the angular difference between the preplanned trajectory and the physical screw path

Technology Platform

The AR software application was developed by Hoth Intelligence (Philadelphia, Pennsylvania) and operates on the Microsoft Hololens 2 HMD (head mounted display) (Redmond, Washington). The system uses an ultra-fast, markerless registration process which allows a user to accurately register preoperative patient imaging for navigation quickly in any clinical setting

1. The registration system operates entirely out of the Microsoft Hololens 2, an untethered 1.2 lb headset connected wirelessly the Hoth Intelligence cloud data server.
2. Registration does not require fiducials. The user simply looks down at the spinal vertebra and the 3D digital model is overlaid onto the physical model.
3. While wearing the HMD, the user scans the spine using the various sensors on the Microsoft Hololens 2.
4. The various sensor streams are integrated and merged to create a reconstruction of the physical phantom model. This then serves as input for the alignment and orientation algorithms – used to match a 3D reconstruction of the model with the real physical model. Matching algorithms produce a transformation matrix that is used to reproject the 3D cloud-based model with the real physical model in real-world space.
5. After registration is complete, user can see the digital model overlaid on the spine – to visualize physical trajectories from different viewpoints. Trajectories represent optimal path for screw placement.
6. User can reference trajectories while inserting screws into spinal model. (Figure 1)

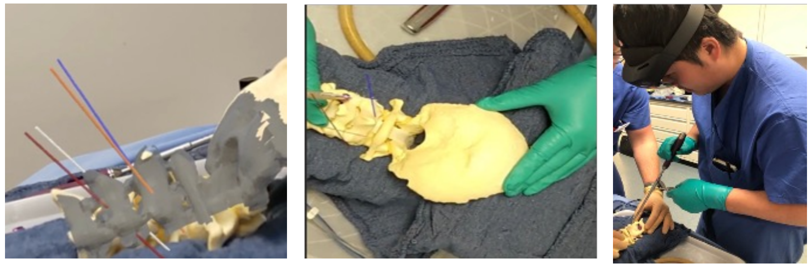

Figure 1 Users view the AR headset displaying 3D digital model overlaid onto physical spine model. A-C) Multiple views of the reconstructed vertebrae and trajectory lines overlaid onto the spine model. D) While wearing the AR headset, the user sees the insertion point and insertion path and can align tools with the trajectory lines while performing steps for screw insertion.

Methods:

CT imaging of the phantom spine models are completed and subsequently segmented with screw trajectories placed by one of two PGY6 or 7 neurosurgery residents with over 500 spine cases completed. These models and trajectories are then uploaded to the headset which was subsequently used by the surgeons to place the screws along the pre-planned paths. After screw insertion the phantom spines underwent CT scanning and error measured at the X,Y,Z coordinates of the pre-planned trajectories and inserted screws(Figure 3)

Results

Screw Number	Insertion Type	Insertion Point Distance Error (mm)	End Point Distance Error (mm)	Trajectory Angle Error (degrees)
1	Right C2 pars interarticularis screw (Model 1)	2.89	1.89	1.8
2	Left C2 pars interarticularis screw (Model 1)	1.88	2.54	2.6
3	Right C3 lateral mass screw (Model 1)	3.22	4.02	3.4
4	Left C3 lateral mass screw (Model 1)	2.13	2.22	2.8
5	Right C3 lateral mass screw (Model 2)	3.65	3.54	2.0
6	Left C3 lateral mass screw (Model 2)	2.53	2.00	2.2
7	Right C4 lateral mass screw (Model 2)	2.22	1.98	3.6
8	Left C4 lateral mass screw (Model 2)	2.77	2.76	3
9	Right C5 lateral mass screw (Model 2)	2.19	3.22	2.5
10	Left C5 lateral mass screw (Model 2)	3.02	2.65	3.1
11	Right C6 lateral mass screw (Model 2)	3.43	2.98	3.2
12	Left C6 lateral mass screw (Model 2)	2.87	3.12	2.1

Conclusions:

- Our Novel AR system can produce accurate results in placement of cervical screws in phantom spine models

Limitations:

- Phantom spine models vs cadavers
- Only cervical spine screws, not lumbar or thoracic

Disclosures

BS and JO are consultants for Hoth Intelligence. CS is a consultant for Nuvasive; has ownership interest in the Maryland Development Corp; receives royalties from Stryker; and is on the editorial board of the Journal of Neurosurgery. SL is a board member for the American Board of Orthopaedic Surgery, the American Orthopaedic Association, the Cervical Spine Research Society, and the Society for Minimally Invasive Spine Surgery; is a consultant for DePuy Synthes and K2M/Stryker; is a board member for Nuvasive; receives payment for lectures and travel accommodations from DePuy Synthes and K2M/Stryker; receives payment for patents and royalties from DePuy Synthes; has stock in Innovative Surgical Designs and the American Society for Investigative Pathology; receives research support from AO Spine North America Spine Fellowship support and AOA Omega Grant; is a board member of Maryland Development Corporation; receives royalties from Thieme, Quality Medical Publishers; is on the editorial board of Journal of Spinal Disorders and Techniques, The Spine Journal, and Contemporary Spine Surgery