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Digital Navigation for Shoulder Arthroplasty

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Comparison of navigational accuracy for various workflows within the glenoid space

PLACEMENT ACCURACY AND IMPLANT PERFORMANCE

Introduction and Purpose

- Deviations from the preoperative plan, specifically in the initial placement of the K wire, can directly affect the performance and reliably of the implant and the post operative quality of life for the patient.
- "The durability of implants in total shoulder arthroplasty depends largely on the stability of the glenoid component" (Theopold et al., 2021)
- Digital navigation within the glenoid seeks to improve upon the freehand approach by allowing for a more accurate and reliable method of K wire insertion.
- Other studies using the same navigation system for the humeral component have shown registration error of 2.5±1.2 mm (Cavanagh, Athwal, Johnson and Langohr, 2021) for a single known point on the humeral head.
- The purpose of this work was to validate a navigation tool for the glenoid component. To do this an accurate workflow is required. Inaccuracies between the tool and patient will directly manifest in the placement of the implant.

POINT CLOUD FITTING AND ITERATIVE CLOSEST POINT (ICP)

Methods

- To evaluate the relative accuracy of the three proposed workflows, each workflow was conducted on the same intraoperative registration data set, repeated for all seven specimens.

Workflow 1:

- Performs a landmark registration of the 6 and 12 clock points to initialize ICP registration of the glenoid rim, which in turn initializes ICP of the STL vertices for the entire model.

Workflow 2:

- Performs a landmark registration using SIAP points of the glenoid rim to initialize ICP of the STL vertices for the entire model.

Workflow 3:

- Performs a landmark registration of the first and last points of a coracoid trace, including the lateral most point of the coracoid to initialize ICP registration of the coracoid trace, which in turn initializes ICP of the STL vertices for the entire model.

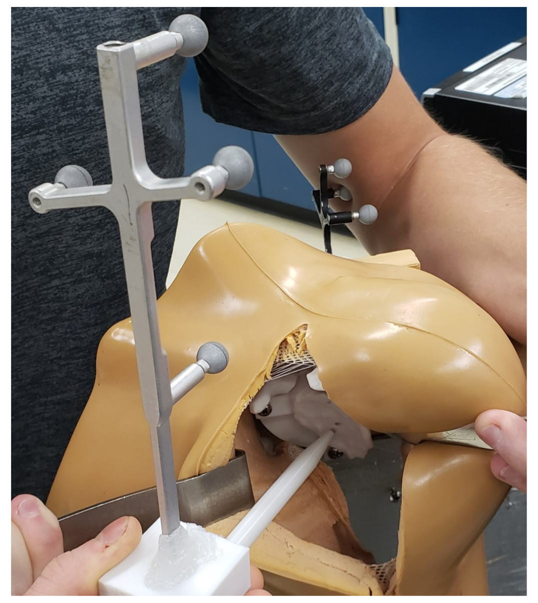

Figure 1: Performing registration on the 3D printed specimen

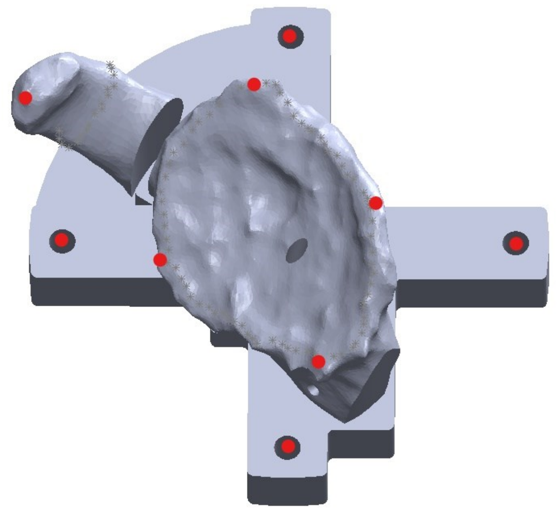

Figure 2: SIAP landmark and screw locations, lateral coracoid

- During registration, the Superior, Inferior, Anterior and Posterior (SIAP) screw points were digitized as the concave nature of the screw heads provides a repeatable probing point for the tip of the K wire insertion tool.
- The intraoperative data points had the resulting T matrix from each workflow applied to convert them back into the preoperative space.
- The navigational error is the difference between the known and converted coordinates of the SIAP screw head locations.
- Due to the orientation of the model in the preoperative space, navigation need only be accurate in the XY plane, as the Z axis is irrelevant to the tip placement and the angle of an inserted K wire.

COMPARISON BETWEEN KNOWN AND NAVIGATED POINTS

Results

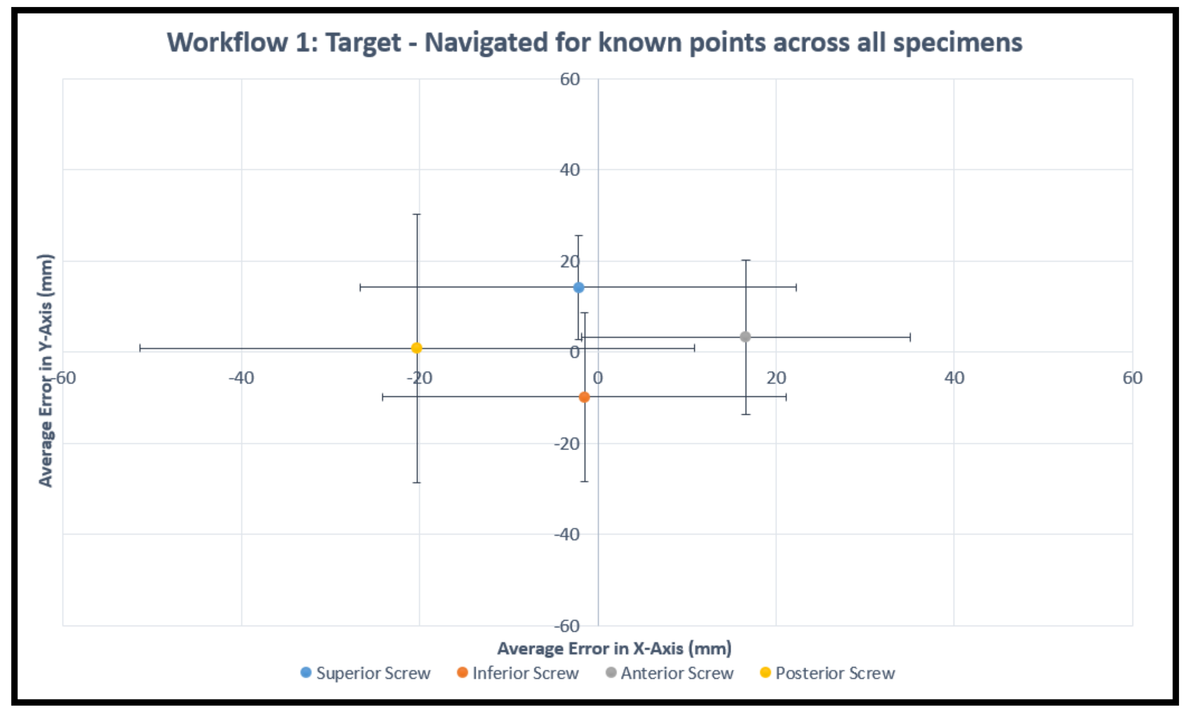

Figure 3: Error in X-Axis and Y-Axis across 7 specimens in workflow 1

- Workflow 1 had large inaccuracies across the SIAP screw locations. The maximum deviation in the X axis was -80.6 mm and the maximum deviation in the Y axis was -41.2 mm. The standard deviation for the XY error vector for each of the SIAP screw locations was 15.3mm, 15.9mm, 20.2mm, and 27.3 respectively.

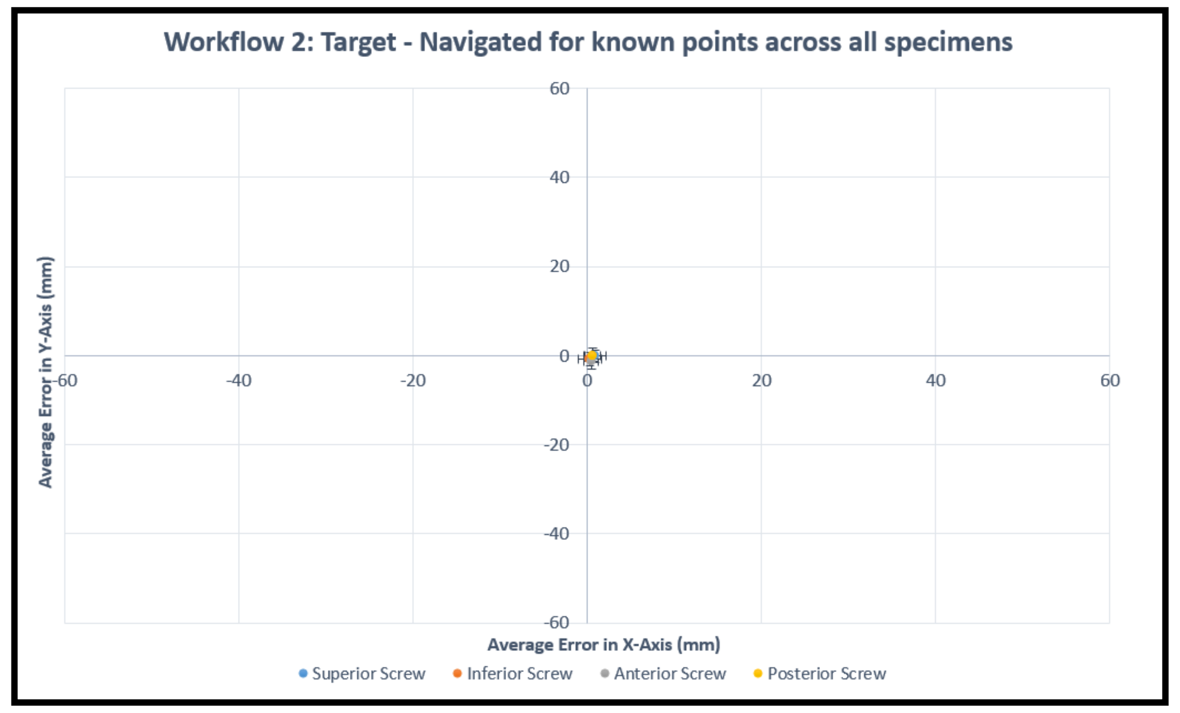

Figure 4: Error in X-Axis and Y-Axis across 7 specimens in workflow 2

- Workflow 2 had relatively small inaccuracies across the SIAP screw locations. The maximum deviation in the X axis was 2.2mm and the maximum deviation in the Y axis was 3.1mm. The standard deviation for the XY error vector for each of the SIAP screw locations 0.9mm, 0.8mm, 0.8mm, and 1.4mm respectively.

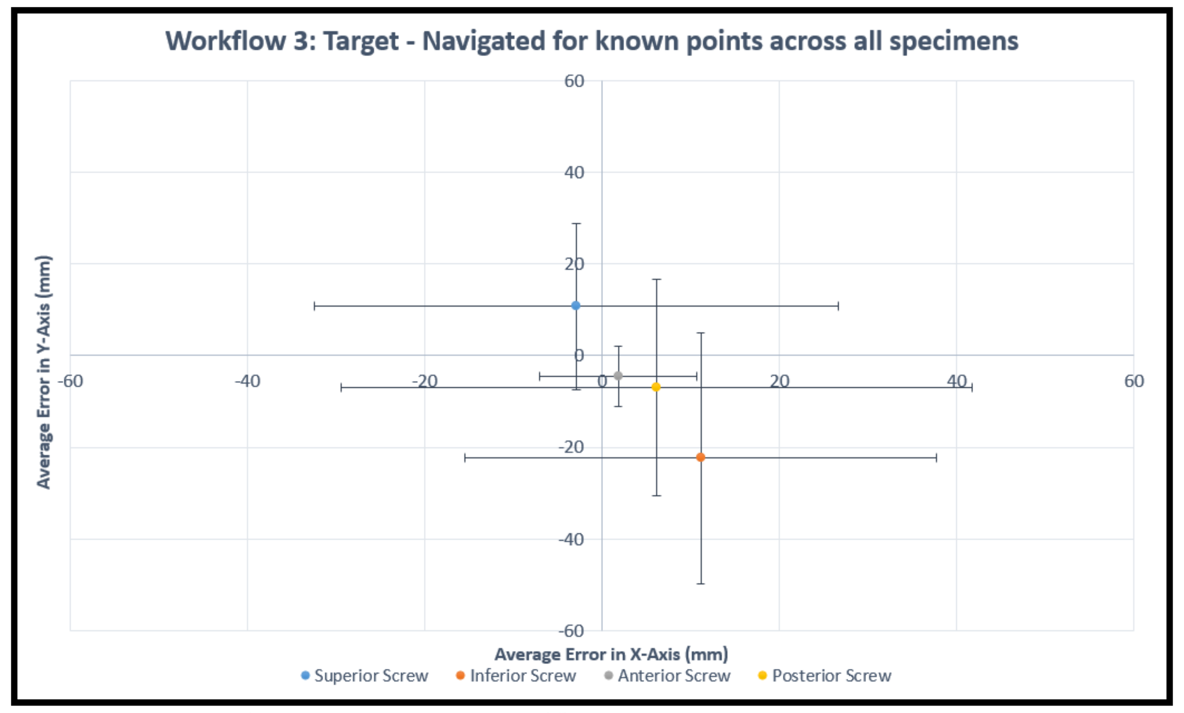

Figure 5: Error in X-Axis and Y-Axis across 7 specimens in workflow 2

- Workflow 3 had large inaccuracies across the SIAP screw locations. The maximum deviation in the X axis was 65.5mm and the maximum deviation in the Y axis was -61.1mm. The standard deviation for the XY error vector for each of the SIAP screw locations was 22.3mm, 28.8mm, 5.9mm, and 24.2mm respectively.
- Overall workflow two proved to be the most accurate with a registration error of 1.7±1.0mm. This result is consistent with the degree of error found in [2] for the humeral component of the shoulder and proves that digital navigation can be used as a means of limiting error in the placement of shoulder implants.

References

[1] Theopold, J., Pieroh, P., Scharge, M., Marquaß, B., Hohmann, T., Josten, C. and Hepp, P., 2021. *Improved accuracy of K-wire positioning into the glenoid vault by intraoperative 3D image intensifier-based navigation for the glenoid component in shoulder arthroplasty*. [online] PubMed. Available at: <https://pubmed.ncbi.nlm.nih.gov/27132036/> [Accessed 7 August 2021].

[2] Cavanagh, J., Athwal, G., Johnson, J. and Langohr, D., 2021. Navigation and Patient Specific Instrumentation in Shoulder Arthroplasty.