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# Accuracy of Glenoid Component Positioning in Reverse Shoulder Arthroplasty: A Biomechanical Comparison between 3D Preoperative Planning, PSI, Computer-Assisted Navigation, and Mixed Reality Navigation

Cole T. Fleet[1,2], Ryan Gao[3], G. Daniel G. Langohr[1,2], James A. Johnson[1,2], George S. Athwal[1]

[1] The Roth McFarlane Hand and Upper Limb Center, St. Joseph's Hospital, London, Canada
[2] Department of Mechanical and Materials Engineering, Western Univeristy, London, Canada
[3] Wrightington Hospital, Wrightington, England

cfleet3@uwo.ca, ygao921@gmail.com, dan.langohr@gmail.com, jajohnso@uwo.ca, gsathwal@hotmail.com

**Abstract**

Accurate glenoid component positioning in shoulder arthroplasty is important to avoid potential impingement, loosening, and instability. Several techniques are currently utilized to assist in glenoid guide pin positioning, although no studies exist that directly compare the accuracy between these techniques. The objective of this study was to compare guide pin insertion accuracy using traditional 3D software planning (TSP), patient specific instrumentation (PSI) guides, computer-navigation (C-NAV), and mixed reality navigation (MR-NAV).

Twenty shoulder computer tomography scans exhibiting glenohumeral arthritis or rotator cuff tear arthropathy were preoperatively planned for reverse shoulder arthroplasty. Quadruplicate models of each glenoid were plastic 3D printed and were used to randomly assess four guide pin insertion techniques by a fellowship trained surgeon as follows: (1) TSP, (2) PSI guides, (3) C-NAV, and (4) MR-NAV. Following guide pin placement, the absolute error in guide pin position and orientation relative to the preoperative plan was measured using a digitization system.

Similar inclination (P>0.066) and version (P>0.515) accuracy occurred between PSI, C-NAV, and MR-NAV techniques. Furthermore, all three methods exhibited significantly less error in guide pin

inclination compared to TSP (P<0.025). Greater version error was also observed with TSP (4±3°) but was not significantly greater than the other techniques (P>0.063). The error in guide pin entry point was similar between all four methods utilized (P>0.086).

This study showed that the accuracy of PSI, C-NAV, and MR-NAV are superior to TSP for glenoid pin insertion in-vitro. Further investigation is needed to validate the accuracy of all guide pin insertion techniques in-vivo.

# 1 Introduction

Accurate insertion of the glenoid guide pin in both total (TSA) and reverse (RSA) shoulder arthroplasty is important as glenoid component malposition can increase the risk of impingement, component loosening, and instability. Three-dimensional (3) preoperative planning has been shown to improve the accuracy of glenoid guide pin placement compared to standard two-dimensional (2D) radiographs, although can still result in significant glenoid component malposition relative to the preoperative plan[1,5,6]. Several newer technologies, including patient specific instrumentation (PSI) guides[5,6], computer assisted navigation (C-NAV)[10,11], and mixed-reality navigation (MR-NAV)[7,8], which utilizes surgical visualization and holographic navigation, have recently been developed to improve the accuracy of glenoid component positioning. However, no studies exist that directly compare the accuracy of these techniques. Therefore, the objective of this study was to compare glenoid guide pin insertion accuracy using traditional 3D software planning (TSP), PSI, C-NAV, and MR-NAV.

# 2 Materials and Methods

Twenty (20) computer tomography (CT) scans were obtained from patients (mean age 68±12 years) exhibiting glenohumeral arthritis or rotator cuff tear arthropathy according to the Walch and Favard classifications[2,12]. All scans were automatically segmented and planned for either TSA (n=5) or RSA (n=15) by the senior author using validated preoperative planning software. Each scapula was exported to a computer-aided design software, where the glenoid (with coracoid) was manually sectioned from the medial scapular body. Quadruplicate models of each glenoid with coracoid were then plastic 3D printed, resulting in a total of 80 plastic models (4 techniques X 20 cases). Four guide pin insertion methods were randomly performed by a fellowship trained surgeon who was blinded to the original preoperative planning. The first method employed 3D preoperative planning (TSP) which permitted the surgeon to view and manipulate the 3D preoperative plan at the time of guide pin insertion. The second method utilized rigid PSI guides that were created during the preoperative planning process for each patient. The third method employed an in-house C-NAV system which utilized an optical tracking system with an accuracy of 0.1mm and a resolution of 0.01mm. The fourth method used an MR-NAV system comprised of a Microsoft HoloLens II head mounted display. Both navigation systems were used to complete the glenoid model registration and guide pin insertion processes. The same registration process was utilized for both methods, with the surgeon digitizing six points on the glenoid and coracoid, followed by a trace of the glenoid surface, coracoid foot to knee, and coracoid tip. The C-NAV system provided real-time feedback through a monitor position beside the glenoid model, while the MR-NAV system provided real-time holographic visualization and guidance through the head mounted display. Once all guide pins had been inserted, an optical tracking system and custom digitization device was used to quantify the position and orientation of the guide pin relative to the glenoid model. The primary outcomes for this study were the absolute error in guide pin inclination, version, and entry point relative to the preoperative plan. Statistical analysis was performed using a one-way repeated measures analysis of variance.

# 3 Results

Figure 1 illustrates the mean error for guide pin inclination, version, and entry point for all four guide pin insertion techniques while Figure 2 displays the maximum error for guide pin inclination, version, and entry point for all four techniques. Similar inclination accuracy was observed between PSI, C-NAV, and MR-NAV techniques (2±1°, P>0.066). Furthermore, all three of these methods exhibited significantly less error in guide pin inclination compared to TSP (5±3°, P<0.025). Similar accuracy in guide pin version was also observed between PSI (1±1°), C-NAV (2±2°), and MR-NAV (1±1°) (P>0.515). Greater version error was observed with TSP (4±3°) but was not observed to be significantly greater than the other techniques (P>0.063). The error in guide pin entry point was similar between all four methods utilized (TSP: 2±1mm, PSI: 2±1mm, C-NAV: 3±1mm, and MR-NAV: 2±1mm).

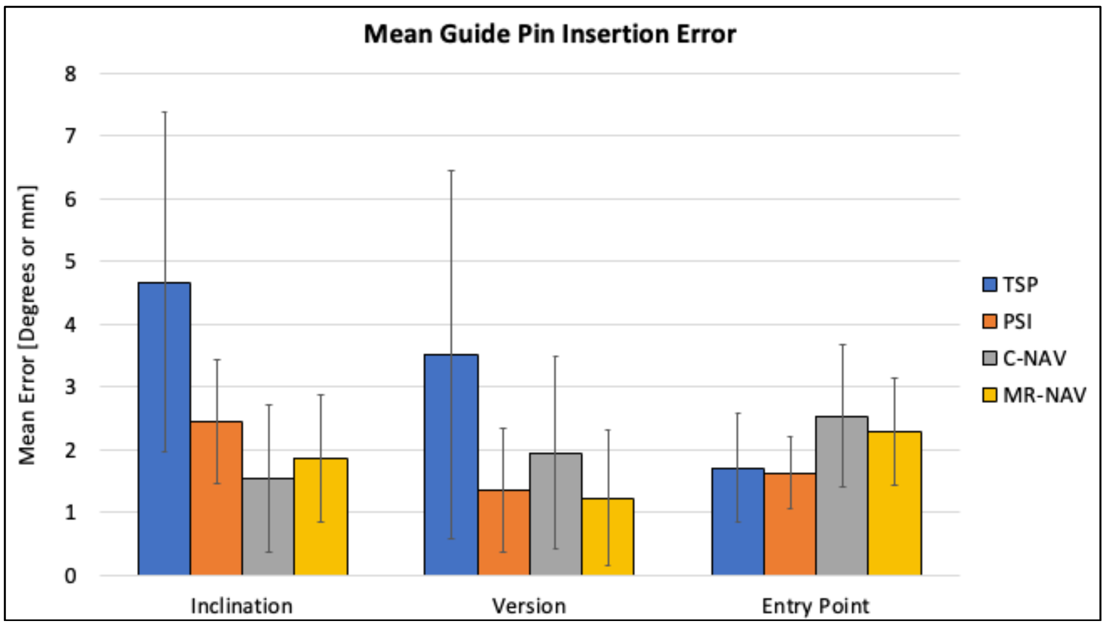


**Figure 1:** Mean (±1 standard deviation) guide pin insertion error in inclination, version, and entry point for traditional software planning (TSP), patient specific instrumentation (PSI) guides, computer-assisted navigation (C-NAV), and mixed reality navigation (MR-NAV).

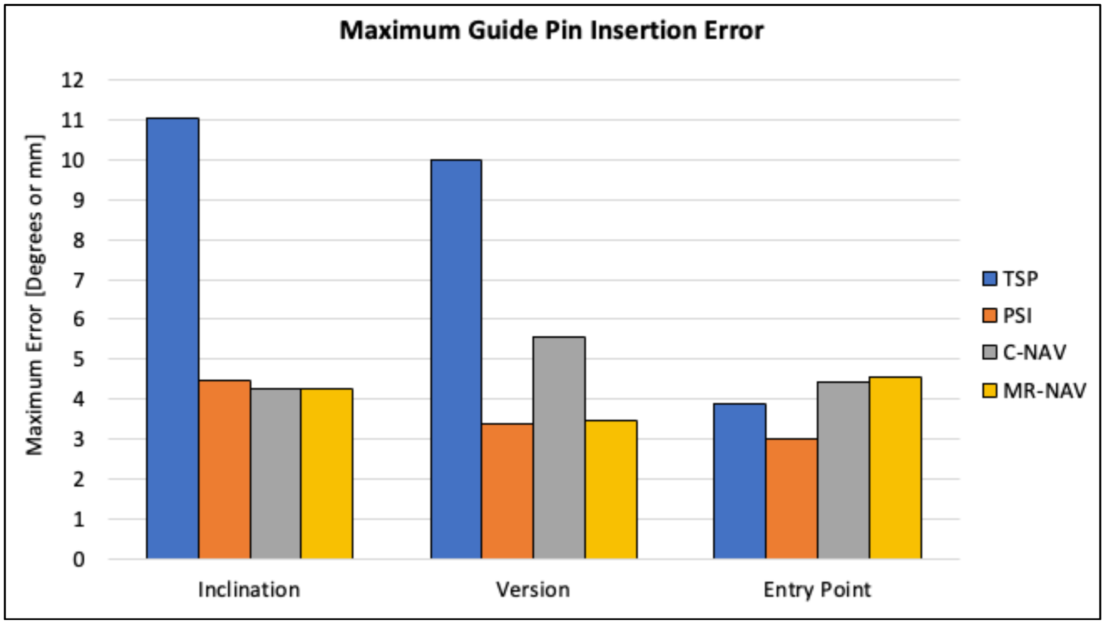


**Figure 2:** Maximum guide pin insertion error in inclination, version, and entry point for traditional software planning (TSP), patient specific instrumentation (PSI) guides, computer-assisted navigation (C-NAV), and mixed reality navigation (MR-NAV).

# 4 Discussion

This study showed that the accuracy of PSI, C-NAV, and MR-NAV are superior to TSP for glenoid guide pin insertion in-vitro. The improved accuracy with these assistive techniques likely stems from the physical or computer guidance provided to the surgeon during this procedure, as opposed to TSP in which the surgeon must estimate the correct guide pin position and orientation from the preoperative plan. While some of the statistically significant differences observed in this study may not be clinically relevant, the maximum errors in inclination and version observed with the TSP could result in glenoid component malposition and corresponding glenoid component complications[3,4,9].

This study was limited in that all testing was conducted in a laboratory setting, and therefore did not replicate the difficulty in achieving adequate soft tissue retraction and glenoid exposure. Additionally, this was a single surgeon study, and it is therefore unclear if surgical experience would influence these findings. Further investigation is needed to validate the accuracy of all guide pin insertion techniques in-vivo.

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