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The New Standard in Town: An Updated Look at Computer-Aided Surgery Metrology

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The New Standard in Town: An Updated Look at Computer-aided Surgery Metrology

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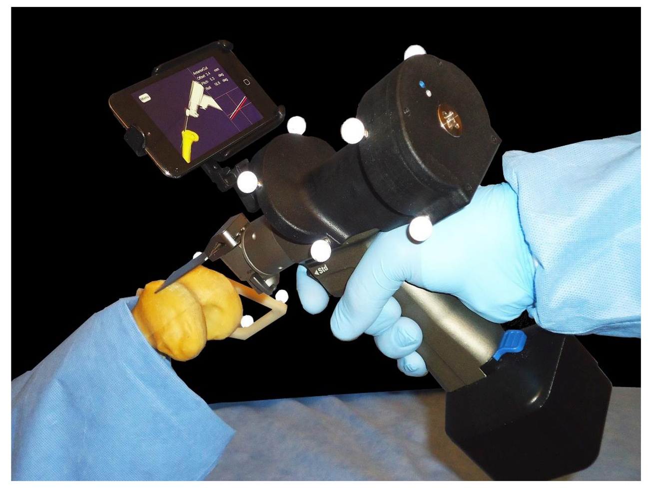
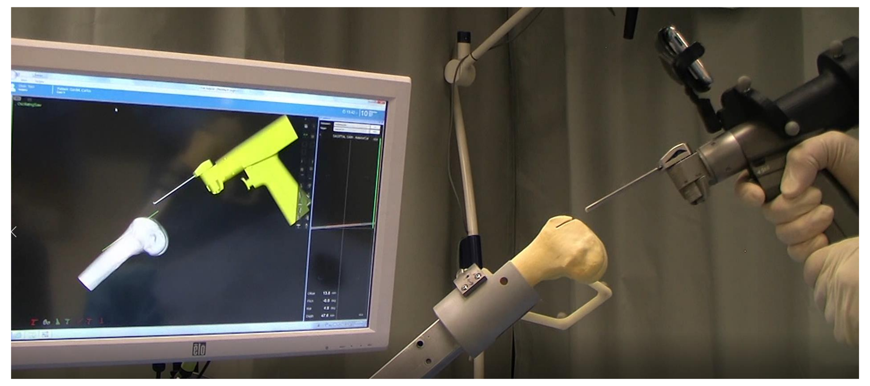
Introduction

Technological advances in surgical interventions include the use of computer-aided surgery systems. Arthroplasty is a prime example where navigation and robotics aid in alignment and positioning of bone resections to insert implants with less mechanical cutting guides and associated jigs.



Use of a navigated saw for bone cutting using the Simplified Orthopaedic Surgery (SOS) software developed here in our lab.

In our lab, proprietary software has been developed for segmentation and reconstruction of patient CT scan data for use with navigation/tracking to plan and execute total knee arthroplasty with more accurate bone resections and better alignment of implants.

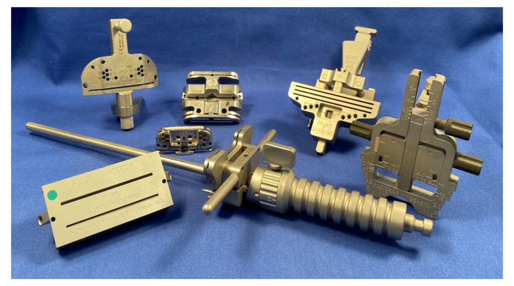


Externally tracked freehand navigation software in use for a demo at the ISTA conference in 2013.

Bench testing is needed to evaluate the accuracy and precision of the navigation tracker and associated transformations by software. An ASTM International standard for this evaluation is undergoing updates to ensure adequate application for modern computer-aided surgery systems.

In this study, we report from a recent comprehensive test series for such an evaluation.

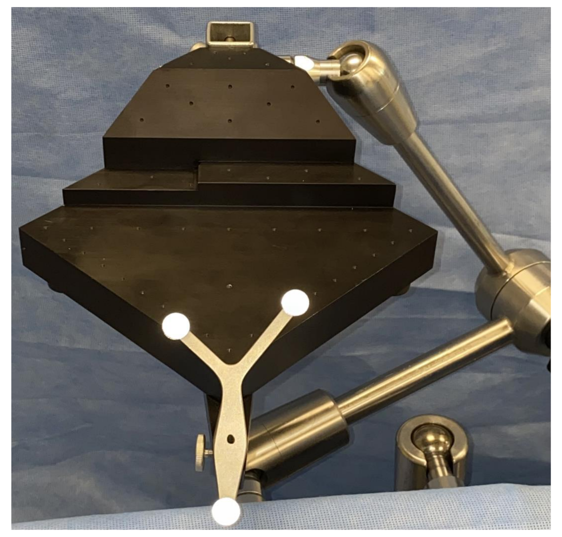
A right total arthroplasty of the knee seen with x-ray imaging



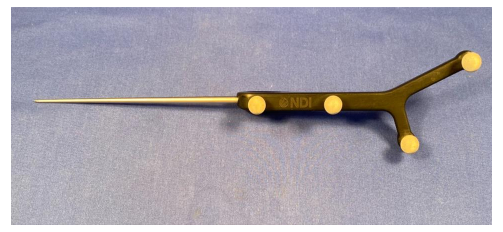
A sample of the many cutting guides and jigs currently used in arthroplasty. All can be eliminated by freehand navigation software.

Methods

A phantom with divots in a known location was mounted using a rigid, multi-axis repositionable arm. A computer connected to the tracker and running appropriate software was connected to a viewing screen positioned near the operator for reference.

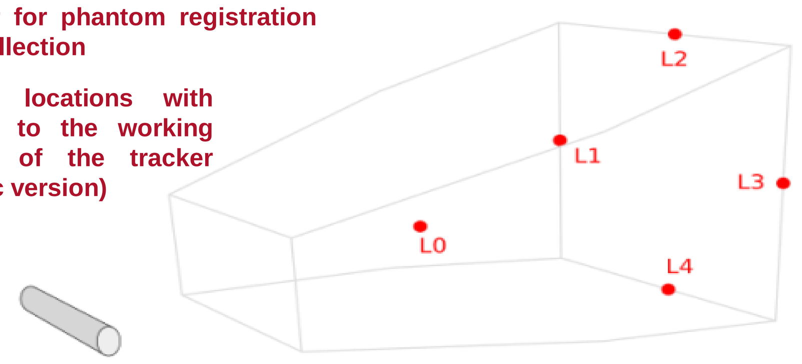


The phantom with the multi-axis table mount



NDI pointer for phantom registration and data collection

A Northern Digital Inc. (NDI) Polaris Spectra tracking system was used in compliment to the software using only passive (external) tracking.



Testing locations with relation to the working volume of the tracker (generic version)

Testing was completed as described in ASTM F2554-22 comprised of a Single Point Test, Axial Rotation Tests, Multi-point Test and Phantom Rotation Test at 5 locations in the working volume of the tracker.

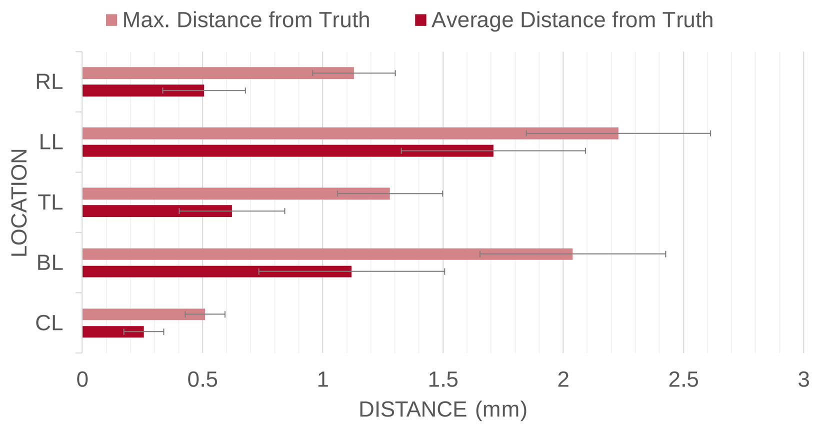
Data was recorded with screen recordings of real time positional data of the pointer throughout testing.

Results

Each of the following tests were performed at all 5 testing locations within the working volume of the tracker. These locations included the central location (CL), bottom location (BL), top location (TL), left location (LL), and right location (RL). BL, TL, LL, and RL are all located at the rear-most functional extremes of the working volume.

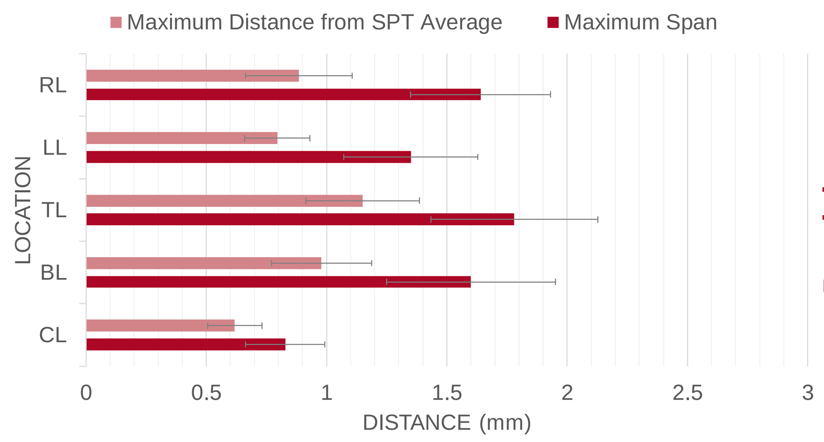
Single Point Test

The accuracy and precision evaluated from data on 20 acquisitions of the central divot

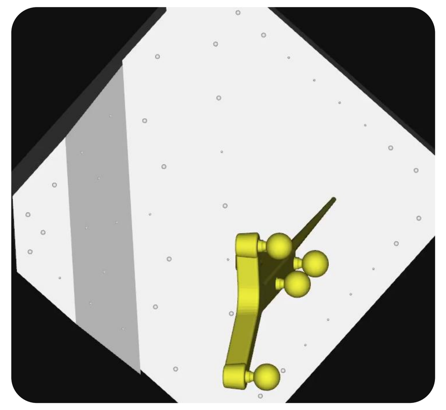


Accuracy

0.25mm accuracy under operation conditions (CL). Extreme locations average ~1mm accuracy.

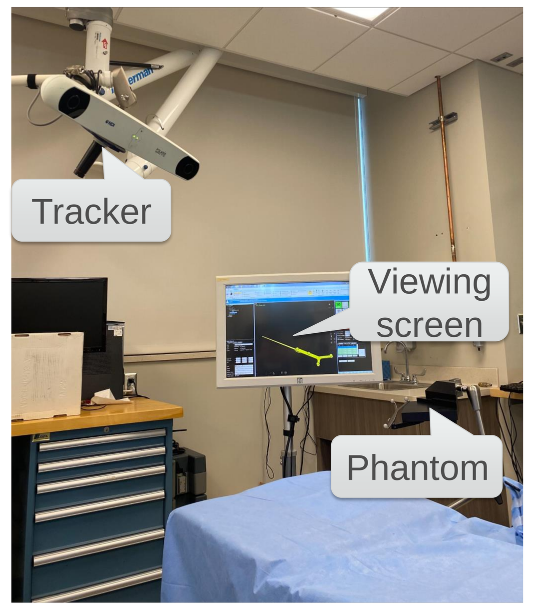


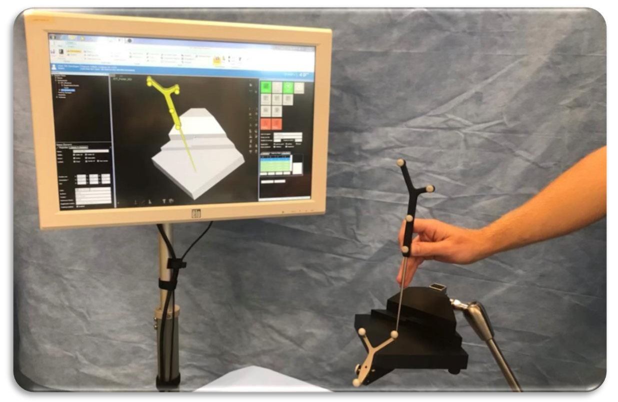
Precision



The user's view on UNMC's SOS software during the Single Point Test

4 out of 5 locations reported all measured values within ~1mm of that location's SPT average. The maximum distance between any 2 measured points (span) remained consistent at all extreme locations.



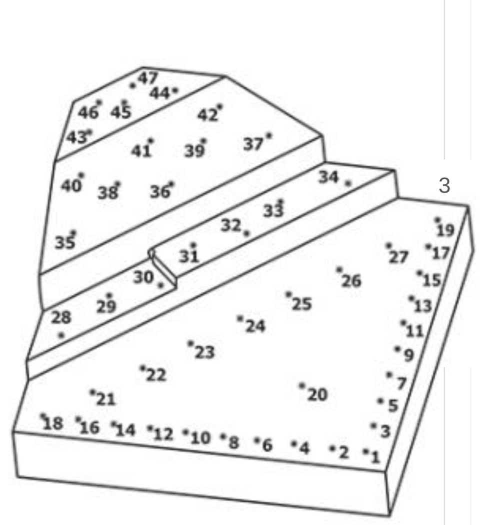


Operation of the testing setup during the standard testing sequence.

Multi-point Test

The accuracy evaluated from data from acquiring 20 different points on all faces of the phantom

All locations reported average error values of around 0.5mm with actual values being both positive and negative.



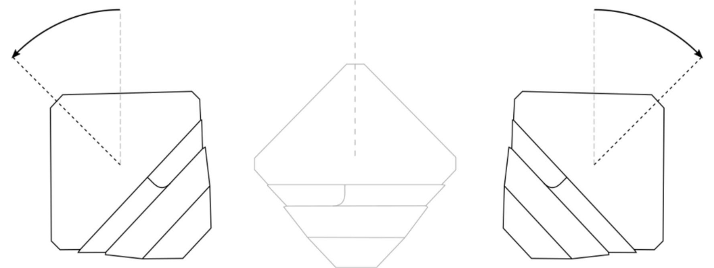
A mapping of all 47 possible points for the Multi-point Test

Reported averages for registration error are in line with the accuracy values reported in the SPT.

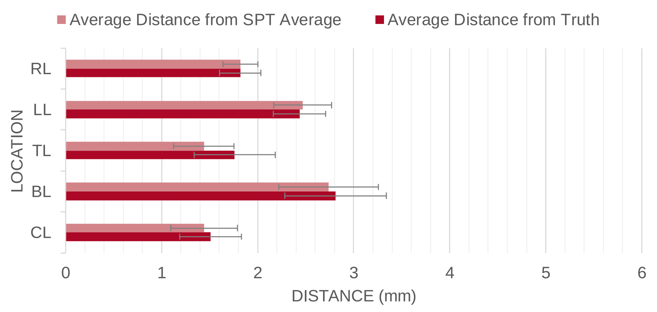
Phantom Rotation Test

The accuracy and precision evaluated after orienting the phantom at functionally extreme angles and repeating the protocol for a Single Point Test

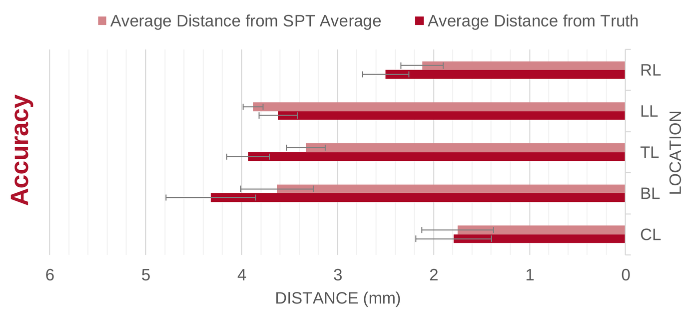
Counterclockwise rotation of the phantom only resulted in modest increases in accuracy error values. Precision also saw only modest increases or maintenance.



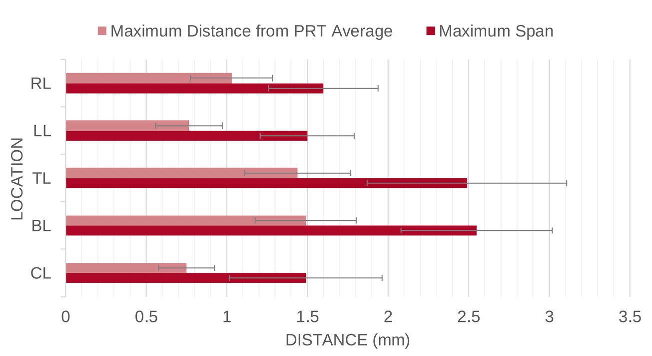
Clockwise rotation resulted in some locations experiencing double or worse increases in accuracy and precision error.



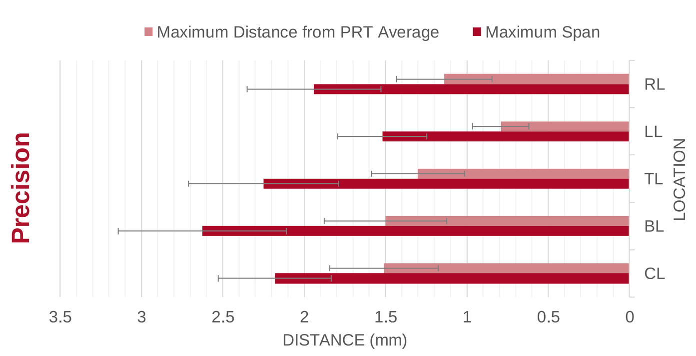
Accuracy



Accuracy



Precision



Precision

Conclusion and Discussion

The use of ASTM F2554-22 successfully quantifies both the accuracy and precision of a computer-aided surgery system to support further development or use in a surgical setting.

Data collected from the functional extremes in both location and orientation of the phantom likely do not accurately represent actual conditions found in an operating room. Further exploration into areas of the working volume and orientation of reference frames that return values poor in accuracy or precision followed by artificial constraints on the system's data return for these areas and orientations will improve the metrological and surgical results of using these systems.

Acknowledgements

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