Bi-planar videoradiography for tracking post-arthroplasty shoulder joint motion

[1]Stylianou AL, [2]Patel T, [2]Crisco JJ

[1]Brown University Providence RI

[2]Department of Orthopedics, Warren Alpert medical School of Brown University, Providence, RI

INTRODUCTION

Conventional skin-based motion tracking techniques, which utilize reflective markers that are placed on the skin of the subject, have shortcomings that contribute to error when measuring skeletal motion. X-ray based skeletal motion tracking eliminates many of the common problems associated with external markers, including soft-tissue artefact. More accurate *in-vivo* kinematic analysis of the shoulder joint after arthroplasty may offer compelling insight into the mechanistic link between joint stability and arthroplasty-related kinematic change; this information can then be used for the betterment of implant design and replacement procedures.

Purpose: Determine the accuracy of bi-planar videoradiography in tracking the motion of the humerus bone in patients that have undergone total shoulder arthroplasty

X-ray Reconstruction of Moving Morphology (XROMM): *X-ray motion analysis that combines 2D bi-planar x-ray videos with 3D bone/implant morphology data.*

Optical Motion Tracking (OMC): *Motion capture utilizing skin-based reflective markers.*

Bead-based tracking: *Tracks tantalum bead markers implanted in the humerus bone in each frame of the bi-planar x-ray video.*

METHODS

Tasks:

- Static trial
- Planar elevation trial
- Scapular elevation trial
- Rotation trial

Figure 1: *The W.M. Keck Foundation XROMM Facility at Brown University*

3D Modeling:

- <u>*Bone:*</u> Cadaveric humerus bone model created using Computed Tomography (CT) scan.
- <u>*Implant:*</u> Tornier Inc. T5559AC 17 and C 4326AD 8 press-fit humerus with articulating head implant model created using volume data provided by the manufacturer.

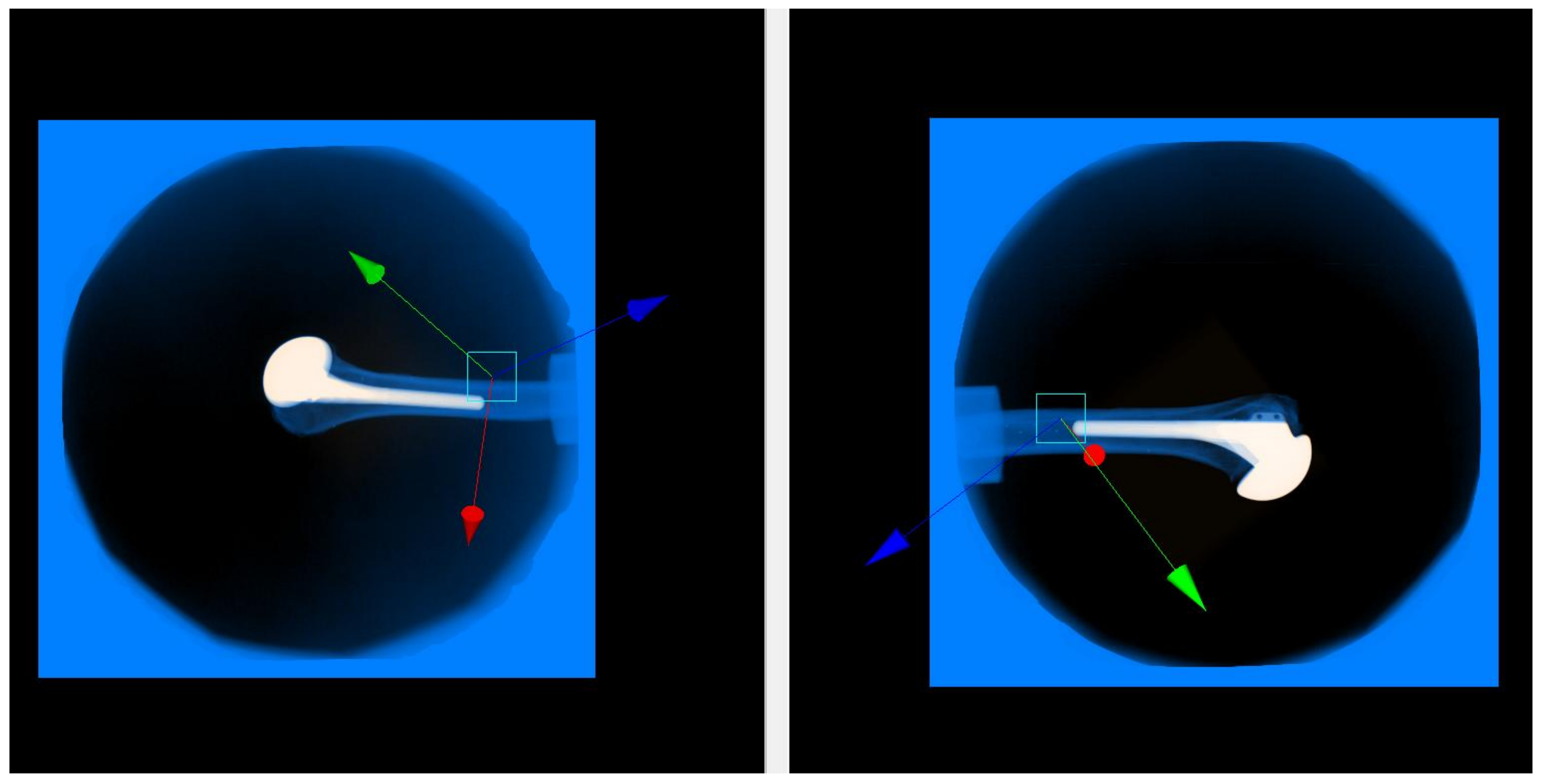

Figure 2: *Autoscoper software combines bi-planar X-ray data from XROMM cameras 1 and 2 with 3D implant/bone model*

Data Collection:

- XROMM data was acquired during each task performed using a novel high-speed, high-resolution, bi-plane video radiography system (XROMM) recording at 250 Hz. This data was then processed using the custom Autoscoper software's marker-less tracking algorithm, which finds the closest match of the 3D bone model over the video sequences.
- Bead-based tracking was performed using a custom Matlab program (XrayProjects), which allows a graphical interface for marker-based tracking of the tantalum beads over the video sequences.
- OMC data (gold standard) was acquired using a set of Qualisys Q500 System Version 2.9 infrared cameras, (Gothenburg Sweden)

3D kinematics assessment :

- Helical axis of motion (H.A.M.) parameters were computed to facilitate comparisons between XROMM and OMC data as well as between Bead and OMC data.
- Since the pendulum rotation is confined to planar rotation (about an axial bearing), only rotation about the helical axis was considered in the analysis.
- The mean root mean square error between the method in question and the gold standard OMC data was computed for each trial, as well as the average rotation angle for each tracking method.

RESULTS

- The data suggests that the translation of both the humerus and implant can be tracked within approximately 0.2 mm, and the rotation of implant and bone within approximately 0.6 degrees, consistent with results of previous studies[1].

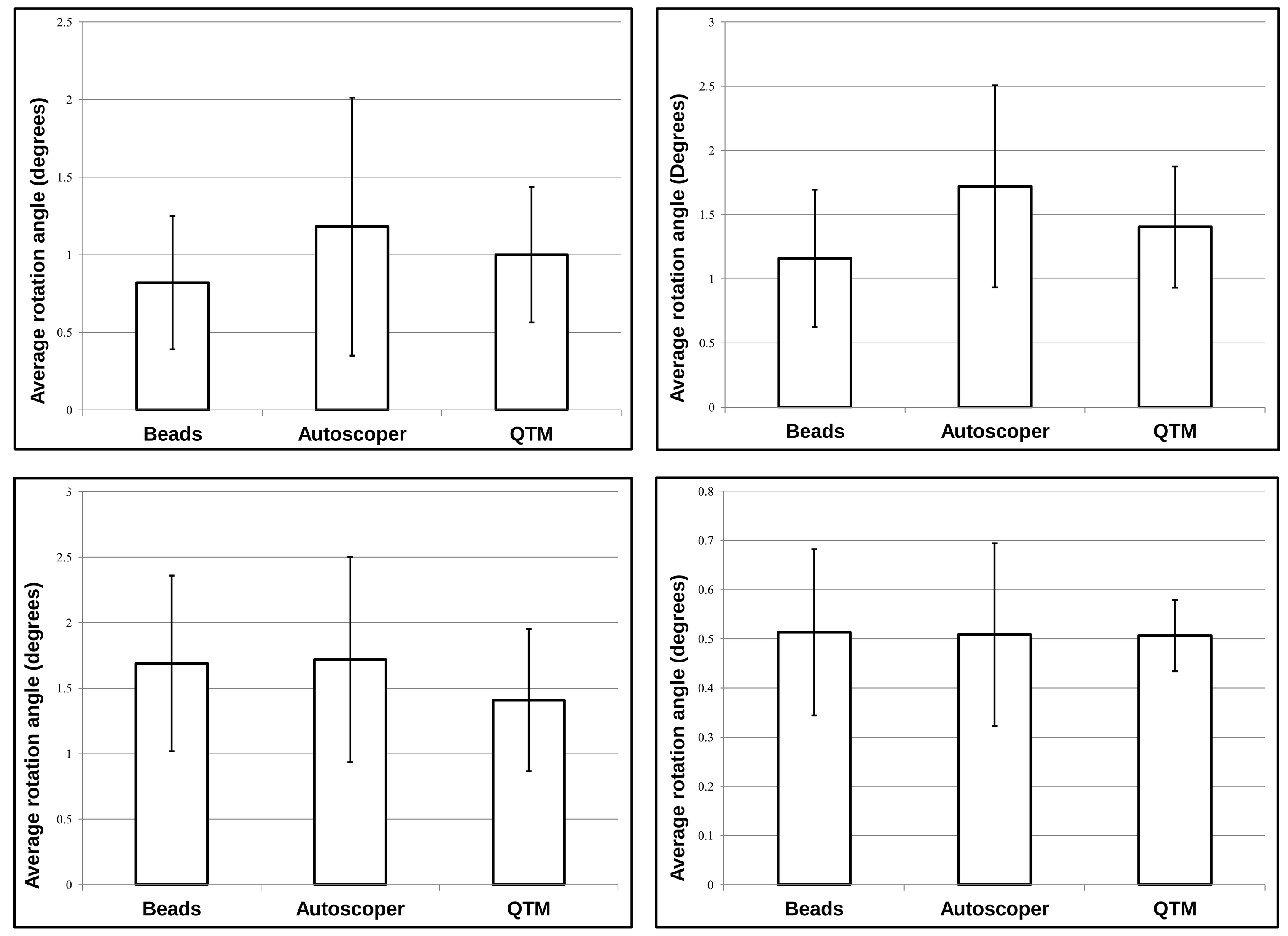

Figure 3: *Graphs of average Helical Axes of Motion (H.A.M.) rotation angle of the humerus for each of three tracking methods. Clockwise from top left: Planar Elevation trial, Scapular Abduction trial I, Scapular Abduction trial II, Rotation trial*

- The average difference between Autoscoper and bead tracked translation values over the four trials was 0.0005 mm, and the average difference between Autoscoper and bead tracked rotation values over the four trials was 0.0792 degrees.

		Peak Socket-Humeral Rotation (deg)	Resultant Force (N)
Planar Elevation	Translation	0.1482	0.1481
	Rotation	0.7156	0.4520
Scapular Elevation 1	Translation	0.1598	0.1602
	Rotation	0.6518	0.6570
Scapular Elevation 2	Translation	0.08690	0.08550
	Rotation	0.6194	0.5849
Internal Rotation	Translation	0.04250	0.04240
	Rotation	0.1771	0.1637

Table 1: *Mean Root Mean Square Error (MRMSE) for each trial.*

DISCUSSION

- The data supports the use of bi-planar video-radiography for studying the kinematics of shoulder arthroplasty subjects.
- Limitations include the fact that the study was not performed in-vivo; replicating the exact conditions of dynamic muscle loading and arm momentum is difficult in an experiment involving a single cadaveric bone

REFERENCES

1) Miranda, D.L., et al. Journal of Biomechanical Engineering, 2011. 133(12): p. 121002.