

A novel Workflow for in Vivo Assessment of Glenohumeral Contact Patterns Following Anatomic Total Shoulder Arthroplasty Using Biplanar Radiography

Nazanin Daneshvarhashjin^{a*†}, Laurens Jansen^{a†},
Philippe Debeer^b, Filip Verhaegen^b, Lennart Scheys^a

^a KU Leuven, Leuven, Belgium

^b UZ Leuven, Leuven, Belgium

[†] Shared first authorship

* Corresponding author: nazanin.daneshvarhashjin@kuleuven.be

Received date: 16/01/2026

Accepted date: 16/03/2026

Publication date: 02/06/2026

Keywords: anatomic total shoulder arthroplasty, glenoid component loosening, in vivo contact patterns, automated workflow

© 2026 The Authors

Licence CC-BY 4.0

Published by Société de Biomécanique

1. Introduction

Glenoid component loosening remains a relevant complication after anatomic total shoulder arthroplasty (aTSA). Glenohumeral contact patterns govern load transfer and bone-implant mechanics, making their accurate estimation critical for patient-specific biomechanical models aiming to predict loosening. Yet, their inter- and intra-subject variability across different functional arm poses remains poorly documented and hence rarely accounted for in such models. Therefore, this study presents a workflow to assess in vivo glenohumeral contact patterns across multiple arm poses after aTSA.

2. Methods

2.1 Data collection

Input data were collected as part of a prospective clinical study approved by the Ethics Committee of the University Hospitals Leuven (S64986) and included postoperative supine CT scans and low-dose biplanar radiographs (EOS imaging) from aTSA patients implanted with a Comprehensive[®] glenoid component (Zimmer Biomet). Biplanar radiographs were acquired in six upright functional arm poses: relaxed standing (RS), 45° extension (45EX), 45° and 90° flexion (45F, 90F), and 45° and 90° abduction (45AB, 90AB).

2.2 Workflow definition

The workflow comprises four main stages (Fig. 1):

- 1) 3D model creation and coordinate system definition:** Patient-specific 3D models of the scapula and humerus, including humeral implant, were created from postoperative CT scans using threshold-based segmentation in Mimics (Materialise), with manual refinement applied to the humeral model (Fig. 1a). To reconstruct the postoperative scapula, a preoperative model was registered to the rough postoperative segmentation using 3-matic (Materialise) and further refined manually (Fig. 1b). Patient-specific coordinate systems were defined for both bones as in our previous work (Daneshvarhashjin et al., 2025).
- 2) Glenoid component registration:** The manufacturer-provided glenoid component 3D model was semi-automatically registered to the postoperative CT scan using landmark-based alignment and manual adjustment, guided by peg-related contours and radiolucent zones (Fig. 1c).
- 3) Pose-specific joint reconstruction:** For each pose, the scapula and humerus were segmented as 2D contours from the biplanar radiographs. Custom MATLAB code (Dzialo et al., 2018) then iteratively repositioned the 3D bone models until their projected contours matched the segmented ones (Fig. 1d). All bone models and the registered glenoid component were transformed into a unified patient-specific coordinate system in 3-matic (Fig. 1e).

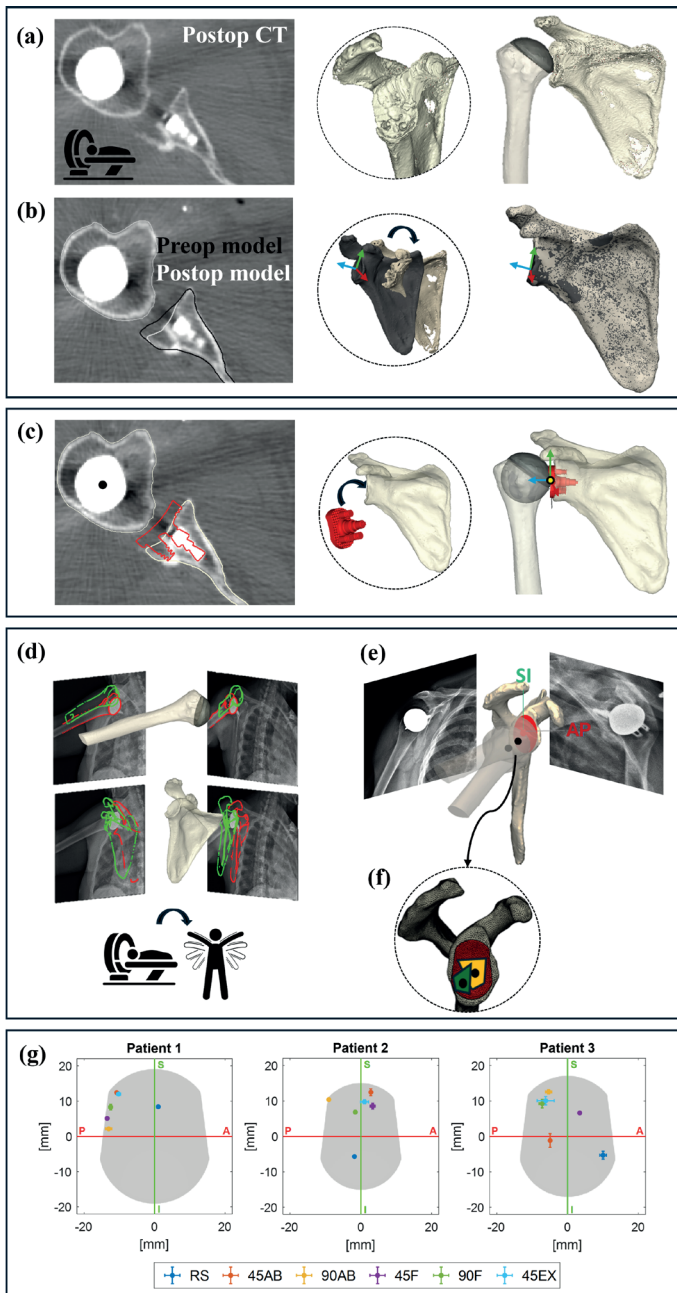


Figure 1. The proposed workflow (a-f) and proof-of-concept application to three patients (g).

4) *Contact calculation:* For each pose, the glenohumeral contact area and center were automatically computed using a custom Python script in 3-matic. The algorithm first generates triangular meshes for the humeral and glenoid components (0.1 mm edge length) and defines the contact area as the region of the glenoid component closest to the humeral component, using a threshold equal to 50% of the minimum intra-articular distance, similar to Massimini et al. (2014). The contact center

is then calculated as the centroid of the resulting contact area (Fig. 1f), and expressed in the local glenoid component coordinate system.

2.3 Proof-of-Concept Application

The workflow was applied to three aTSA patients with different glenoid component sizes, using one-year postoperative imaging. The computed contact centers across the six arm poses were projected onto a 2D representation of the component, and displayed in a right-sided configuration to allow visual comparison in MATLAB. Sensitivity to the distance threshold was assessed by repeating the analyses across thresholds ranging from 25% to 75% in 5% increments.

3. Results and discussion

Figure 1g shows the computed contact centers across the six arm poses for the three patients, with ranges reflecting distance threshold sensitivity. Although the small sample size precludes clinical conclusions, the effect of the threshold seems limited and a superior trend is observed (average contact location 20.2% of the component height above its midpoint), suggesting persistent humeral head subluxation after aTSA, consistent with Massimini et al. (2010). The results indicate that the workflow captures patient-specific glenohumeral contact locations across different functional arm poses, and that sensitivity analyses can be readily incorporated. We are currently applying the workflow to 25 patients from the same clinical study, and plan to analyze both contact location and area, include additional predictors such as scapular anatomy and implant placement, and perform sensitivity analyses on key parameters (e.g., segmentation and registration accuracy, mesh size and smoothness), where the most influential parameters will be investigated further. Registration accuracy is expected to be the most critical and can be addressed using multi-operator tracking, as in our previous work (Daneshvarhashjin et al., 2025). Validation against population-level data from the OrthoLoad database may be considered after further model refinements.

4. Conclusions

We developed a workflow to quantify *in vivo* glenohumeral contact patterns after aTSA using postoperative CT scans and biplanar radiography across multiple arm poses. Proof-of-concept application demonstrates feasibility and highlights the potential to analyze larger

cohorts, ultimately supporting predictive biomechanical modeling of glenoid component loosening.

Acknowledgements

The authors wish to acknowledge Anna Tarasiuk for her assistance in coordinating the clinical trial, and Line Ven for her support in acquiring the biplanar radiographs.

Conflict of Interest Statement

The authors declare no conflicts of interest relevant to the content of this work.

Contributor Roles

ND: Conceptualization, Data curation, Methodology, Software, Visualization, Writing – original draft; **LJ:** Data curation, Methodology, Software, Visualization, Writing – original draft; **PD:** Conceptualization, Project administration, Resources, Supervision, Funding acquisition, Writing – review & editing; **FV:** Conceptualization, Project administration, Resources, Supervision, Funding acquisition, Writing – review & editing; **LS:** Conceptualization, Project administration, Resources, Supervision, Funding acquisition, Writing-review & editing.

Funding

This work was supported by a research project from KU Leuven (C2M/25/061) and by the PRosPERoS II project funded through the Interreg VA Flanders-The Netherlands program (2021TC16RFCB041).

Data, software, code availability

The Python code developed in this work for automated calculation of contact locations and areas will be made available upon reasonable request.

References

- Daneshvarhashjin, N., Debeer, P., Andersen, M. S., Verhaegen, F., & Scheys, L. (2025). Biplanar radiography for in-vivo assessment of six degrees of freedom glenohumeral kinematics in shoulder osteoarthritis: an intra- and inter-observer reliability study. *Journal of Biomechanics*, 189. <https://doi.org/10.1016/j.jbiomech.2025.112845>
- Dzialo, C. M., Pedersen, P. H., Simonsen, C. W., Jensen, K. K., de Zee, M., & Andersen, M. S. (2018). Development and validation of a subject-specific moving-axis tibiofemoral joint model using MRI and EOS imaging during a quasi-static lunge. *Journal of Biomechanics*, 72, 71–80. <https://doi.org/10.1016/j.jbiomech.2018.02.032>
- Massimini, D. F., Li, G., & Warner, J. J. P. (2010). Glenohumeral contact kinematics in patients after total shoulder arthroplasty. *Journal of Bone and Joint Surgery*, 92(4), 916–926. <https://doi.org/10.2106/JBJS.H.01610>
- Massimini, D. F., Warner, J. J. P., & Li, G. (2014). Glenohumeral joint cartilage contact in the healthy adult during scapular plane elevation depression with external humeral rotation. *Journal of Biomechanics*, 47(12), 3100–3106. <https://doi.org/10.1016/j.jbiomech.2014.06.034>