



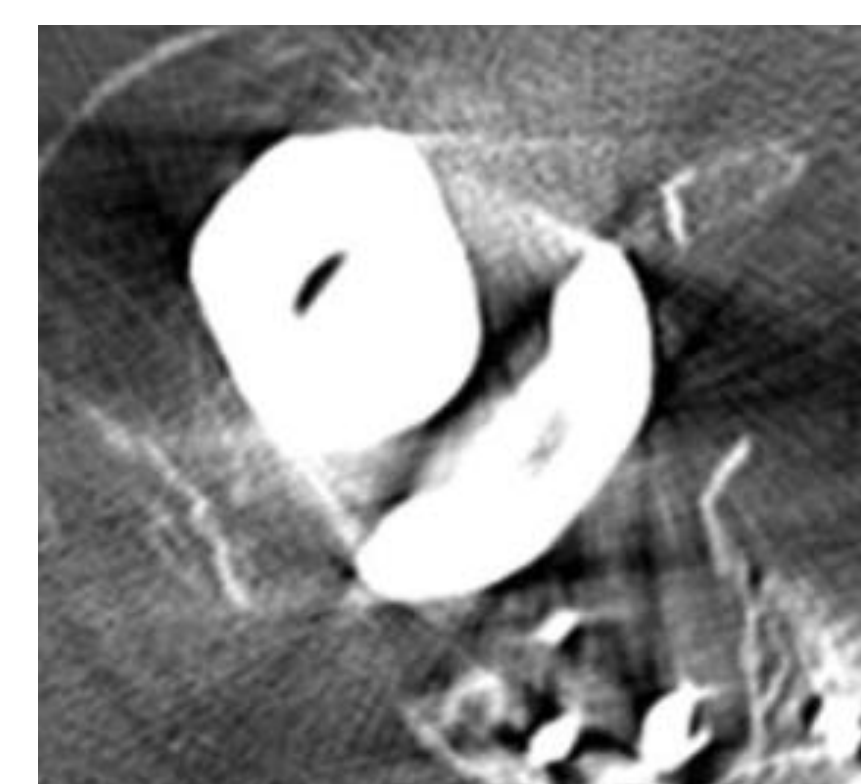
## Utilization of a 6-Axis Robot to Create Bone Grafts for the Reverse Total Shoulder Arthroplasty Procedure

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### Introduction

- Glenoid deficiency is a frequent complication which brings difficulty to the Reverse Total Shoulder Arthroplasty (RTSA) procedure [1]
- Missing glenoid bone stock leads to insufficient support for the baseplate of the implant to be inserted, which leads to early-on implant loosening and restricted motion for the patient [2],[3]
- Humeral head osteotomy autografts are used to replace missing bone stock in the glenoid
- Current methods involve eccentric reaming into the native glenoid, which can only be done for minor deformations and frequently result in implant loosening [4]
- Patient-specific bone grafts could provide a stable foundation for the implant



CT Scan of glenoid with deformation [1]

### Objectives

- Create patient-specific bone grafts using robotics to provide a perfect fit onto the native glenoid, a proper foundation for the implant, and remove no extra bone

### Research Methodology

#### Materials

- Medtronic Integrated Power Console (IPC) and EHS Stylus Surgical Drill for cutting into specimens
- 6-Axis Steward Platform robot to mount the drill and follow a computer-generated path
- Saw bone and porcine scapulae and humeral head osteotomies

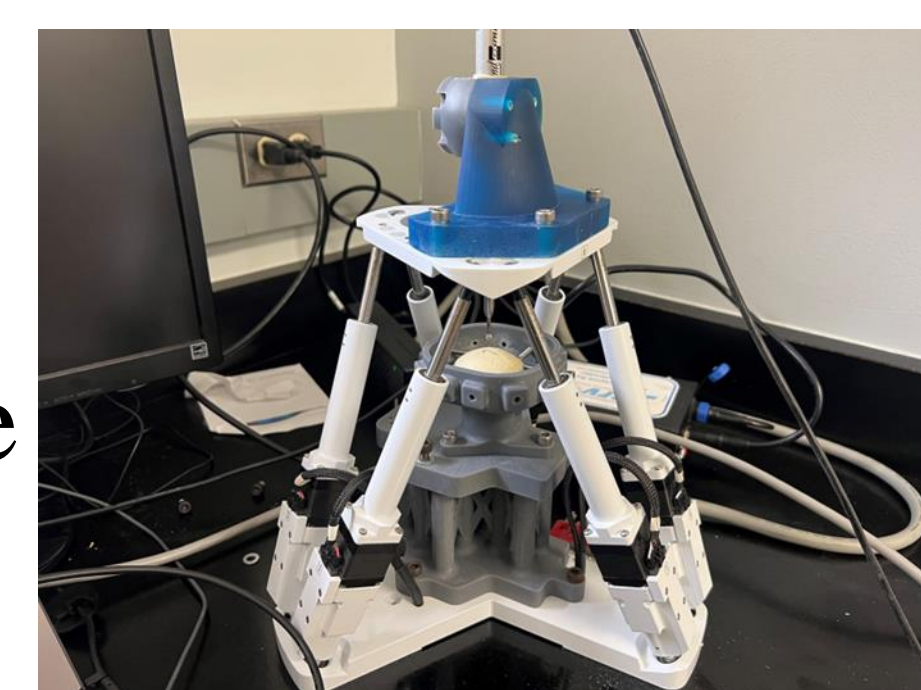


Figure 1: Robot drilling into osteotomy

### References

- [1] P. Boileau *et al.*, "Angled BIO-RSA (bony-increased offset–reverse shoulder arthroplasty): a solution for the management of glenoid bone loss and erosion," AVAILABLE: <https://www.sciencedirect.com/science/article/pii/S1058274617303105>
- [2] B. S. Werner, D. Böhm, A. Abdelkawi, and F. Gohlke, "Glenoid bone grafting in reverse shoulder arthroplasty for long-standing anterior shoulder dislocation," AVAILABLE: <https://www.sciencedirect.com/science/article/pii/S1058274614001566>
- [3] S. Virani *et al.*, "Management of glenoid bone loss with impaction and structural bone grafting in reverse shoulder arthroplasty," AVAILABLE: <https://doi.org/10.1007/s12306-022-00747-w>
- [4] S. Harmsen, D. Casagrande, and T. Norris, "'Shaped' humeral head autograft reverse shoulder arthroplasty," AVAILABLE: <https://doi.org/10.1007/s00132-017-3497-0>

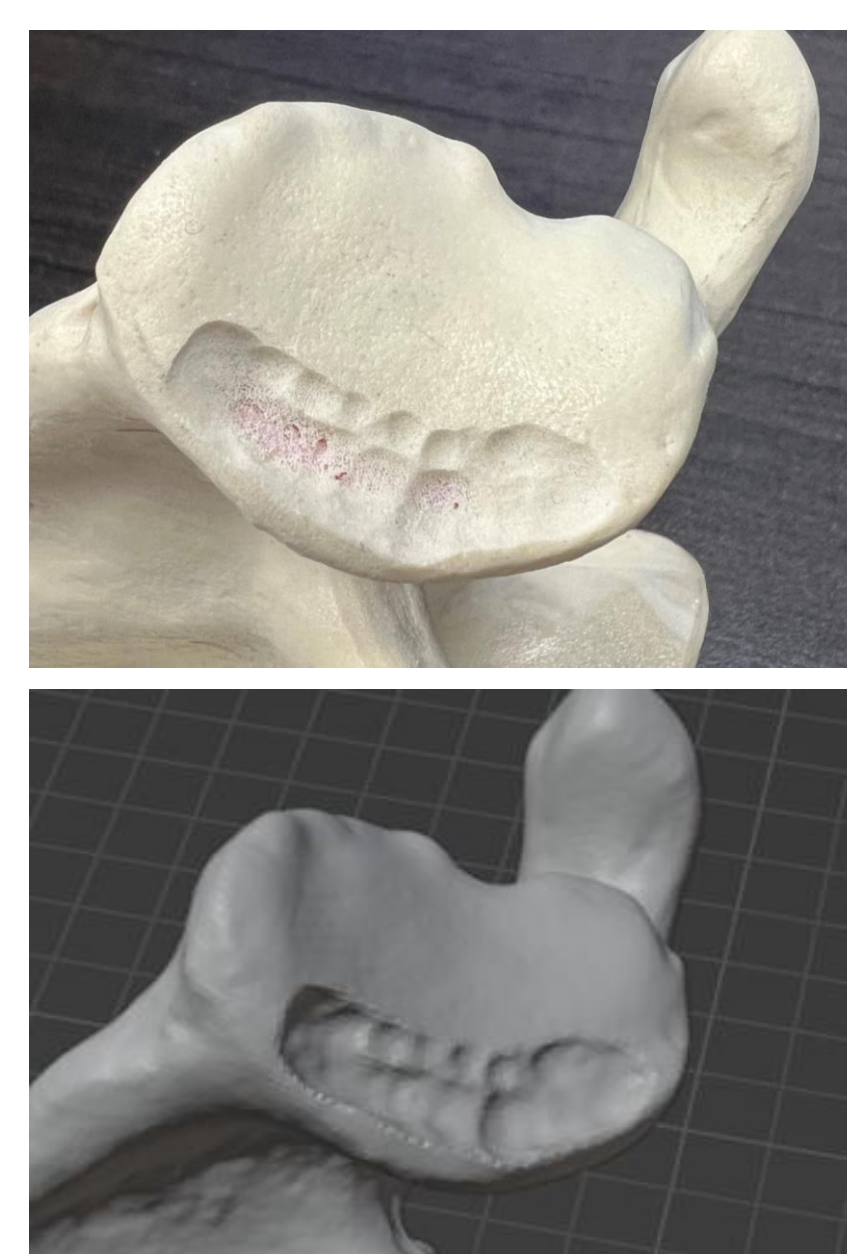
### Research Methodology

#### Materials

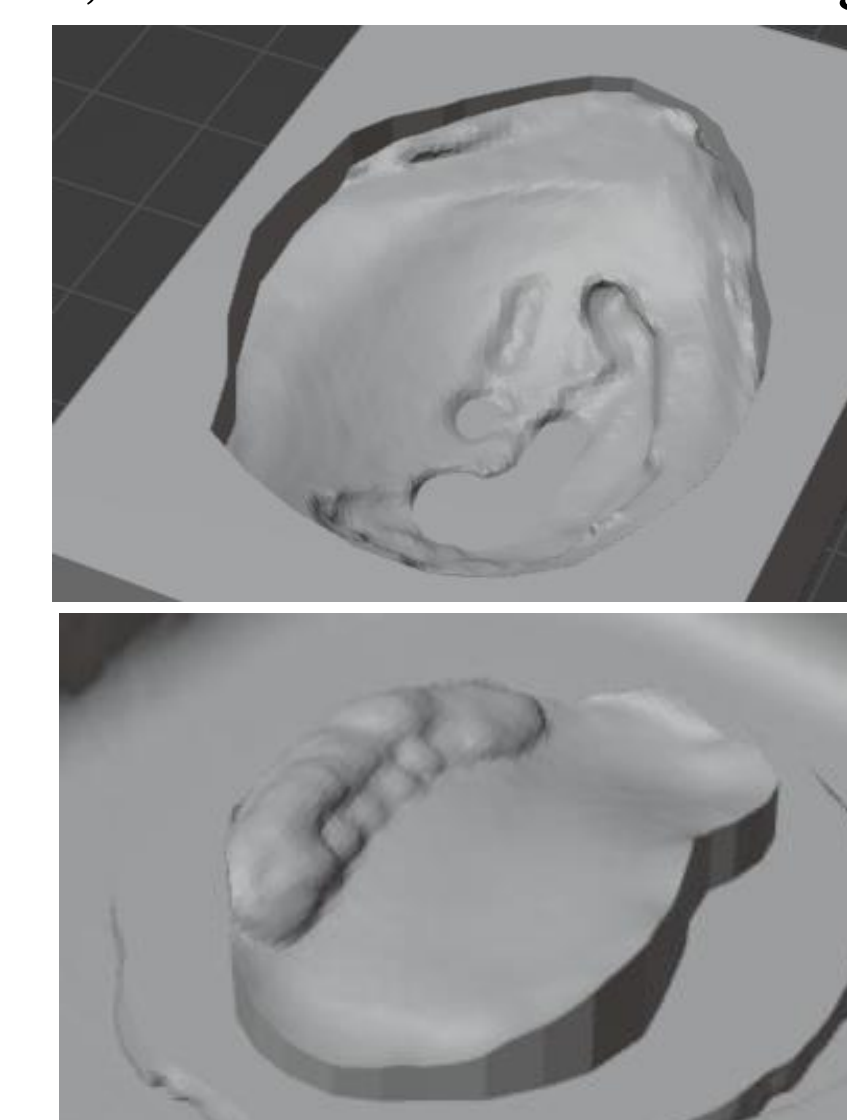
- Artec Space Spider 3D Scanner



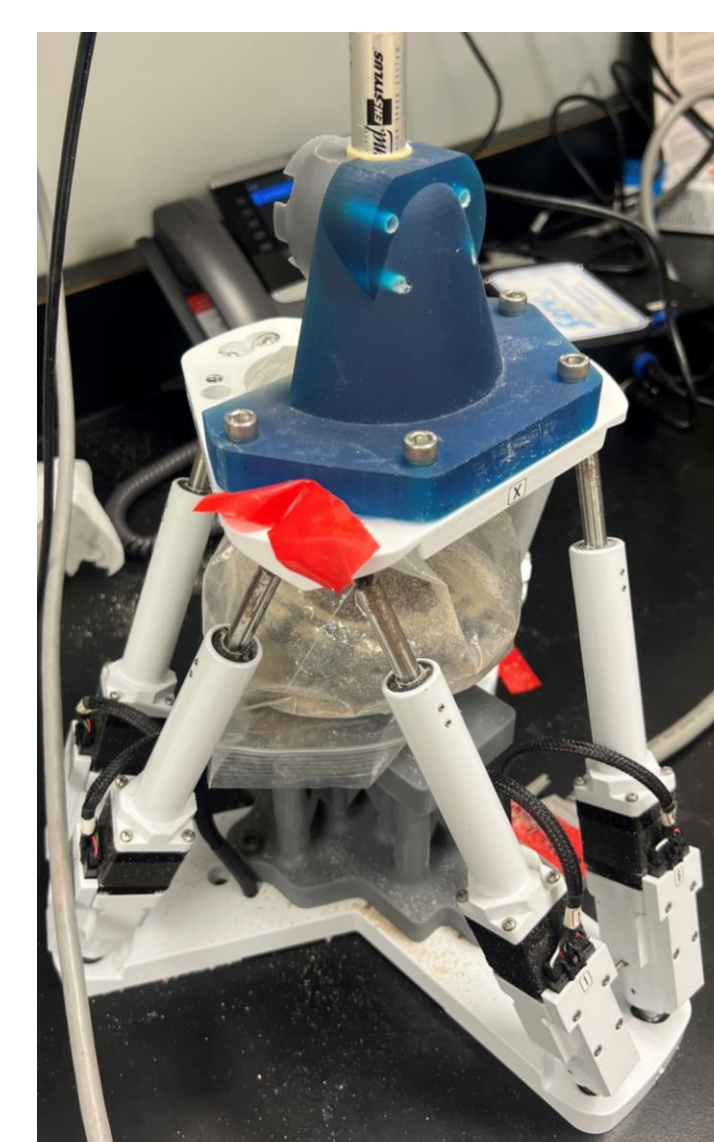
#### Methods



Figures 2&3: Glenoid with posterior defect, 3D Scanned model of glenoid



Figures 4&5: Mold of glenoid, Cast of glenoid on osteotomy



Figures 6&7: Robot milling into osteotomy, saw bone graft after milling operation

- Posterior defects made in the glenoid to resemble common cases in patients
- Scans of the deformed glenoid and humeral head are taken to register 3D models
- Artec Studio used to create scans

- Mold of glenoid is created to obtain a negative impression of the deformation
- Intersecting volumes of the mold and osteotomy are subtracted to obtain a cast of the glenoid
- Blender graphics software used to create molds and casts

- Toolpath is generated for the robot to mill out of the osteotomy using BobCAD
- Final result is scanned again to be compared to the computer-generated model

### Results

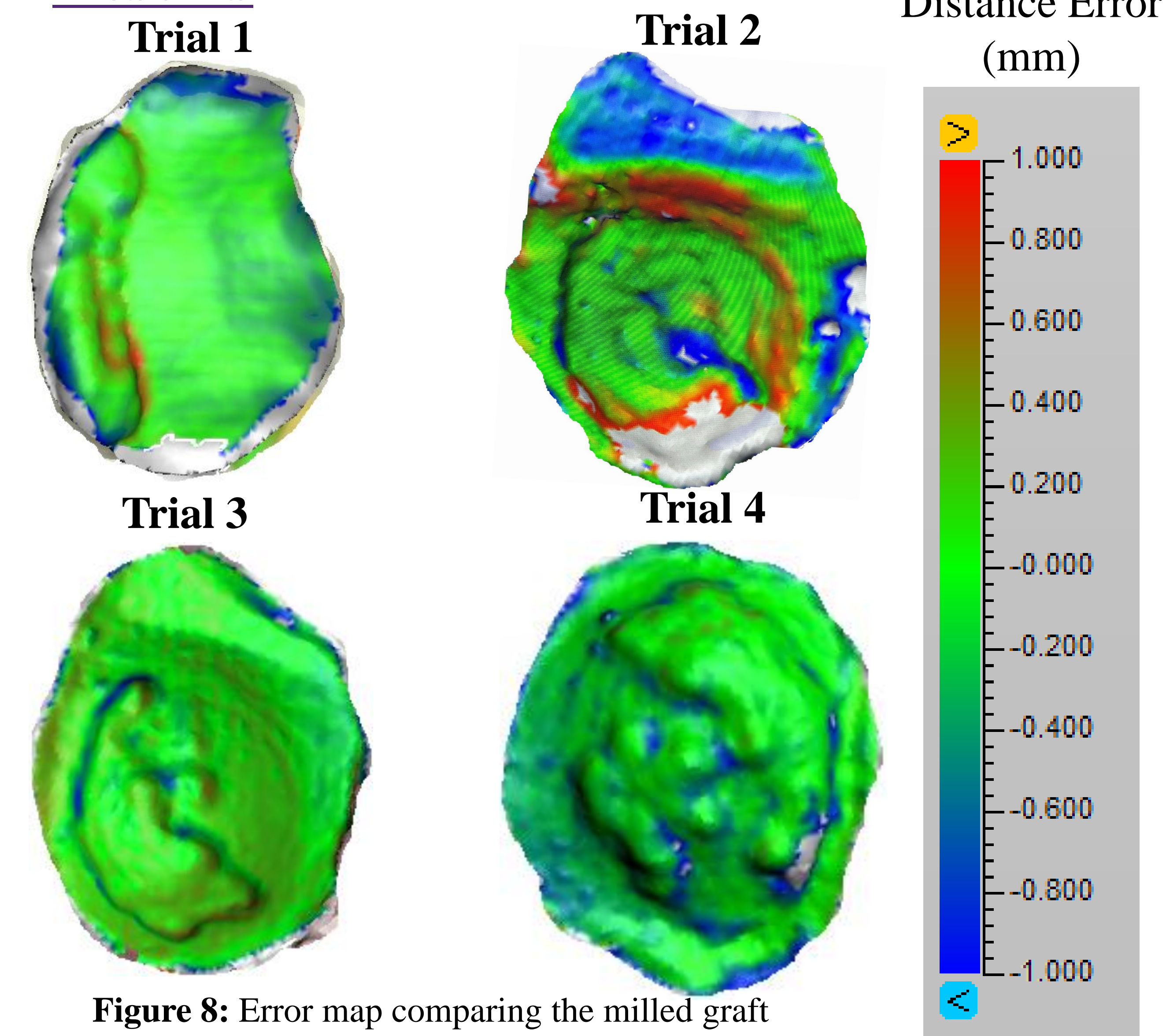


Figure 8: Error map comparing the milled graft to the computer-generated model



Figure 9: Scan of scapula with the bone graft on the glenoid

### Conclusions

- Robot is able to create accurate cuts representing the native glenoid and its deformation
- Correlation between milling speed & step size and resulting error
- Restocks missing bone and restores the glenoid version angle without the need for extra reaming
- May reduce complications such as bone resorption, baseplate loosening, or restricted range of motion
- Lowers chances for the need of a revision surgery