Machine learning and patient-specific biomechanical methods for assessing outcome in total shoulder arthroplasty

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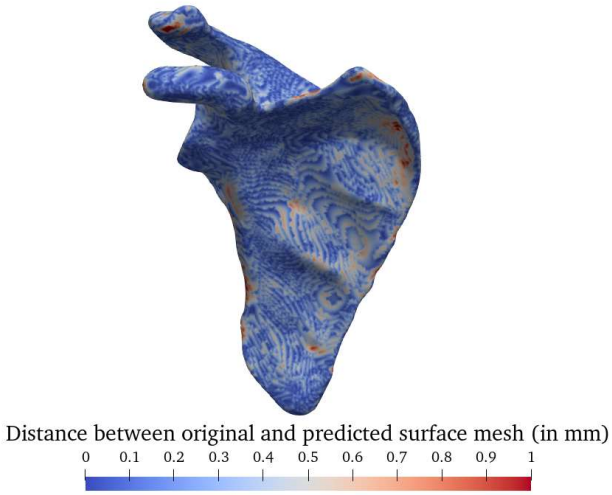
Background & Goals

- Glenohumeral osteoarthritis is increasing worldwide, as in Switzerland, because of the aging population.
- Total shoulder arthroplasty (TSA) is becoming a common surgical procedure intended primarily to relieve pain and disability associated with glenohumeral osteoarthritis and restoring the range of motion.
- However, the success rate of TSA remains poor compared to other main total joint replacements such as hip or knee [1].
- There is a lack of clear indicators able to predict the long-term success of TSA.
- The complex biomechanical configuration of the glenohumeral joint could explain this and potential causes for the observed complications.
- Thus, we propose **image analysis and deep learning-based approaches** to quantify all potential preoperative mechanical markers and identify the ones that are critical to the success of TSA.

Segmentation of Healthy and Pathological Scapulae

- The segmentation is conducted by a Convolutional Neural Network (CNN) based network (UNet).
- Axial slices of CT scans of patients (2D) and volumes of these axial slices (3D) are utilized to conduct the segmentation.
- For healthy scapulae, an average **Dice coefficient of 0.956**, **Hausdorff distance of 3.61 mm** and **average surface distance of 0.14 mm** are achieved.
- For pathological scapulae, **an average Dice coefficient of 0.931**, **Hausdorff distance of 5.94 mm** and **average surface distance of 0.29 mm** are achieved.



Landmark Detection on Scapulae

- Surgical planning is based on the anatomical axes of the scapula, which are used to quantify glenoid version and inclination and plan the position of the prosthesis to correct glenoid erosion [2].
- Specific landmarks identified on the scapula could be used to quantify its 3D anatomy.
- The idea is to predict the geodesic distances between all points and predetermined landmarks on scapula.
- Two different approaches are being investigated:
  - **Image space** → Geodesic distance between all **voxels** and predetermined landmarks with CNN
  - **Shape space** → Geodesic distance between all **nodes** and predetermined landmarks with Graph Neural Networks

Future Work

- Estimation of pre-morbid states of muscles and bones in the shoulder with deep learning-based approaches.
- Investigation of micro-CT images to understand bone anisotropy.
- Prediction of the best implant position based on different markers that will be investigated throughout the project.

References

[1] Singh, J. A., Sperling, J. W., Cofield, R. H. (2011). Revision surgery following Total Shoulder Arthroplasty: Analysis of 2,588 shoulders over 3 decades (1976–2008). J. Bone Joint Surg. Br. 93.
[2] Thomazeau, H., Rolland, Y., Lucas, C., Duval, J. M., Langlais, F. (1996) Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. Acta Orthop Scand. 67:264–8.