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FÉDÉRALE DE LAUSANNE

Measuring the Critical Shoulder Angle in CT scans of normal and pathological shoulders

A semester project in the Laboratory of Biomechanical Orthopaedics

By

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supervised by

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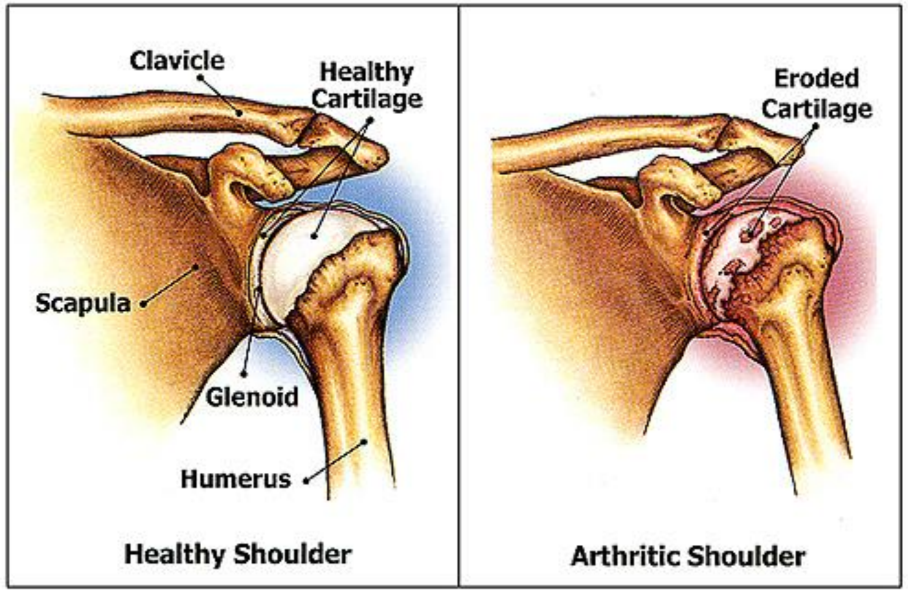
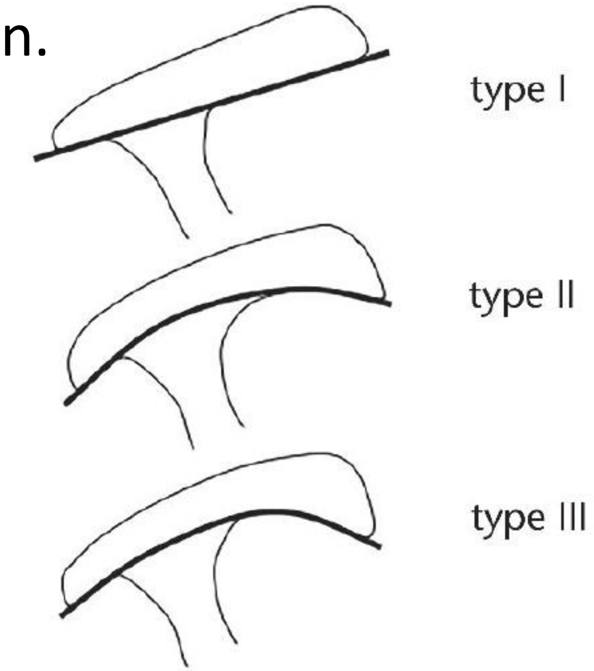
Motivation

- Shoulder pathologies are a very common cause of functional difficulties in elderly patients. ~38% of 60+ citizens in the US have osteoarthritis (OA) of the shoulder.
- Pathologies have been linked with different acromial shapes.
- Researchers have come up with ways to classify the acromion.

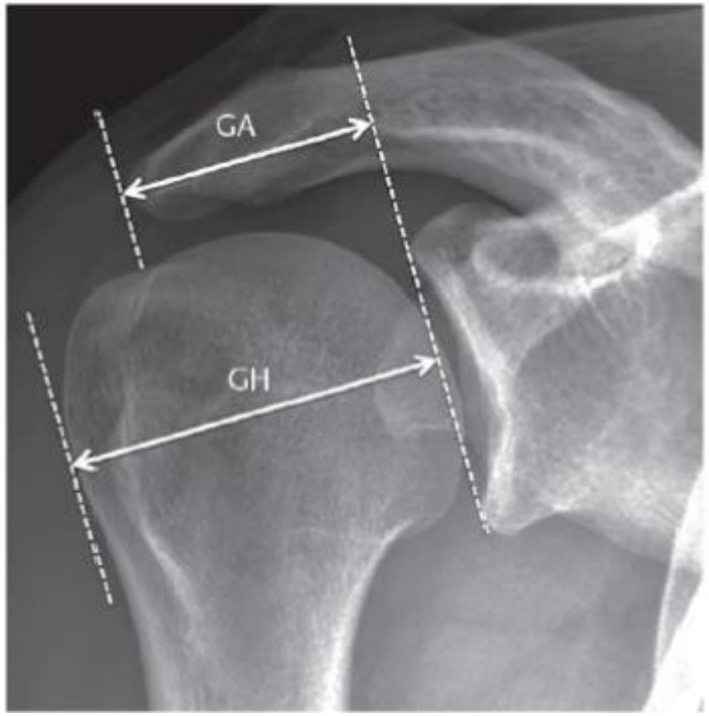


http://progressiveptinc.com/physical-therapists-guide-to-osteoarthritis-of-the-shoulder/

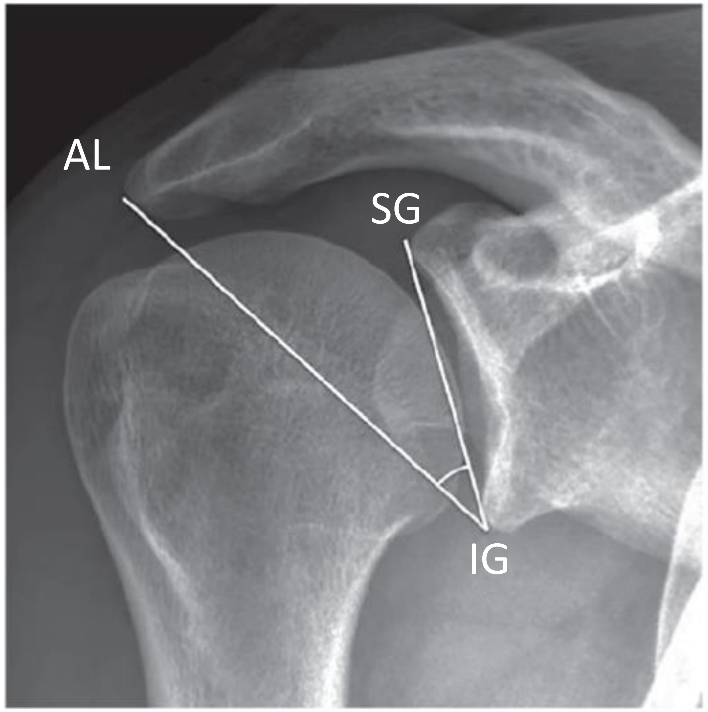


EFORT Open Rev 2017;2. DOI: 10.1302/2058-5241.2.160076.

CSA & AI : What are they?



AL : Acromion Lateral
IG : Inferior Glenoid
SG: Superior Glenoid



Acromion Index (AI) : Ratio of GA to GH
Critical Shoulder Angle (CSA) : Angle formed between lines connecting IG to SG, and IG to AL.

Both parameters have been found to correlate with both rotator cuff tears and osteoarthritis.

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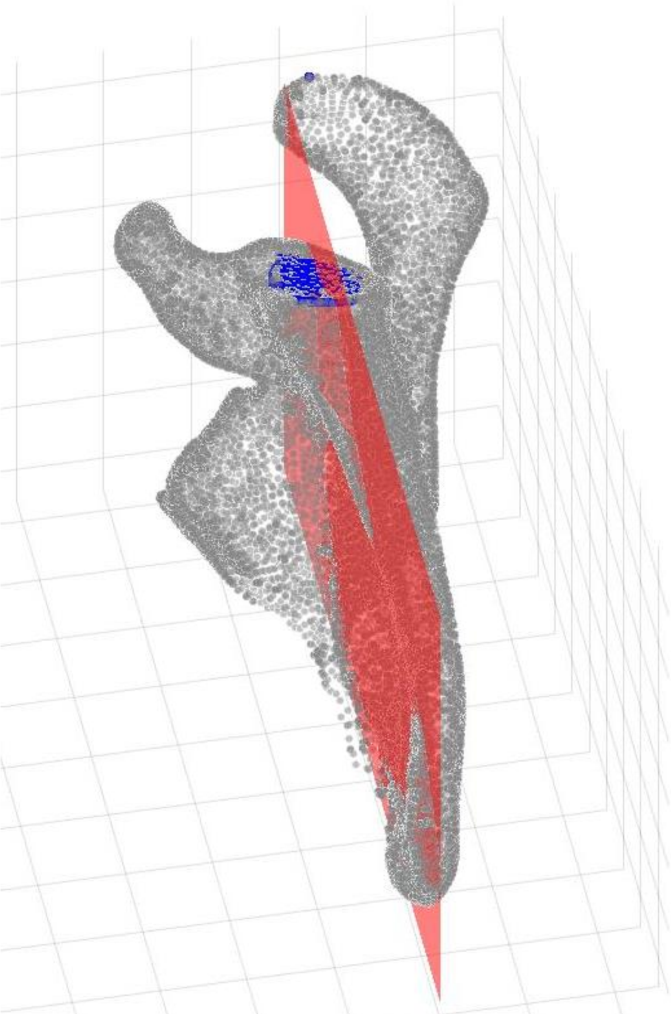
Objective

- Can the Critical Shoulder Angle (CSA) be used as a substitute for the Acromion Index (AI)?
- As of now, the LBO has developed a method to calculate the AI.
- I will calculate the CSA to determine if it will prove to be a better parameter in predicting OA.
- I will then automate the process of segmentation and measurement.

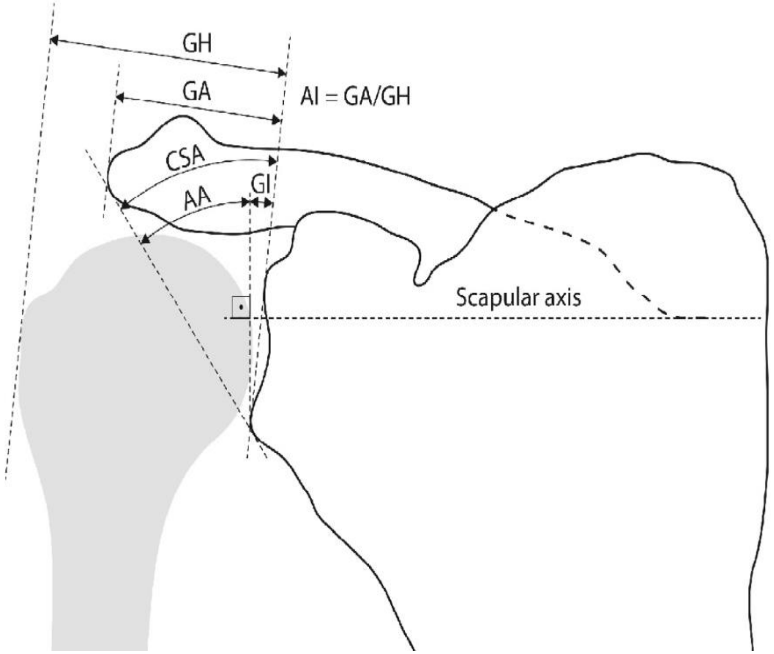
Methods

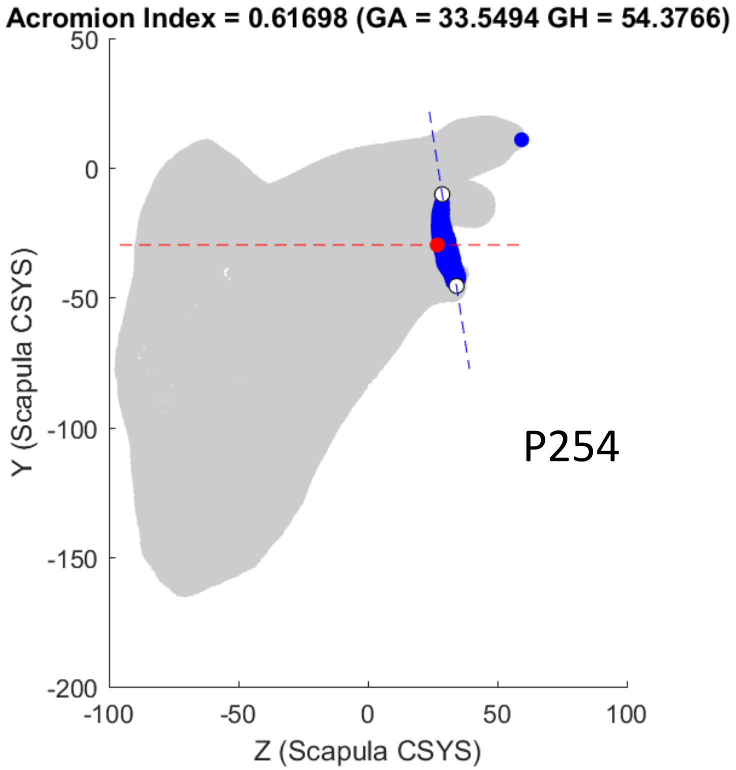
- Measuring the Acromion Index (AI)
- Measuring the Critical Shoulder Angle (CSA)
- Automating the scapula segmentation
- Automating the glenoid extraction
- Automating the measurements themselves

Measuring the Acromion Index



- Glenoid surface points projected in scapular plane
- Principal axes of points
- Major axis passing through superior lateral point
- GA = Distance from axis of most lateral acromion point (SSM)
- GH = diameter of humeral head (5 landmarks)





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This slide had been created by Dr. Alex for a previous presentation

Measuring the CSA

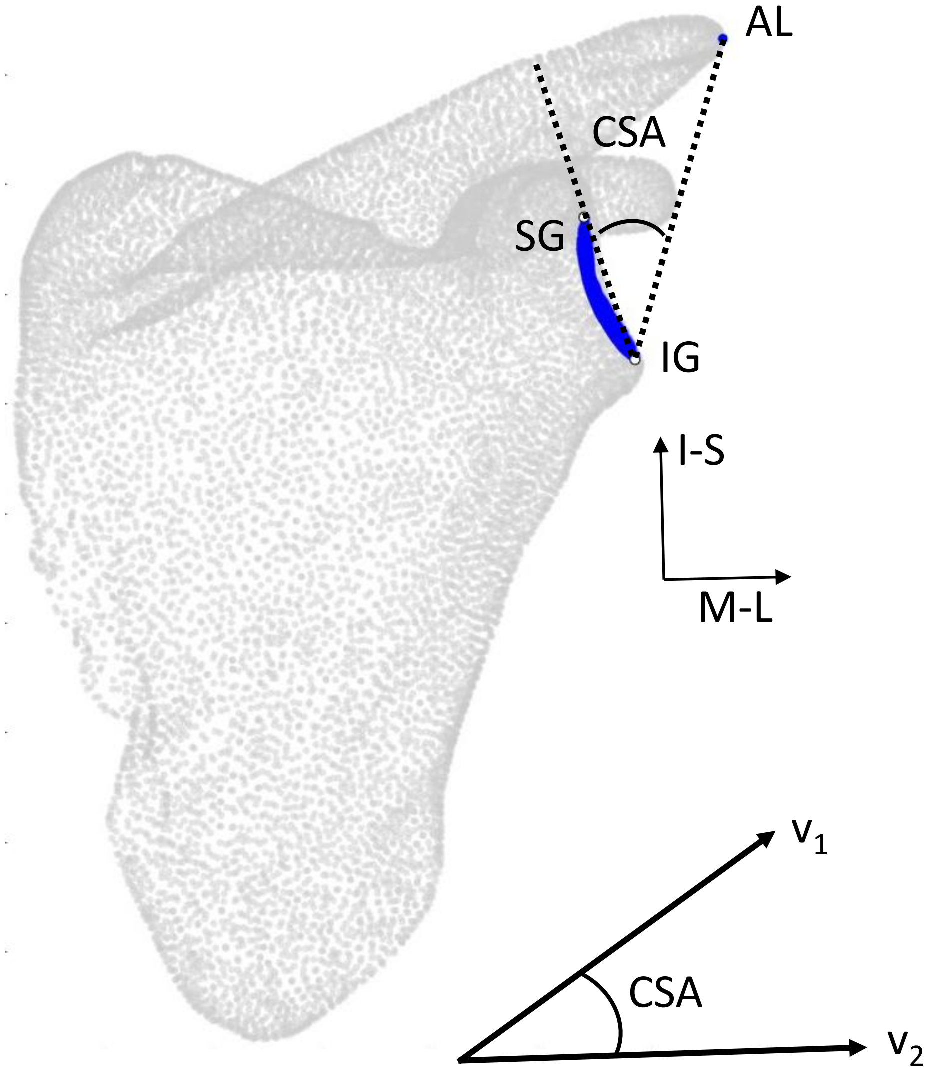
- The Inferior Glenoid and Superior Glenoid are identified as the most inferior and superior points of the glenoid in the I-S axis.

- The Acromial Lateral is defined as the most lateral point of the scapula in the M-L axis.

- Two vectors (v_1 and v_2) are used to connect the IG to the SG and the IG to the AL.

- To calculate CSA we use the dot product rule:

$$\boxed{|v_1|\,|v_2|\cos(CSA) = v_1^T v_2}$$



Automation

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Scapula segmentation

- Run on lbovenus.epfl.ch using putty
  - Loop through each folder OR loops through files provided in a list
  - Output : <u>scapulaSurfaceAuto.ply</u>

Glenoid extraction

- Manual extraction (more reliable)
  - Output : <u>ExtractedSurfaceP224.stl</u>
- Automatic extraction
  - Loop through all existing scapulae and extract glenoid
  - Output : <u>glenoidSurfaceAuto.ply</u>

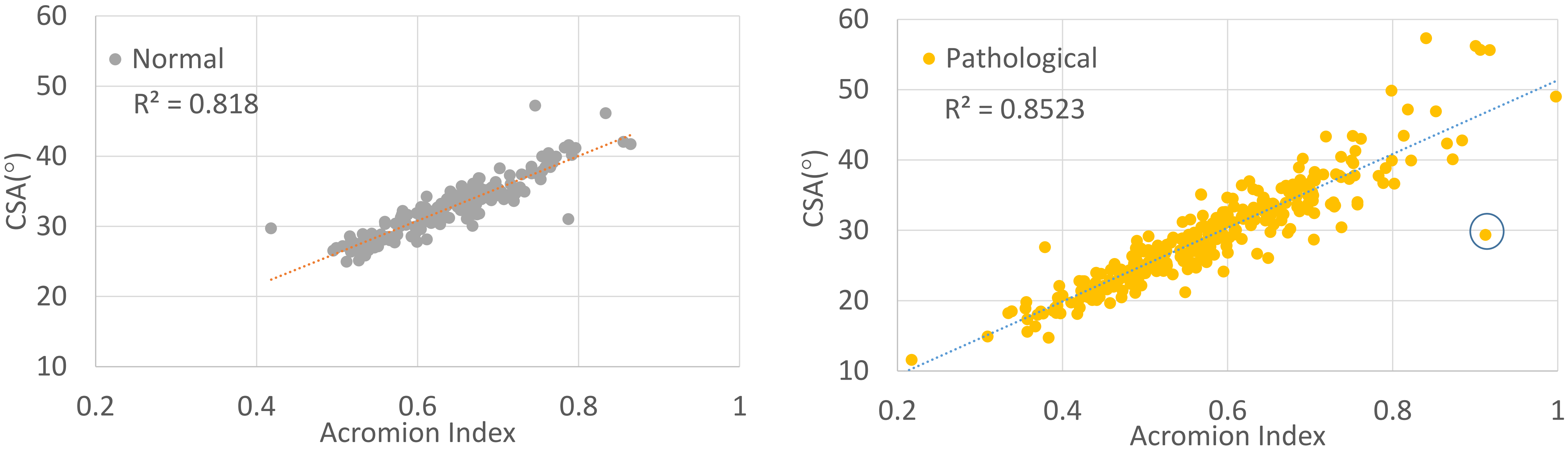
Measurements

- Method 1
  - Done along with the automatic scapula segmentation.
  - Only identifies landmarks.
- Method 2
  - Loops through each segmented scapula and calculates AI and CSA.

Results & Discussion

- Establishing the relationship between CSA and AI
- AI, CSA and their relationship with OA and CTA
- Suboptimal automatic glenoid extraction

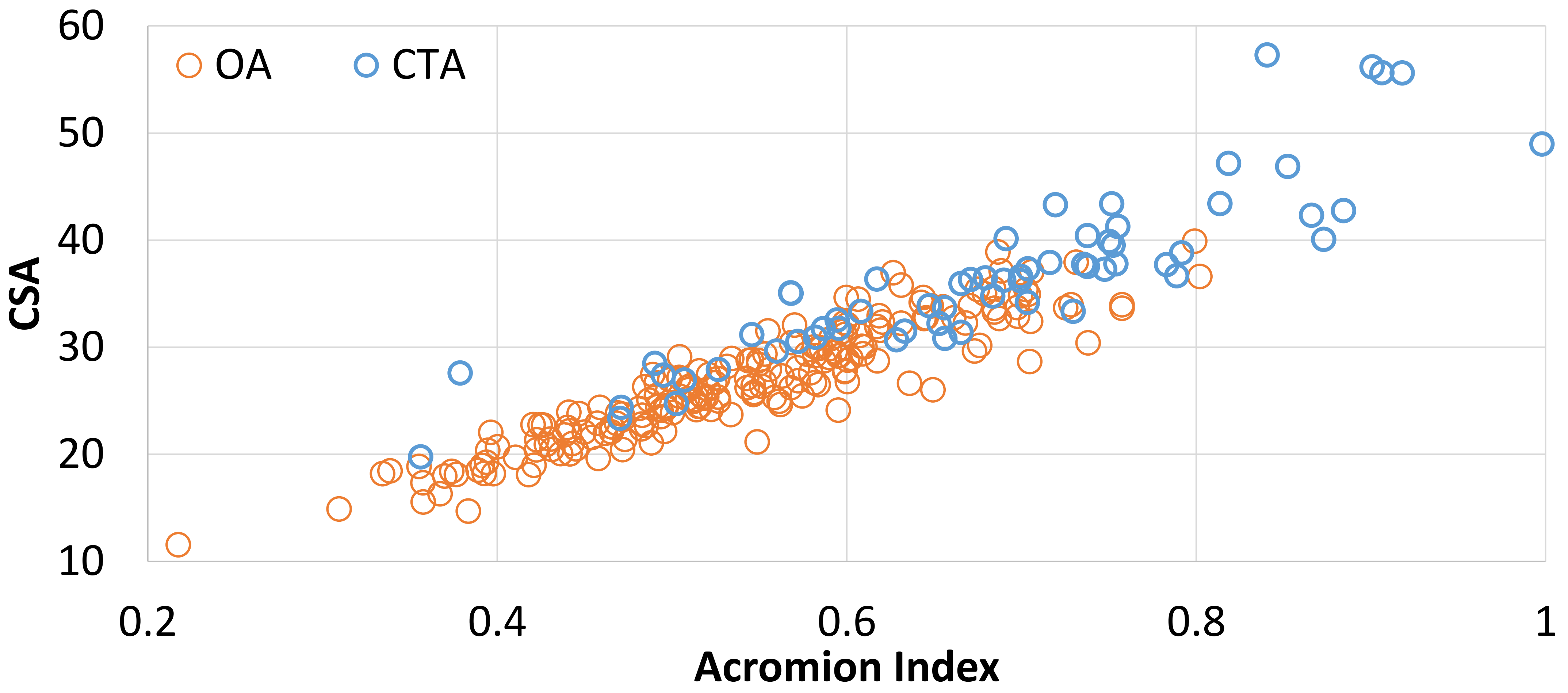
CSA vs AI



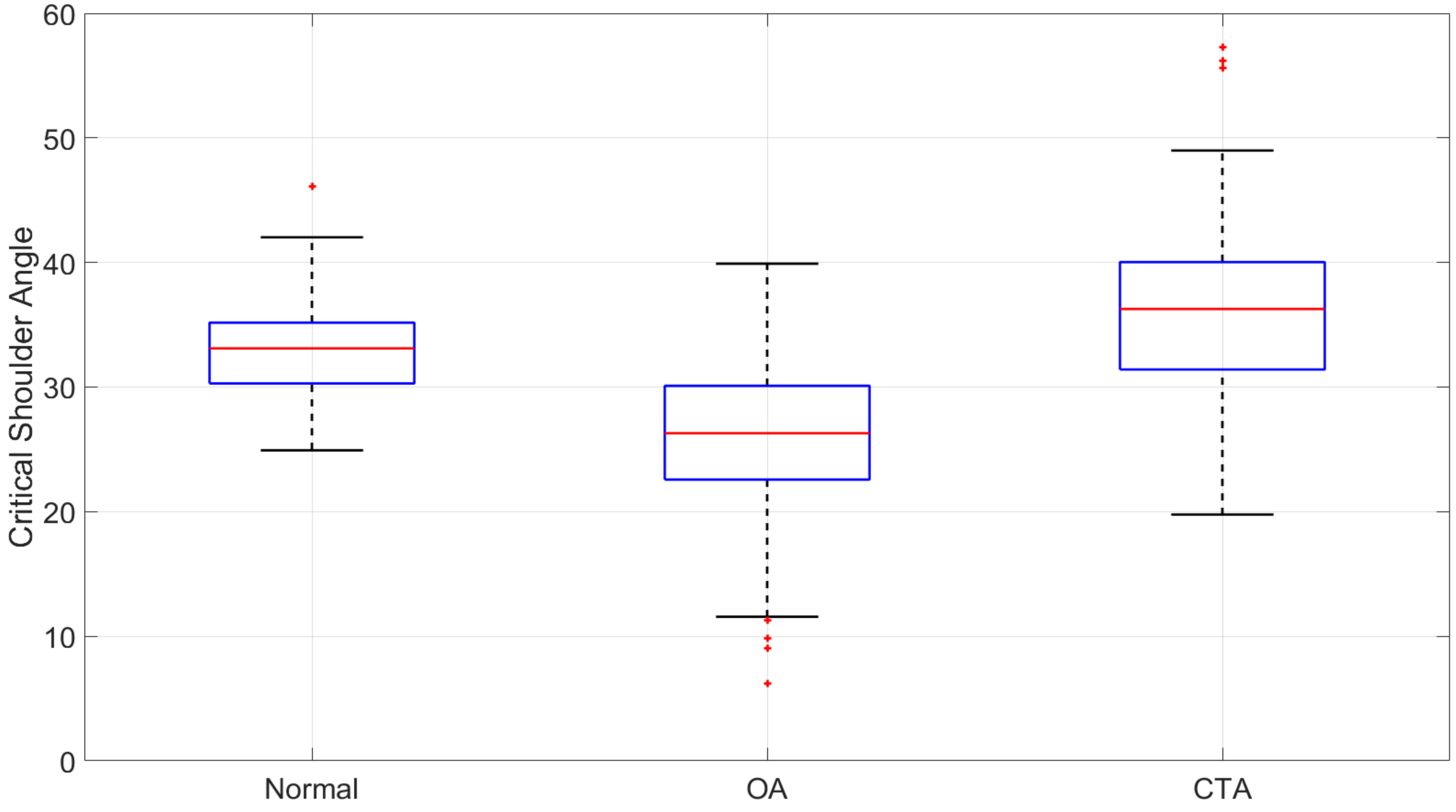
Data points

- Normal : 176, Pathological : 290 (205 have <u>osteoarthritis</u>, 60 have <u>cuff tear arthropathy</u>)

CSA vs AI – separating OA and CTA

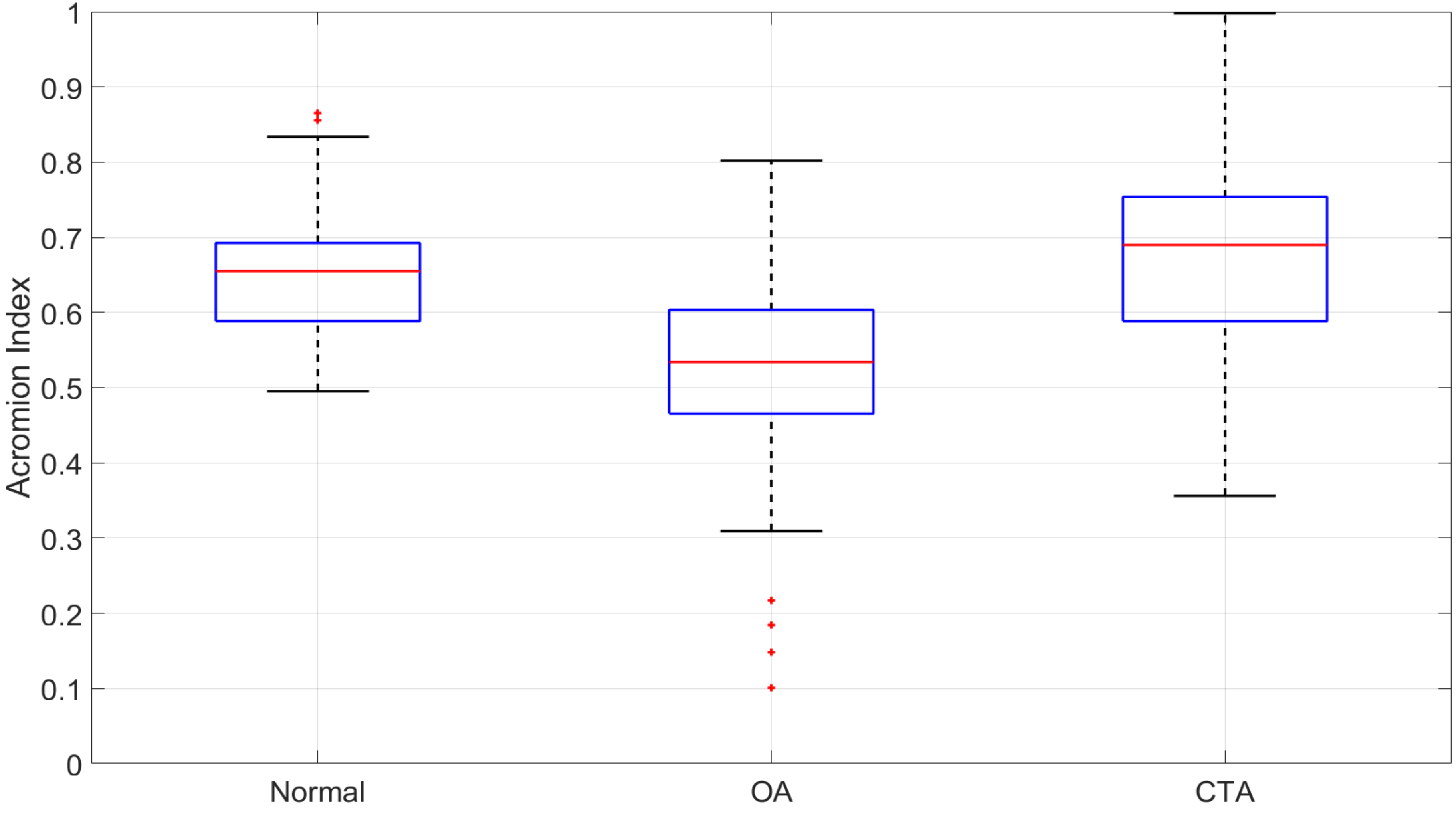


CSA, OA and CTA



	CTA	OA	Norm.
Mean	36.45	26.31	32.94
SD	7.78	5.8	4.15

AI, OA and CTA



	CTA	OA	Norm.
Mean	0.682	0.544	0.648
SD	0.133	0.173	0.08

Statistical effects

Cohen's D	CSA	AI
OA w CTA	1.59	0.84
OA w Normal	1.31	0.75
<u>CTA w Normal</u>	<u>0.66</u>	<u>0.35</u>

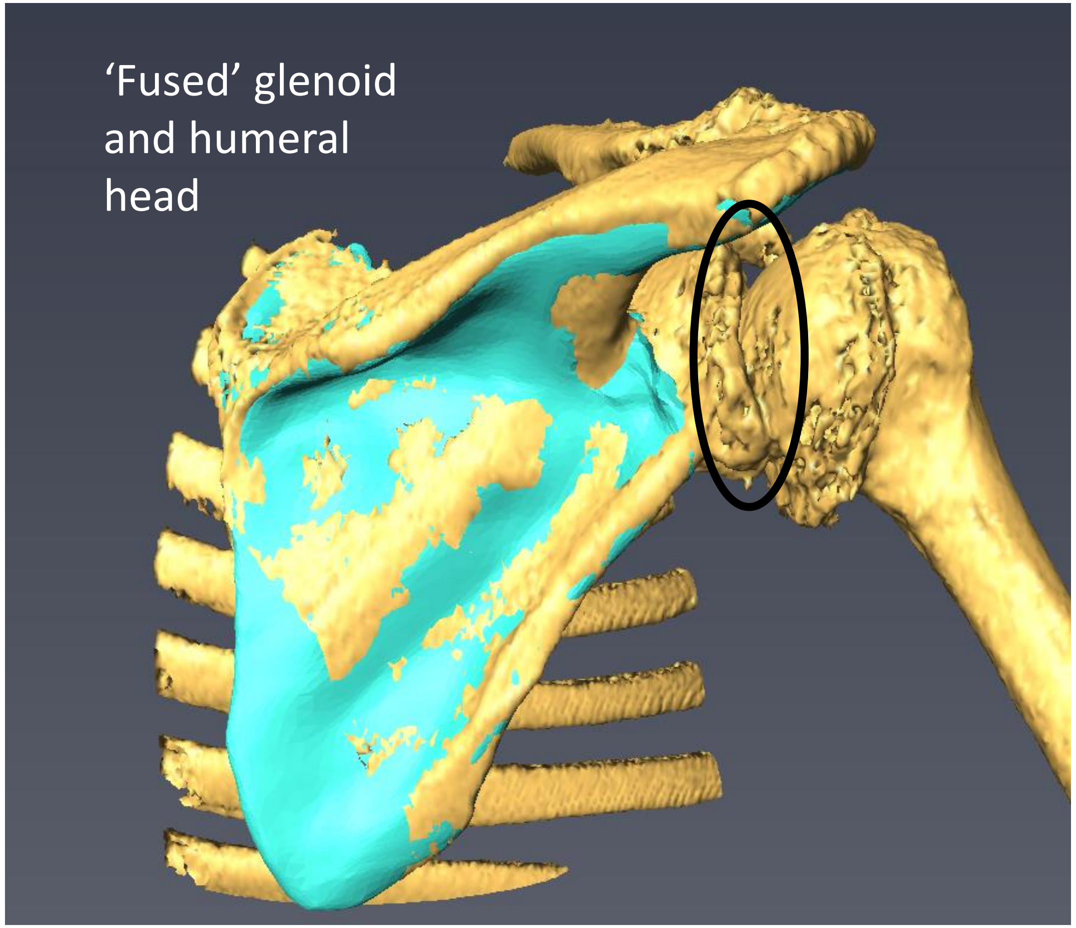
- P- value is ~**1e-08**.
- This tells us that the difference is *significant* and cannot be put down to variability in sampling.
- Knowing that they are different is not enough. We want to quantify the extent of this difference.
- Cohen's d gives us an estimate of the size of the effect or difference.

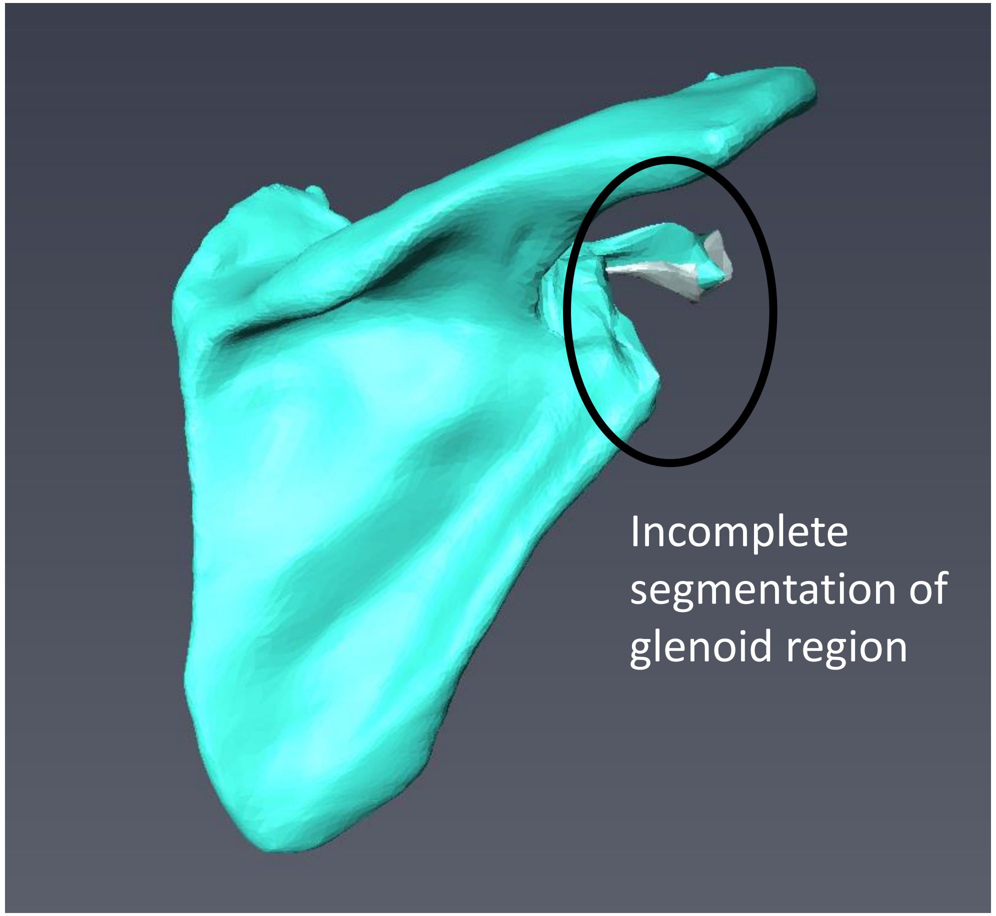
Comparison of CSA with other studies

CSA	Normal	OA	RCT/CTA
LBO	32.94	26.31	36.45
Moor	33.1	28.1	38.0
Ulrich	32.7	28.7	37.3
Arnar	33.3	31.1	33.9

Arnar: the CSA is a better indicator of OA than RCT

Issues with scapula segmentation





Conclusion

- CSA can be safely used as a proxy for AI.
- It might be better to use CSA alone as an indicative parameter
  - For AI, you also need the humeral head. Currently this is not segmented automatically.
  - For CSA, you only need the glenoid surface and the acromion, both of which are segmented already.
- The relation between CSA and OA is stronger than its relation to CTA. This is in line with the findings of Arnar et al.

References

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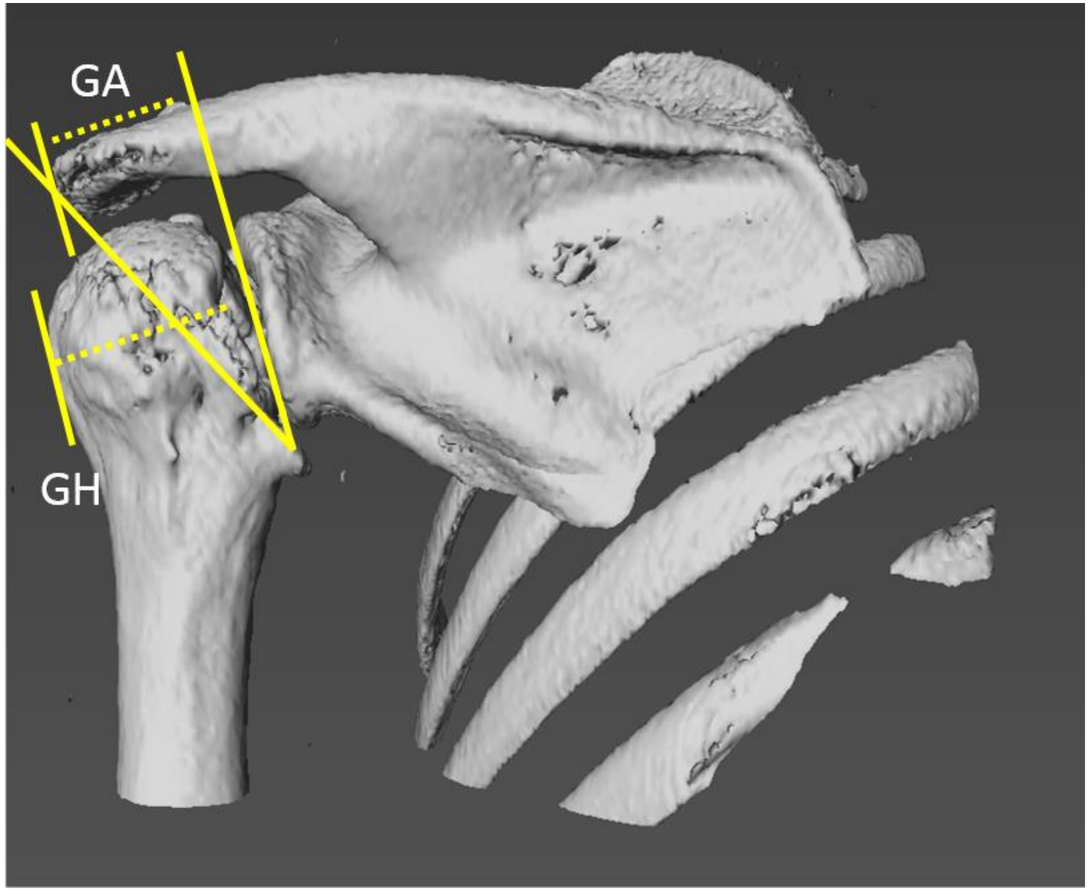
Motivation

- Large dataset of normal and pathological shoulder CTs ~600
    - ~200 Normal
    - ~340 Pathological, mainly Osteoarthritis
- Objective : Verify certain geometric parameters and see if they correlate with any pathologies.
- At the start of the project, we had around 30 Normal and 30 Pathological CTs for which segmentation had been done manually.
- After manual segmentation, the humeral head, **glenoid**, and the scapula plane were all identified using manual landmarks.
- In addition, we only calculated the Acromion Index.
- Shoulder pathologies are a very common cause of functional difficulties in elderly patients for example.

An Interesting Case



- Case P 274 – Avascular Necrosis
- Acromion Index ~0.9
- CSA only 29.3
- Cause: Flattened humeral head

My Objective

- Create a simple way to calculate the Critical Shoulder Angle as well.
- Apply the new measurements to existing data.
- Extend the dataset
  - Use the automatic scapula segmentation algorithm (Berne)
  - <u>Automate the entire process</u> of segmenting each scapula and performing measurements
- Try to segment the <u>glenoid automatically</u> as well, instead of relying on the landmarks

Automation

- Scapula Segmentation
  - Loop through all patient folders and perform the scapula segmentation and store it as a .ply file.
  - Took a number of iterations and bug reports to the developers at Berne
  - Each scapula takes around 12 – 15 minutes to segment and save.
- Glenoid Extraction
  - Used pieces of the Berne code to create my own glenoid extraction algorithm.
  - Major intricacy was figuring out how to match the correct faces and vertices of the scapula that needed to be stored as the glenoid.
  - Looped through all the existing scapulae after they were segmented.
- Actual measurements
  - Least problematic of the lot.
  - Simple looping through all the existing scapulae and glenoid combinations
  - Can use the manually identified glenoid OR the automatically extracted glenoid