Biomechanical Characterization of Isolated Acromioclavicular Joint Stability

Gyu Rim Baek BS, Min-Shik Chung BS, Gyuna Baek, Owen Kao BS, Genevieve Fraipont, Blake Dee, Aaron T. Hui BS, Michelle H. McGarry MS, Gregory Adamson MD, Thay Q. Lee PhD

Orthopaedic Biomechanics Laboratory, Congress Medical Foundation, Pasadena, CA

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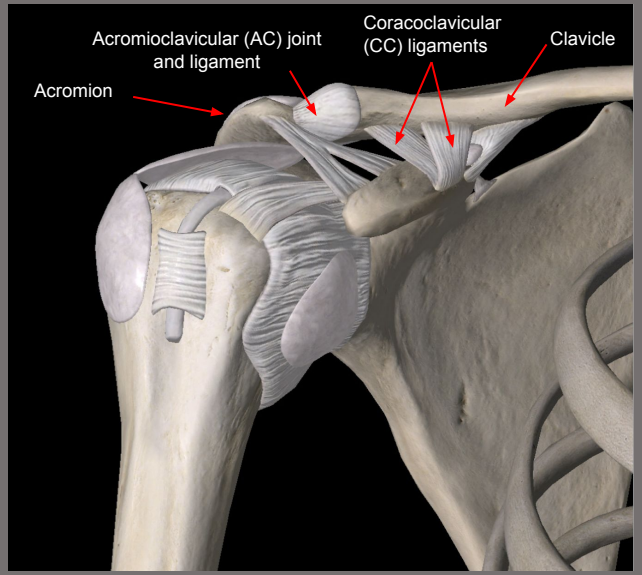
AC Joint Injury

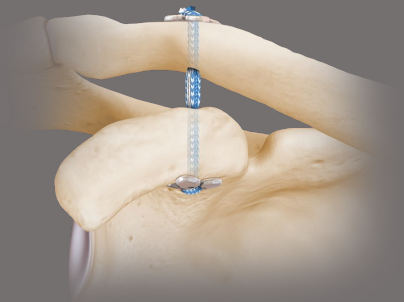
- AC joint dislocation accounts for 12% of shoulder injuries
  - Young patients < 30 yo
  - Contact sports



Hyland et al. StatPearls 2022
Saccomanno et al. JOINTS 2014
Sirin et al. EFORT 2018
Nakazawa et al. AJSM. 2016
Adam FF Int Orthop 2004

AC Joint Surgical Reconstruction

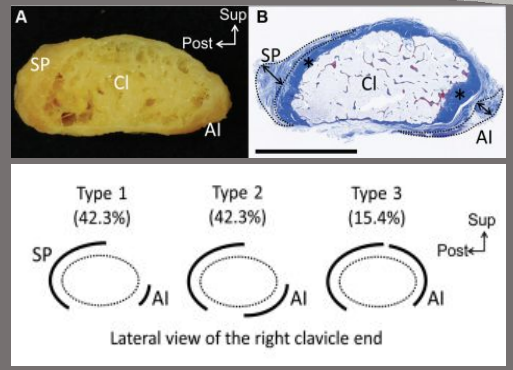
- There are many surgical procedures described but no gold standard
- Reconstruction mainly focused on the CC ligaments
  - Complications range from 27%-44%
- Failures and high complication rates may be due to horizontal or rotational instability
- Better biomechanical understanding of isolated AC joint is needed



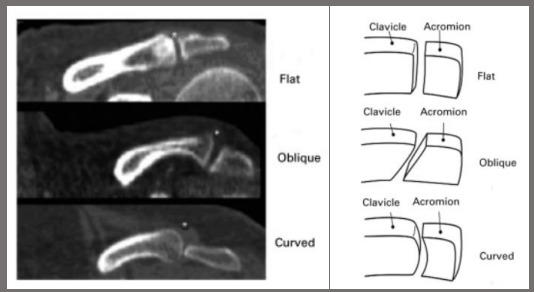
Shin et al. AJSM 2009
Martetschläger F et al. AJSM 2013
Berthold et al. BMC Musculoskeletal Disorders, 2022

Previous AC Joint Biomechanical Studies

- CC ligament contributes to SI stability and AC ligament contributes to AP stability
  - Isolated AC joint not evaluated
- Anatomical description of AC ligament
  - Well developed SP bundle
  - Less developed AI bundle
- AC Joint morphology using radiographic analysis has been described
  - No correlation to stability
- Lack of biomechanical understanding of the role of the AC ligaments



Nakazawa et al. AJSM 2016



Colegate-Stone et al, JBJS 2010

Objective/Hypotheses

Objective:

To biomechanically evaluate the isolated AC joint specifically :

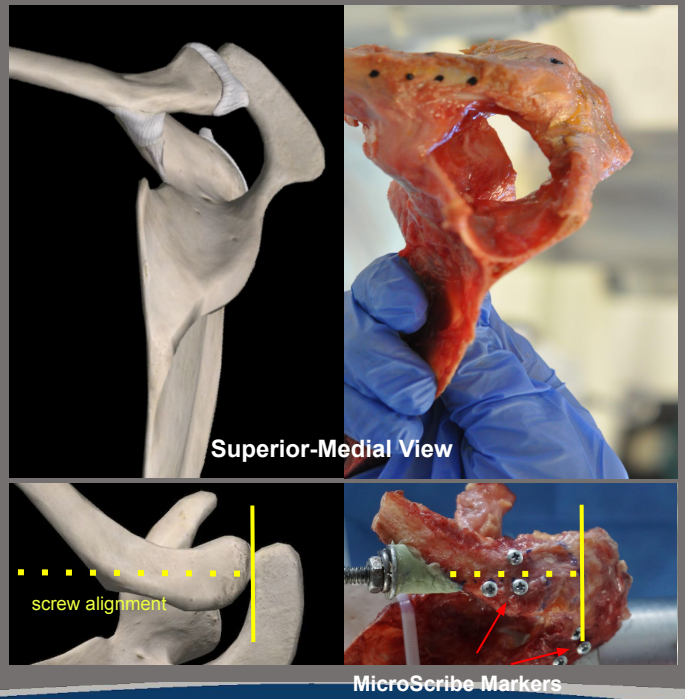
- Contribution of the SP and AI ligamentous structures
- Influence of morphology on translational and rotational stability

Hypotheses:

- Instability
  - SP Tear > AI Tear
  - Flat morphology > non-flat morphology

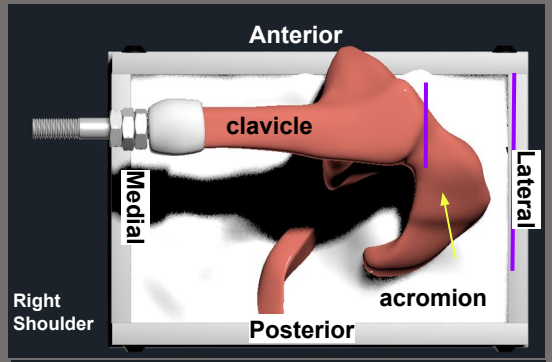
Specimen Preparation

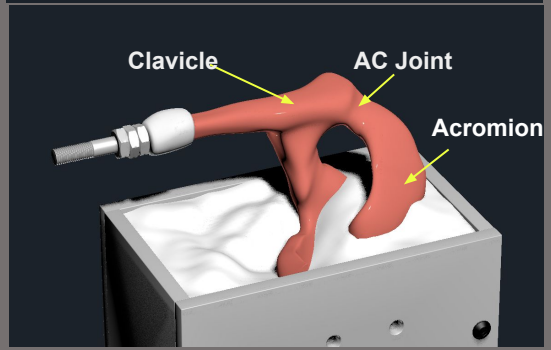
- Specimens dissected isolating:
  - AC joint
  - CC ligament
  - CA ligament
- Intramedullary screw inserted perpendicular to the distal clavicle
- Six screws for digitizing markers (MicroScribe 3DLX)
  - 3 Clavicle
  - 3 Acromion



Specimen Potting

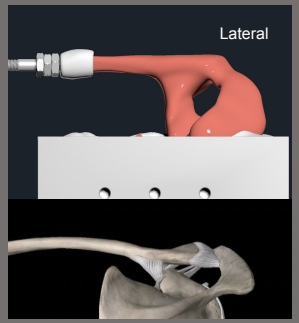
- Scapula potted in a rectangular metal box with plaster of Paris
  - Clavicle parallel to top and anterior sides of the box
  - Distal clavicle parallel to the lateral side

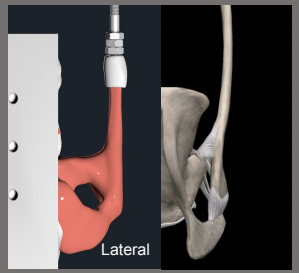


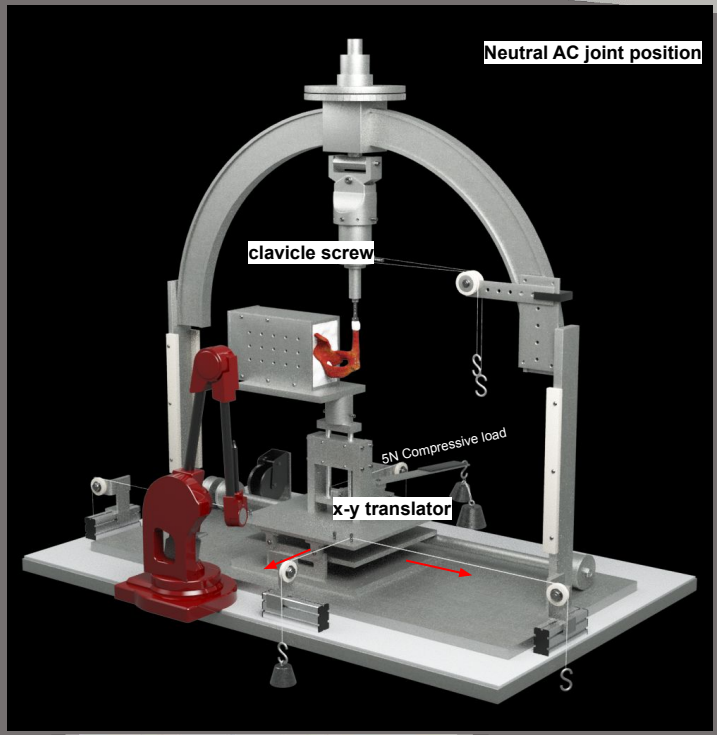


Specimen Mounting

- Scapula box mounted on linear bearing attached to x-y translator
- Clavicle mounted and aligned at 0°(Neutral clavicle)
- CC ligament and CA ligament transected after determining neutral AC joint position
- Intact AC Ligaments tested
  - n = 21 (8F, 13M, 63 ± 2 years)

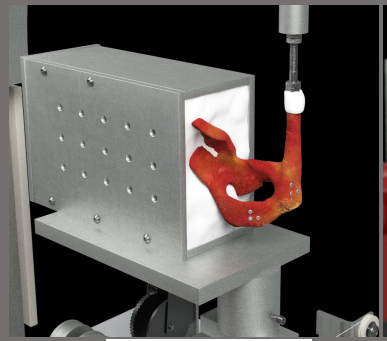




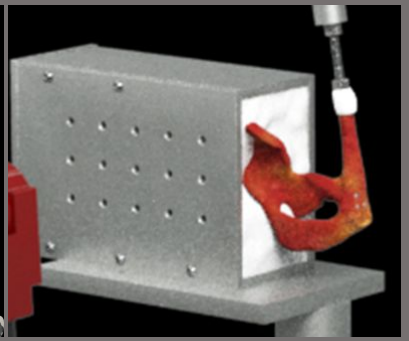


Testing Positions

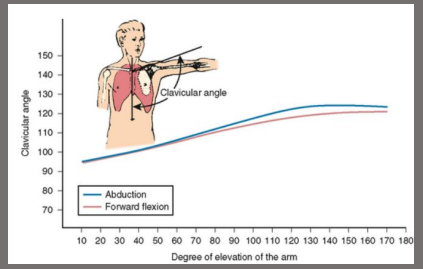
- Neutral Clavicle
- 10° Clavicle elevation
  - Arm positions
  - muscle loading
  - torn ligaments

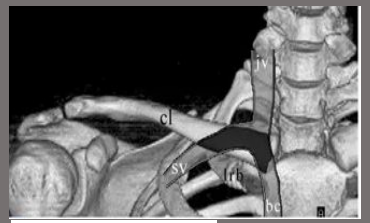


Neutral Clavicle

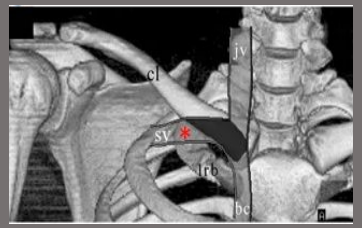


10° Clavicle elevation





Neutral Clavicle



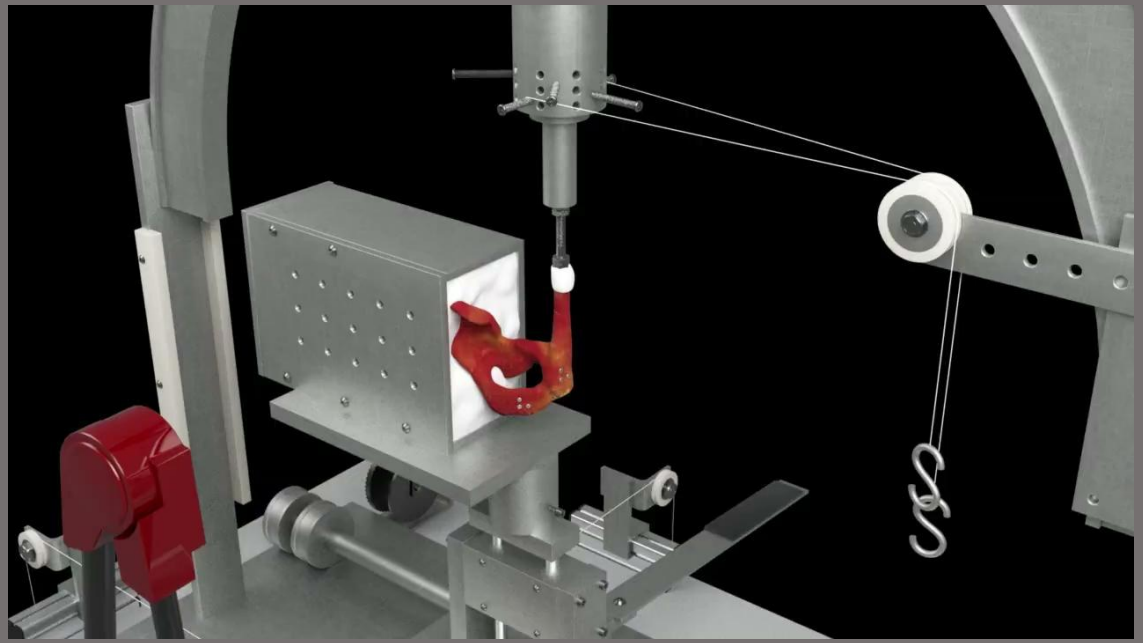
Shrugging Position

Inman VT et al. JBJS , 1944.

Kitagawa N et al. ASA 2004

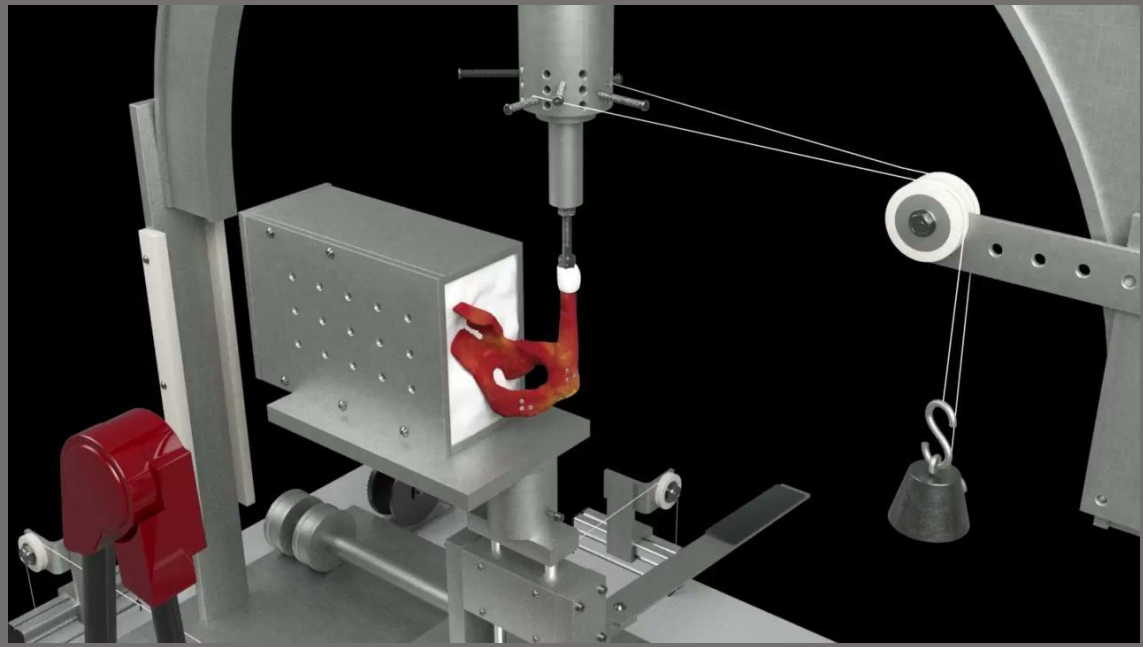
AC Joint translation

- AC joint translation
  - Anterior-Posterior
  - Superior-Inferior
    - 2.5 N
    - 5 N
    - 7.5 N
- 5N AC joint compression



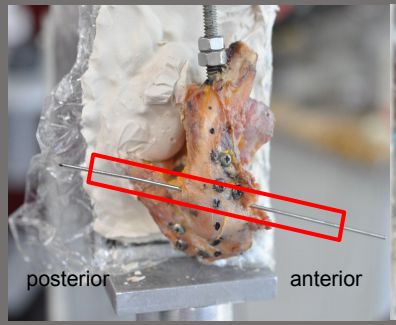
AC Joint Rotation

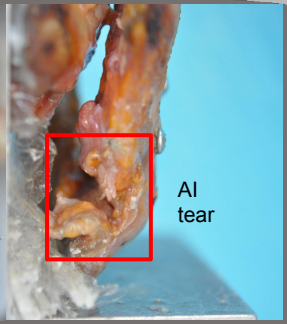
- Anterior-Posterior clavicle rotation
  - 0.08 Nm
  - 0.16 Nm
  - 0.24 Nm
- 5N AC joint compression

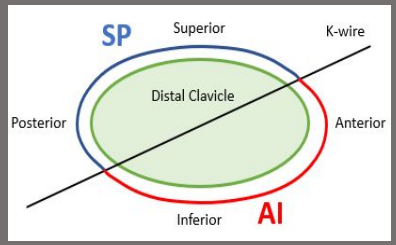


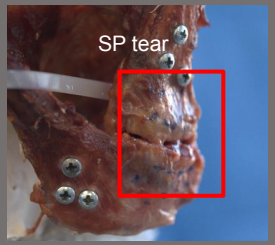
SP or AI Tear

- Following intact AC ligament testing
  - SP Tear
    - n=10 (3F, 7M, 65 ± 2 years)
  - AI Tear
    - n=11 (5F, 6M, 62 ± 3 years)
- To determine SP and AI tear border a K-wire inserted at anterior/superior clavicle border until it emerges at the posterior-inferior border
- One way ANOVA ($P < 0.05$) used for statistical analysis



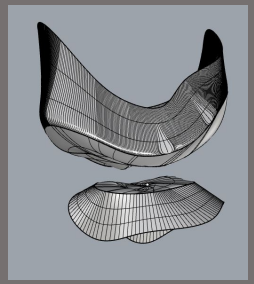


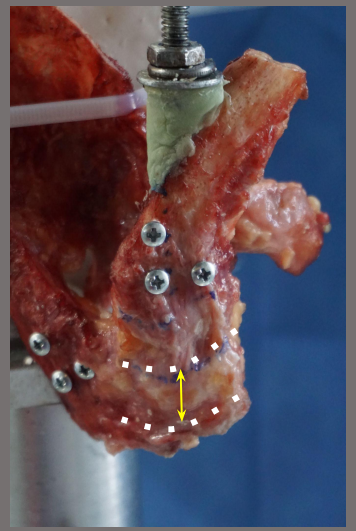




Methods - Anatomical Measurements

- Working ligament length
  - 6 points on clavicle and acromion were digitized
- Ligament insertion areas
  - soft tissues removed from ligament insertion area and dyed with methylene blue solution
  - Borders digitized and area calculated (Rhino 3D)
- Morphology analysis
  - Articular surfaces digitized to plot 3-dimensional geometry

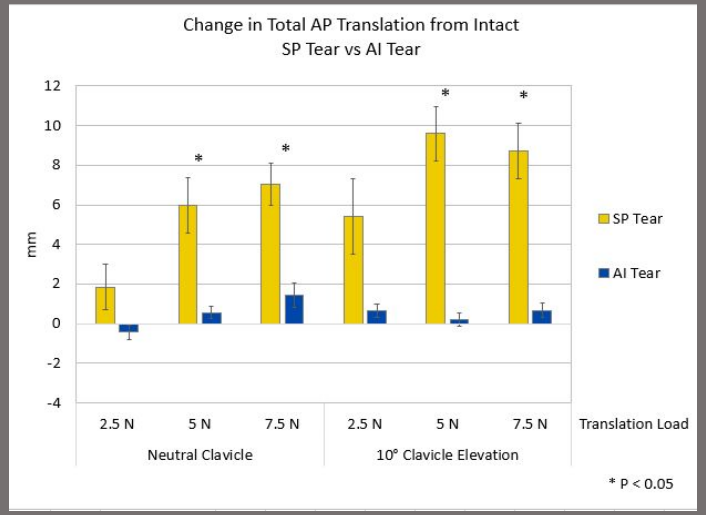


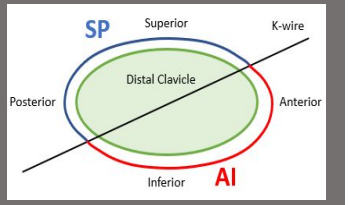


Change in AC Joint Translation: SP vs AI Tear

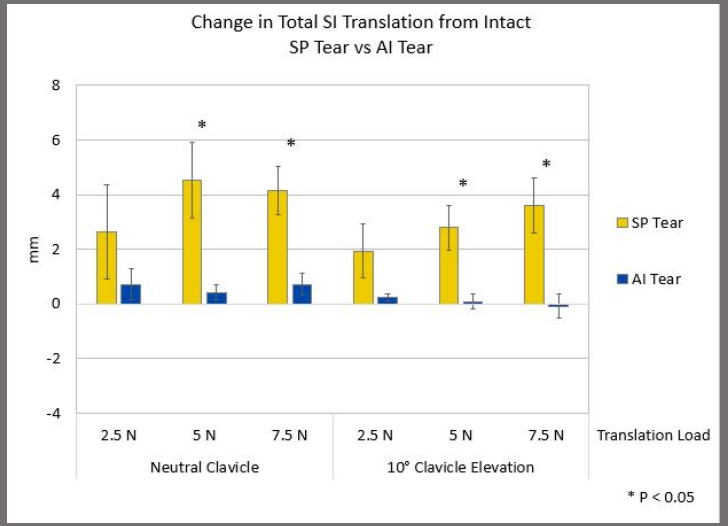
- AP and SI Translation: SP Tear > AI Tear

Anterior-Posterior Translation





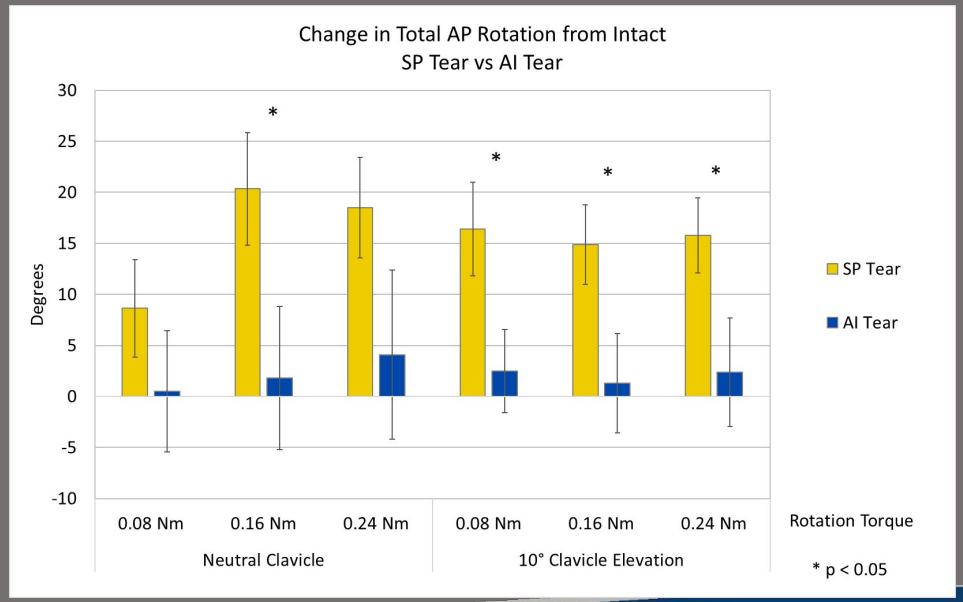
Superior-Inferior Translation

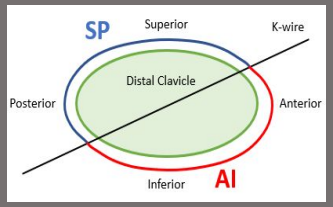


Change in AC Joint Rotation: SP vs AI Tear

- AP Clavicle Rotation: SP > AI Tear

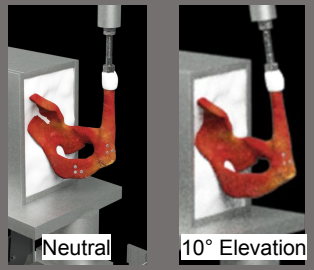
Anterior-Posterior Clavicle Rotation

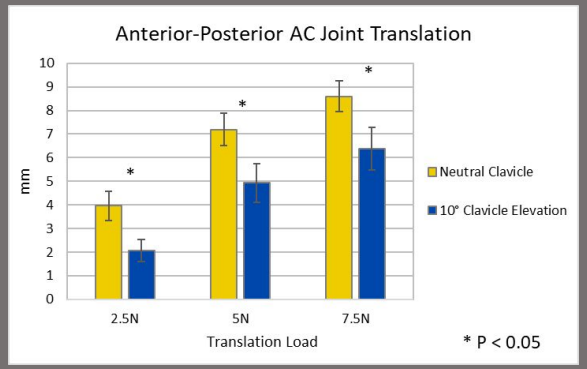


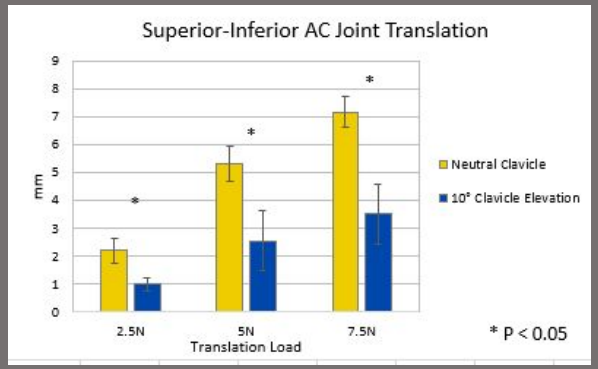


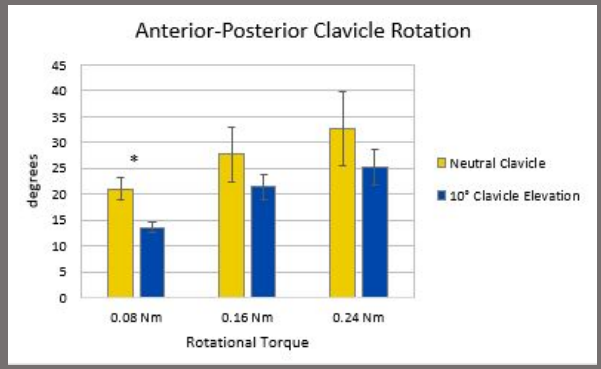
Intact AC Joint: Neutral vs. 10° Clavicle Elevation

- AP and SI Translation:
  - 10° elevation < Neutral clavicle (all loads)
- Clavicle rotation
  - 10° elevation < Neutral clavicle (low load)
  -



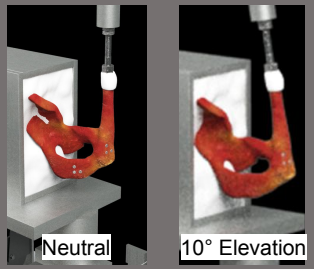


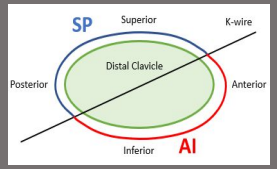




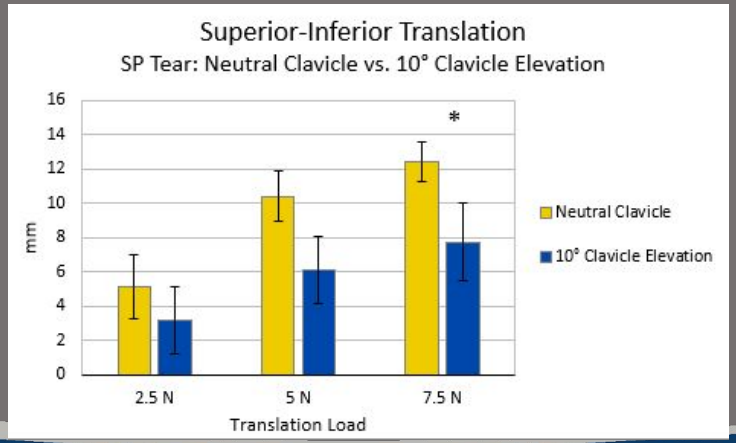
AC Joint Tear: Neutral vs. 10° Clavicle Elevation

- No significant differences in AP Translation
- SI Translation: 10° elevation < Neutral clavicle (all loads)
  - SP Tear (high load)
  - AI Tear (all loads)

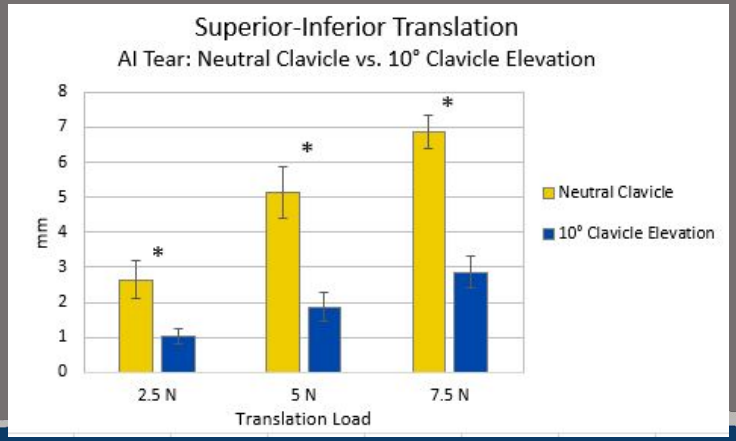




SP Tear

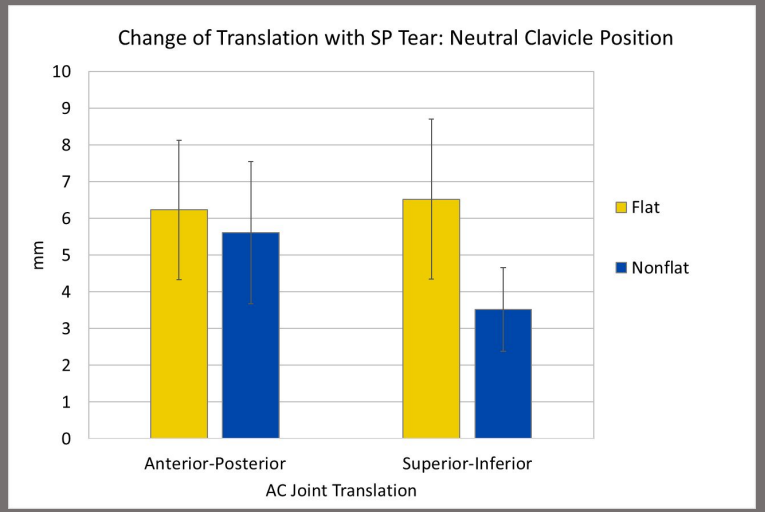


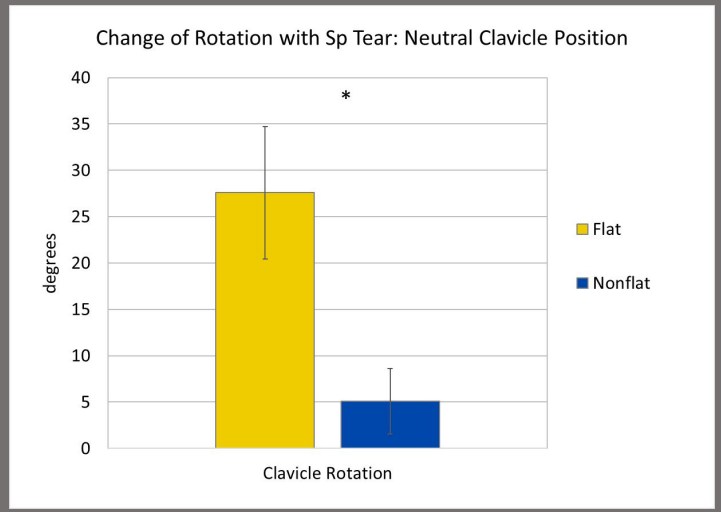
AI Tear

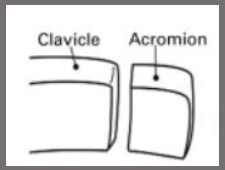


Morphology

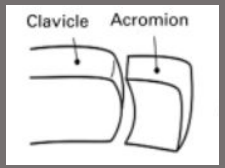
- For SP tear, **Flat morphology (n= 6)** had higher change from Intact with total AP/SI translation and total AP rotation than **Non-Flat morphology (n=4)**, significant for rotation







Flat

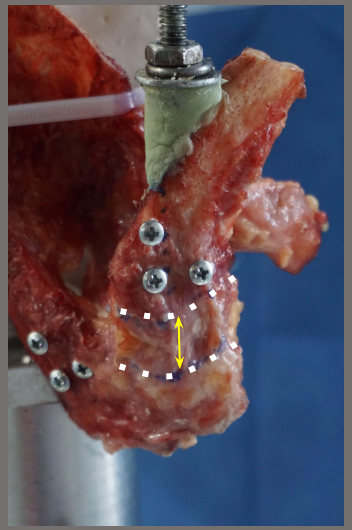


Non-Flat

Working Ligament/Insertion Area

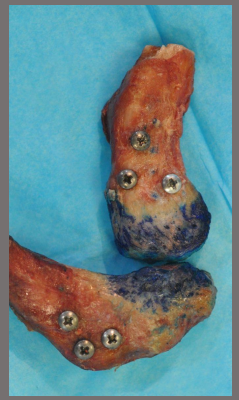
- Working Ligament length

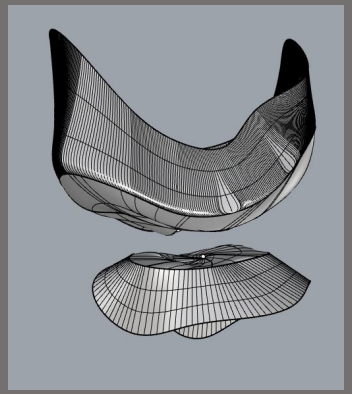
  16.3 ± 1.1 mm



- Ligament Insertion Area
  - Clavicle: 613.9 ± 72.0 mm^2
  - Acromion: 464.7 ± 41.1 mm^2

  (Clavice > Acromion, P = 0.013)





Discussion/Conclusion

- SP tears significantly compromises AC joint stability
- Clavicle side of the AC ligament may see more load than the acromial side due to larger insertion area
  - New surgical reconstructions should consider these anatomical differences of the AC joint and importance of SP bundle
- Joint morphology may be another determining factor in decision-making for the optimal treatment in the setting of type III injury
  - With non-flat morphology possibly having greater propensity for instability

Thank You


Orthopaedic Biomechanics Laboratory
OBL
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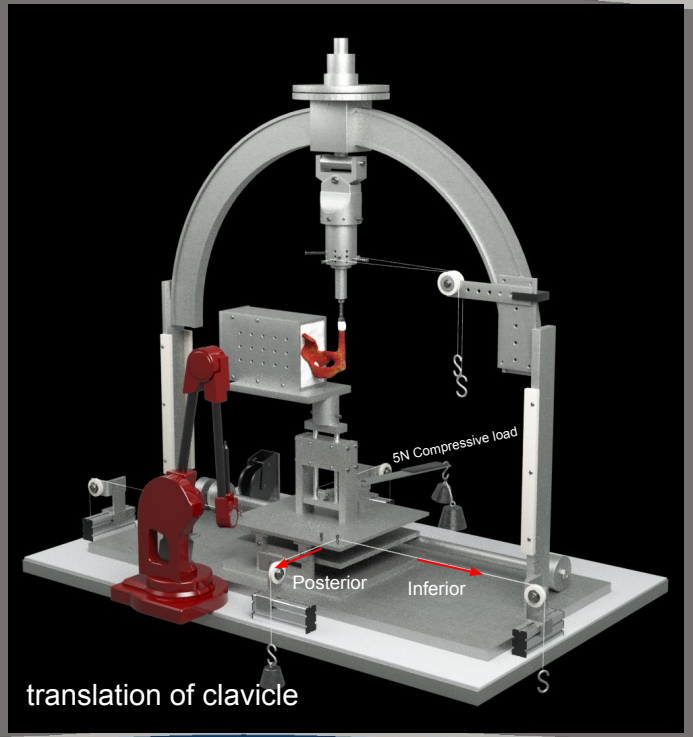
BIOMECHANICS RESEARCH LABORATORY

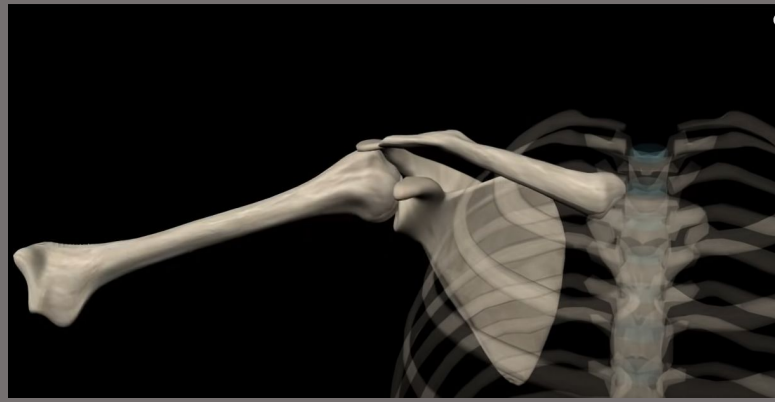
Testing Conditions

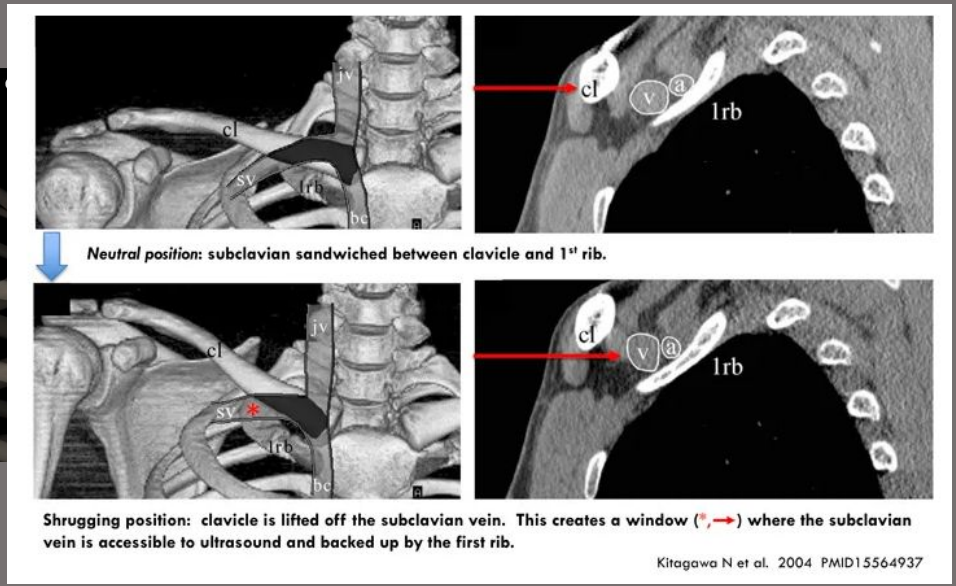
- Intact AC ligaments
- SP Tear
  - n=10 (3F, 7M, 65 ± 2 years)
- AI Tear
  - n=11 (5F, 6M, 62 ± 3 years)



(Inman VT et al. JBJS , 1944.)

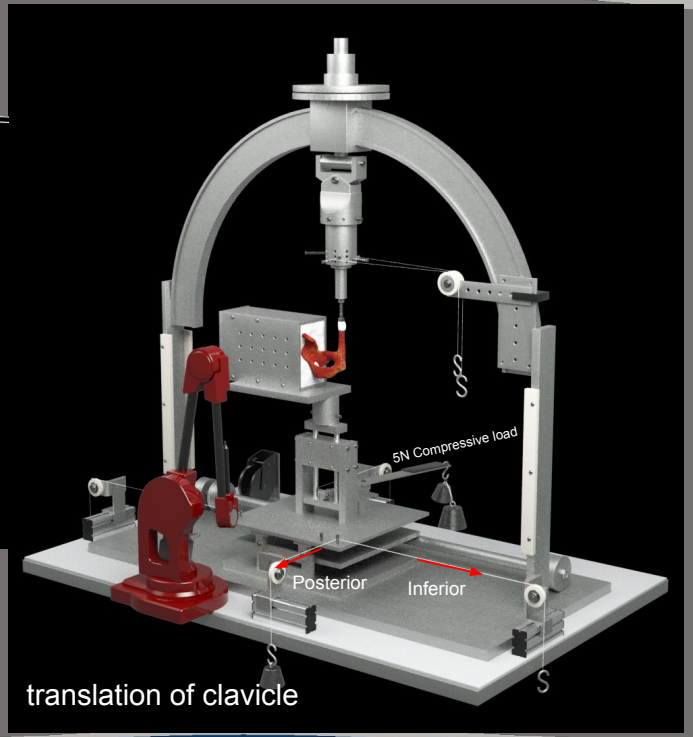
TEAM OBL

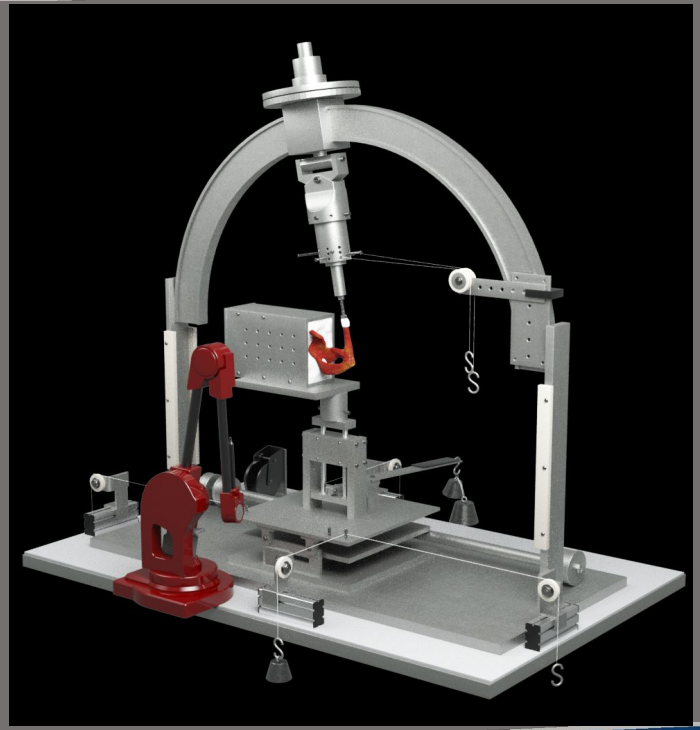



jv
cl
sv
1rb
bc
a
cl
v
a
1rb
Neutral position: subclavian sandwiched between clavicle and 1st rib.
jv
cl
sv
*
1rb
bc
a
cl
v
a
1rb
Shrugging position: clavicle is lifted off the subclavian vein. This creates a window (*,→) where the subclavian vein is accessible to ultrasound and backed up by the first rib.
Kitagawa N et al. 2004 PMID15564937

Biomechanical Measurements

- 5N AC joint compression
- AC joint translation
  - Anterior-Posterior
  - Superior-Inferior
    - 2.5 N
    - 5 N
    - 7.5 N
- AC joint rotation
  - Anterior-Posterior
    - 0.08 Nm
    - 0.16 Nm
    - 0.24 Nm

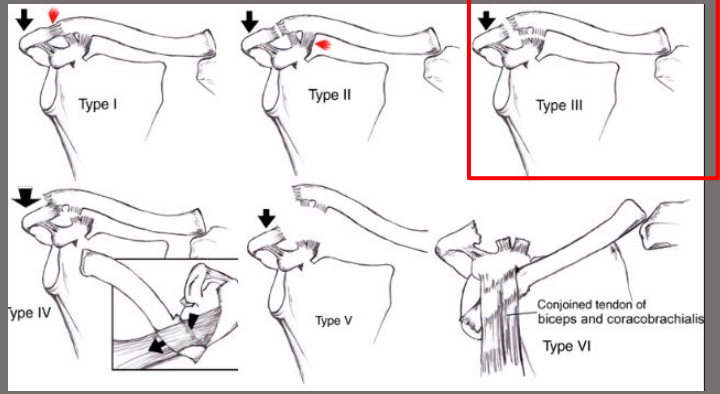




Current Treatment Consensus of AC Joint Dislocation

- Operative vs Conservative treatment depends on
  - Patient activity levels
  - Degrees of separation
  - Degrees of ligament injury
-

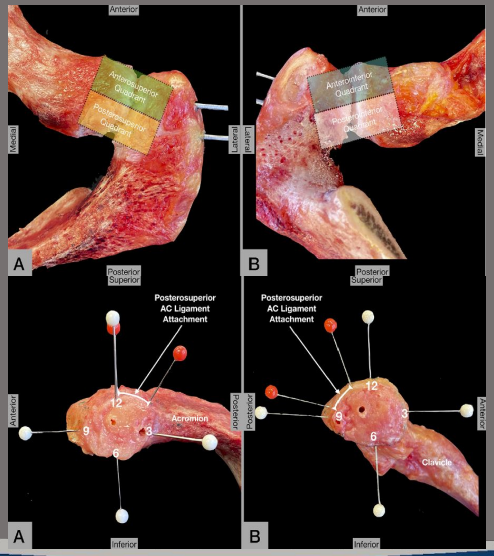
Rockwood classification

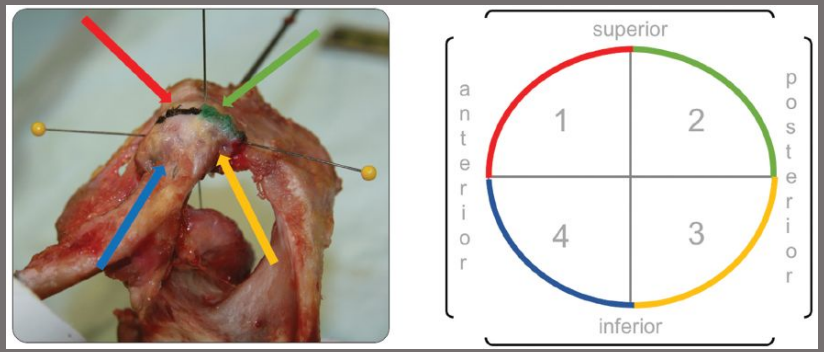


Tamaoki et al. Cochrane Database Syst Rev 2019
Martetschlager et al. Dtsch Arztebl Int 2019
Verstraete et al. J Clin Biomech 2023
Chernchujit et al. J Orthop 2020

AC Joint Ligament Complex

- Anatomic descriptions of the AC ligament complex have simplified the AC joint into quadrants
  - Anterior, posterior, superior, and inferior parts





Stine and Vangsness. Arthroscopy 2009
Dyrna et al. AJSM 2019
Nolte et al. AJSM 2021

Limitations

-
- Limited positions tested
- No muscle loading, only compression load applied
- Assumption of dividing SP and AI ligaments by 50% of the clavicle
- Could not quantify SP and AI insertion area separately
- Measured only SP working ligament length
- Small sample size to compare the influence of different morphology
  - additional specimens being test