Understanding The Biomechanics Of The Craniocervical Junction …And When Do I Intervene

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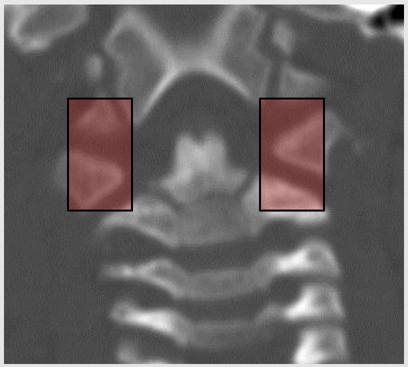
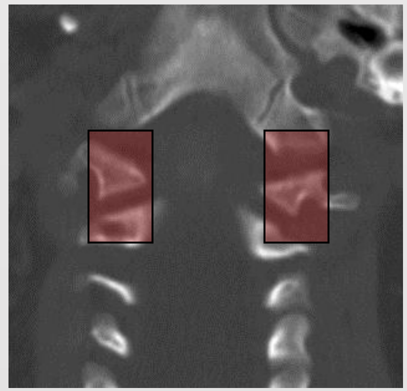
The University of Utah
Division of Pediatric Neurosurgery

No Disclosures

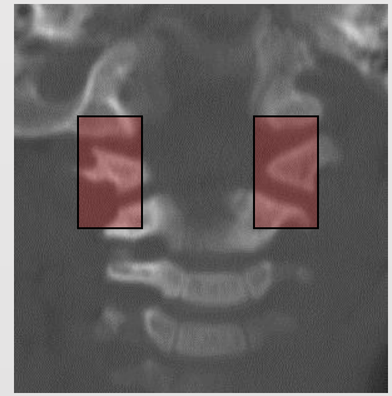
Normal Load TransferThrough the CVJ



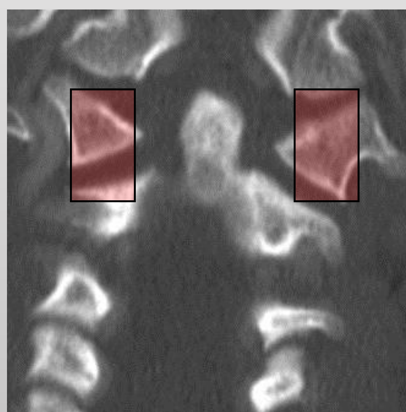
1.5 y



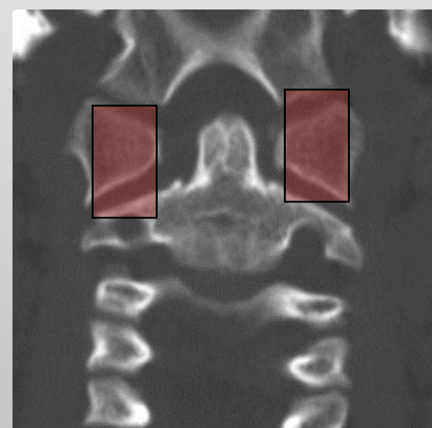
2 y



4 y



6 y



8 y

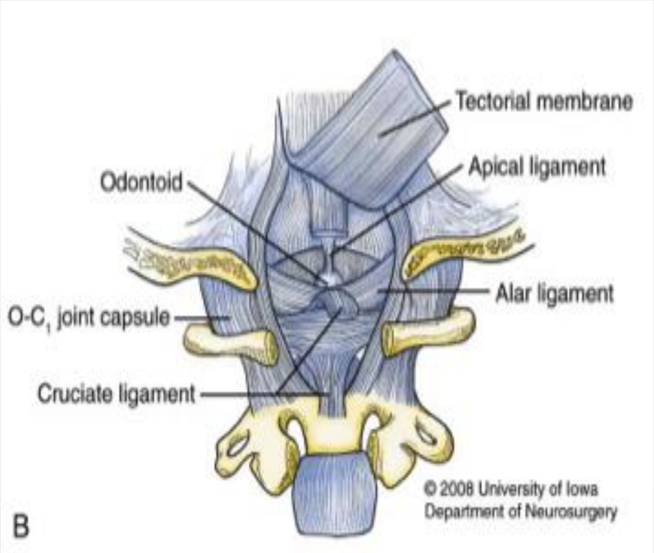
11 y

Traditional Concepts of Occipitocervical Biomechanics

- Determinants of O-C1 stability
  - Cup-shaped joints
  - Capsular ligaments
  - Tectorial Membrane
  - Ant. + post. A-O memb.
  - Alar ligament
  - Apical ligaments

Major (Cup-shaped joints, Capsular ligaments, Tectorial Membrane)

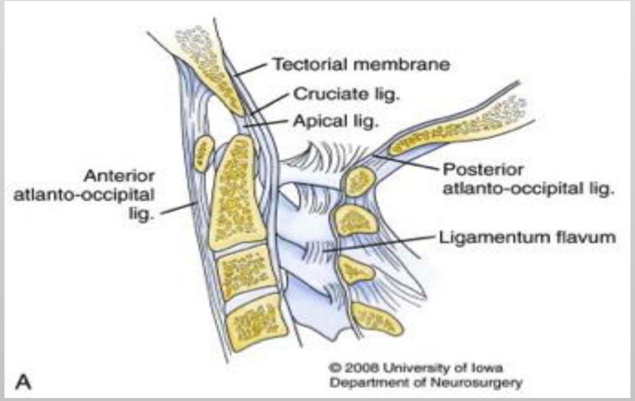
Minor (Ant. + post. A-O memb., Alar ligament, Apical ligaments)



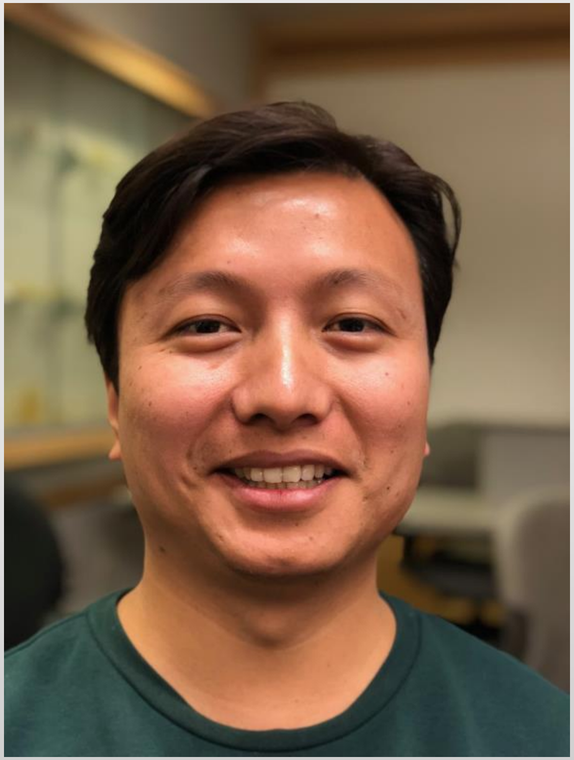
- Determinants of C1-2 stability
  - Transverse ligament
  - Odontoid integrity
  - Alar ligaments

Major (Transverse ligament, Odontoid integrity)

Minor (Alar ligaments)



Acknowledgements



Rinchen Phuntsok, BS

Ben Ellis, PhD

Andrew Dailey, MD

"The Team"

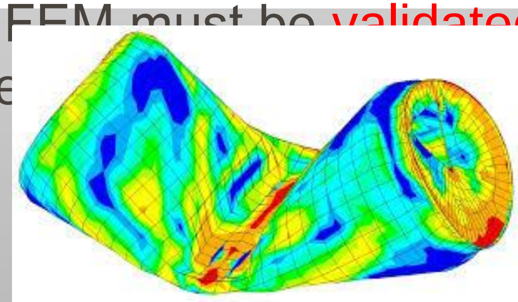
What is the Finite Element Method?

-A numerical solution technique for discretizing a larger geometrical problem into smaller pieces called finite elements.

-Robust FEMs give an accurate representation of complex geometrical structures that contain dissimilar material properties by discretizing the larger structure into numerous smaller pieces for evaluation.

-Recent advances in computational power have allowed researchers to use FEMs to examine the biomechanical behaviors of a wide variety of skeletal structures, including the spine.

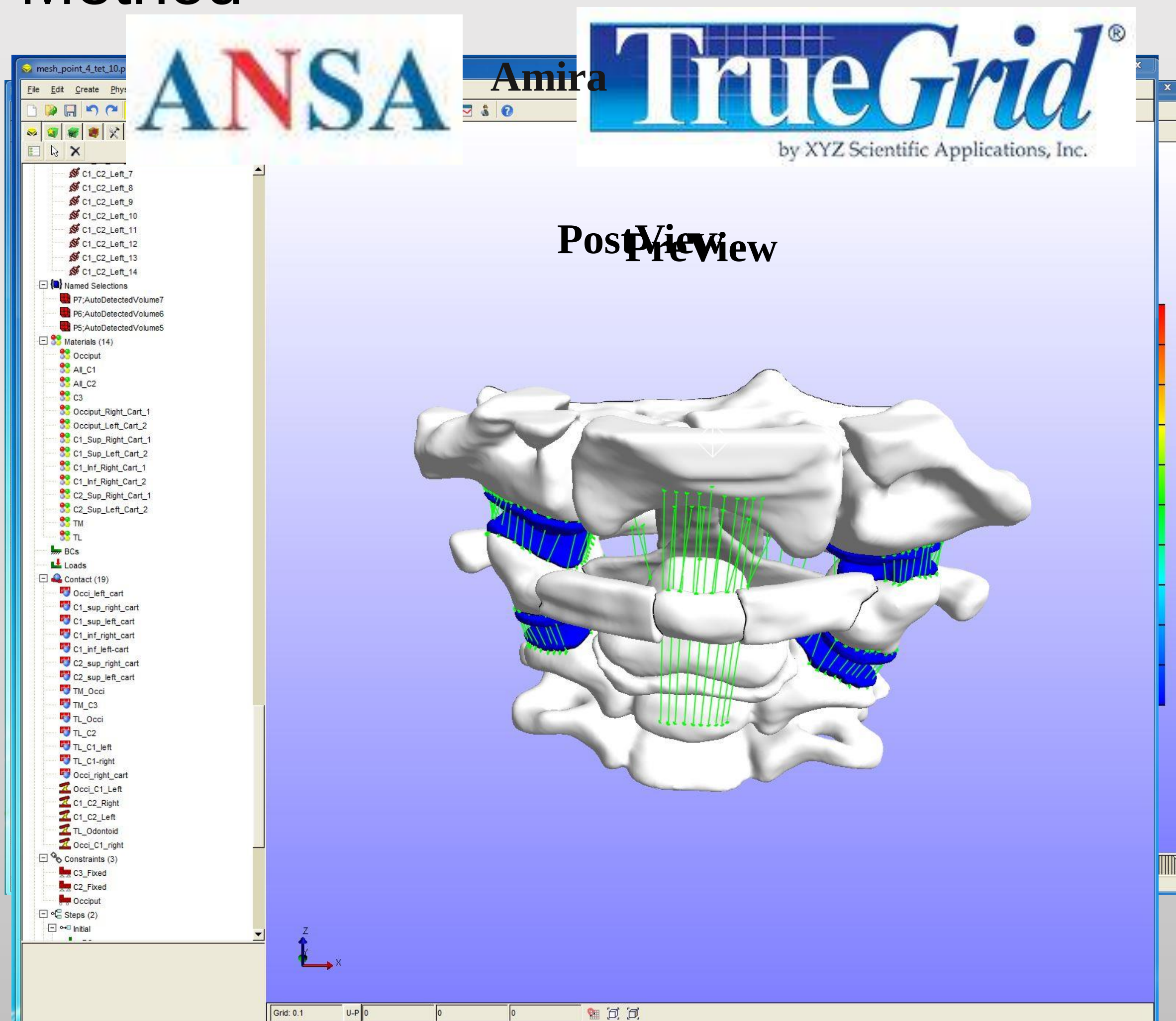
-It's important that a FEM must be validated with cadaveric biomechanical test re



The FE Method In CCJ Biomechanics

Creation: Method

- CT Scan
- Segment CT Data
- Generate Surface
- Mesh Surface
- Material Properties
- Boundary Conditions
- Perform FEA
- Analyze Results

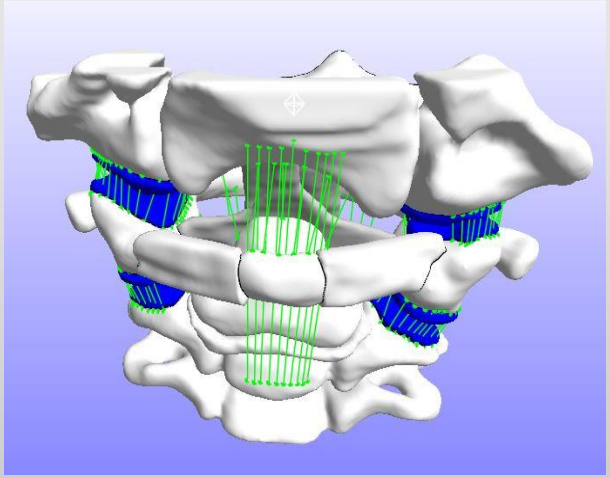


The FE Method In CCJ Biomechanics

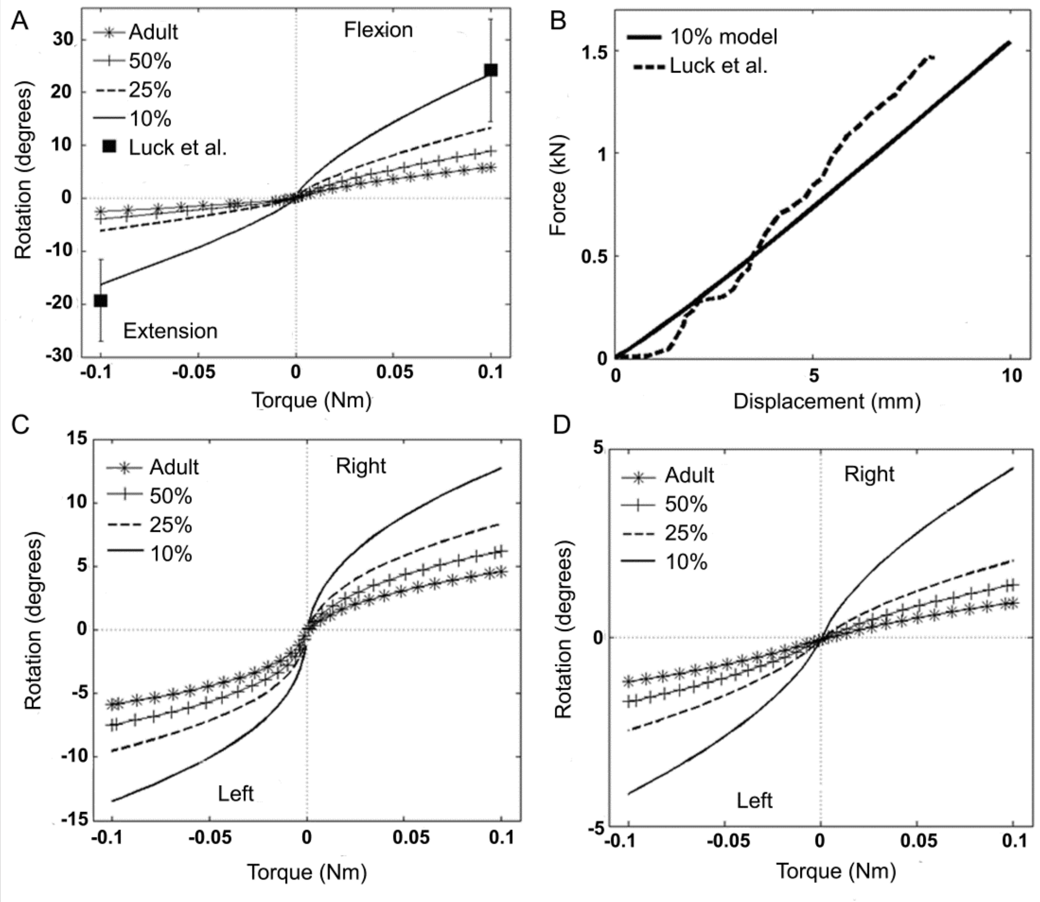
Creation OF Material Properties and Boundary Conditions

- LIGAMENTS – TENSION-ONLY SPRINGS WITH LINEAR PROPERITES
- ADULT LIGAMENT (50%, 25%, 10%)
- SOFT TISSUE –MOONEY-RIVLIN AND NEO-HOOKEAN
- MESH CONVERGENCE

- BONES- RIGID BODIES
- C0 - C1 UNCONSTRAINED
- C2 - C3 FIXED
- CONTACT ENFORCED USING PENALTY METHOD
- ±0.1 – 1.0 NM TORQUE (C0)

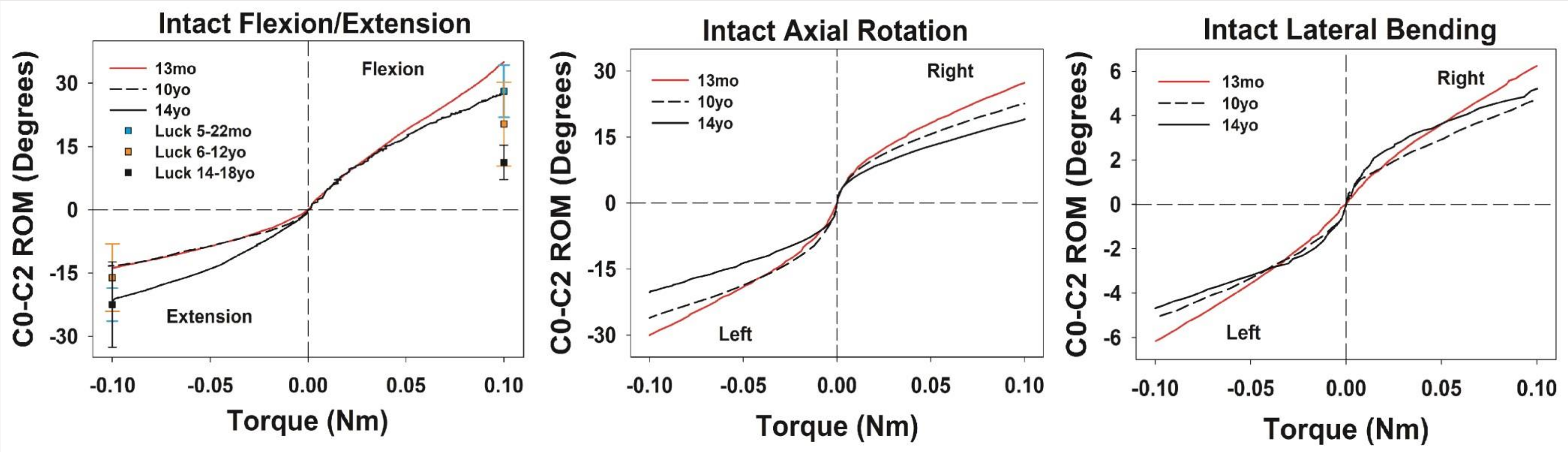


Initial Validation: Pediatric

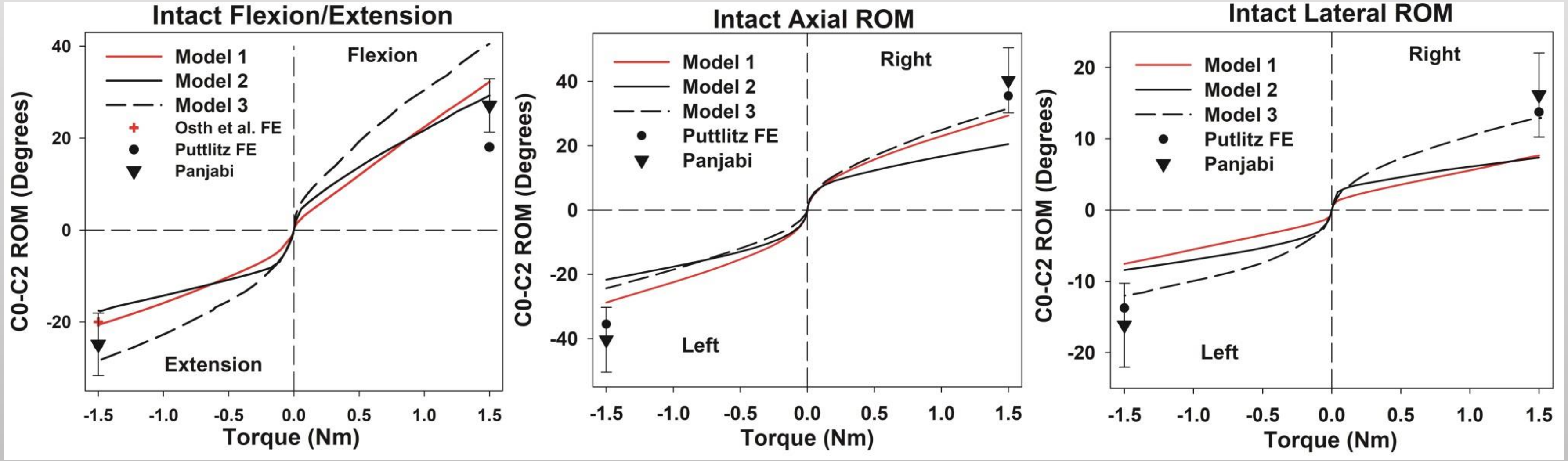


[1] Phuntsok, R. et al., *J Neurosurg Pediatr,* 17: 497-503, 2016.

Pediatric Validation: Normal

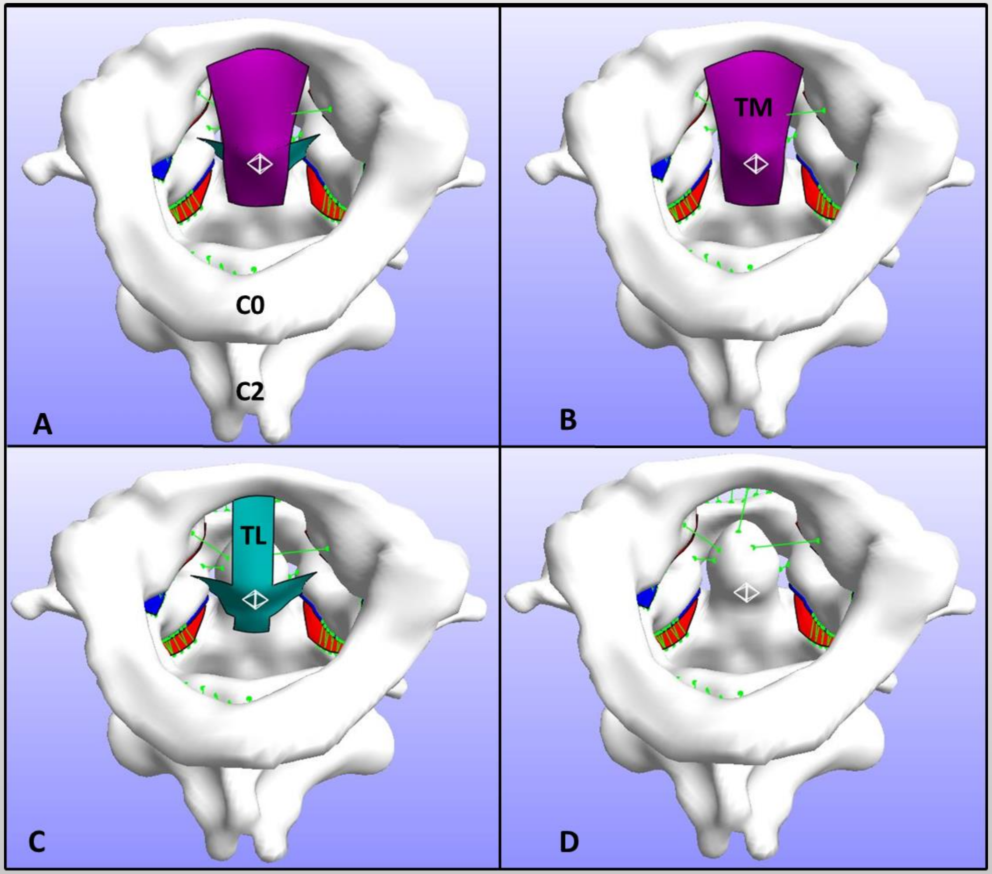


Adult Validation: Normal



Model 1 = 29 YO, Model 2 = 59 YO and Model 3 =64 YO

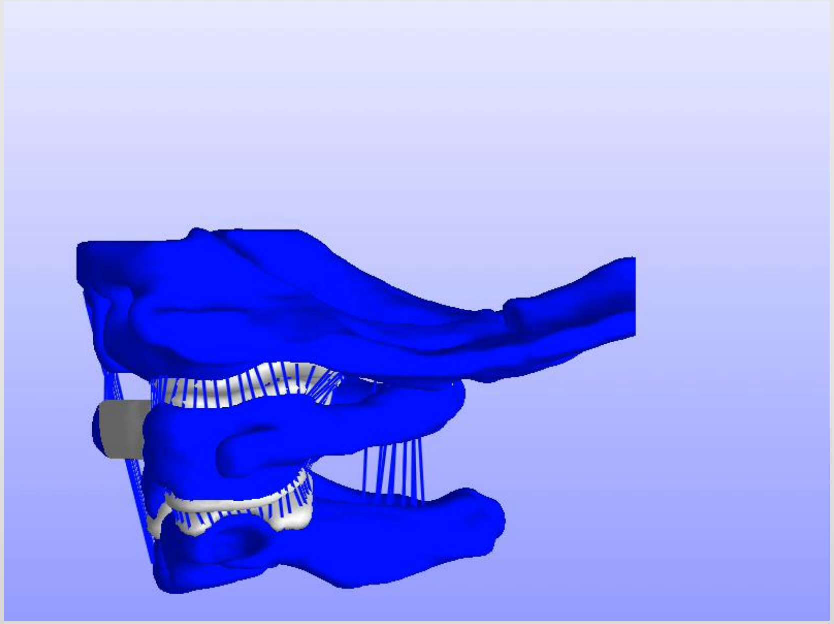
Ligamentous Injury Scenarios: Isolated and Combination



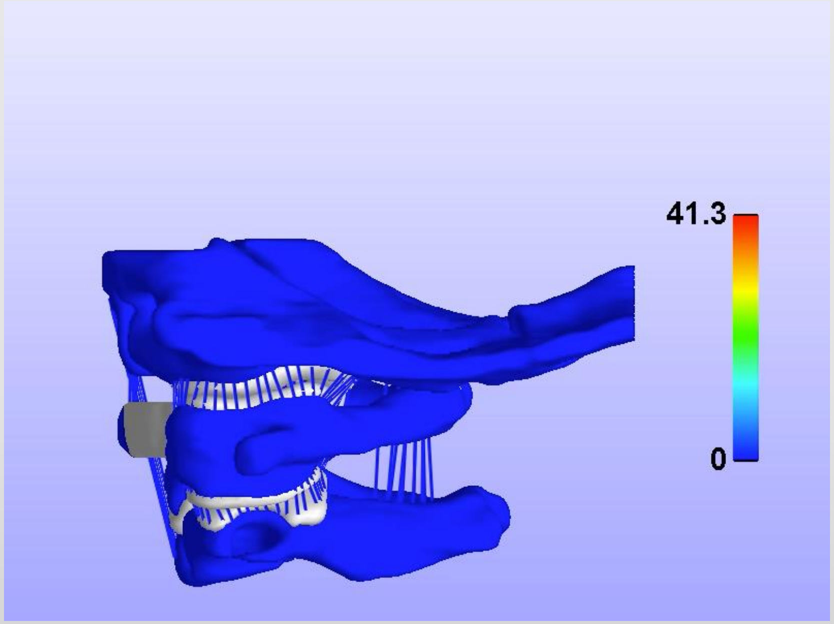
-Intact
-OACL stiffness reduction
-TL removal
-TM removal
-AL removal
-TM + TL
-OACL + TL
-OACL + TM
-OACL + TM + TL
-OACL + AL

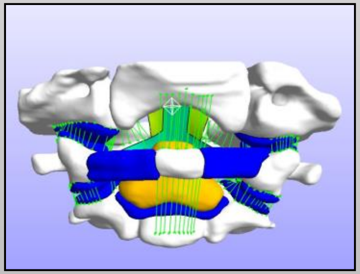
Pediatric OACL + TL Injury

Normal



Injured



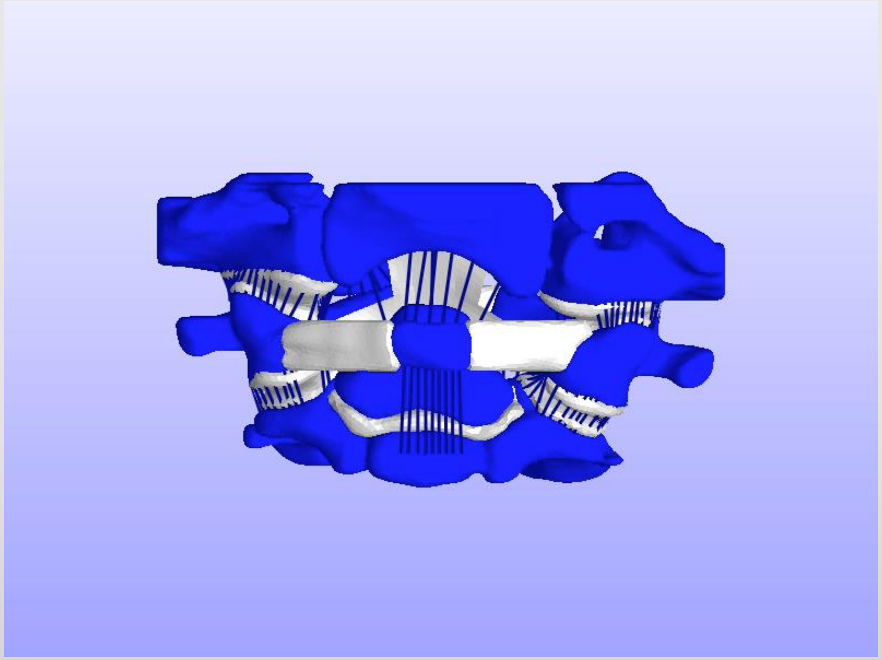


13 Month F

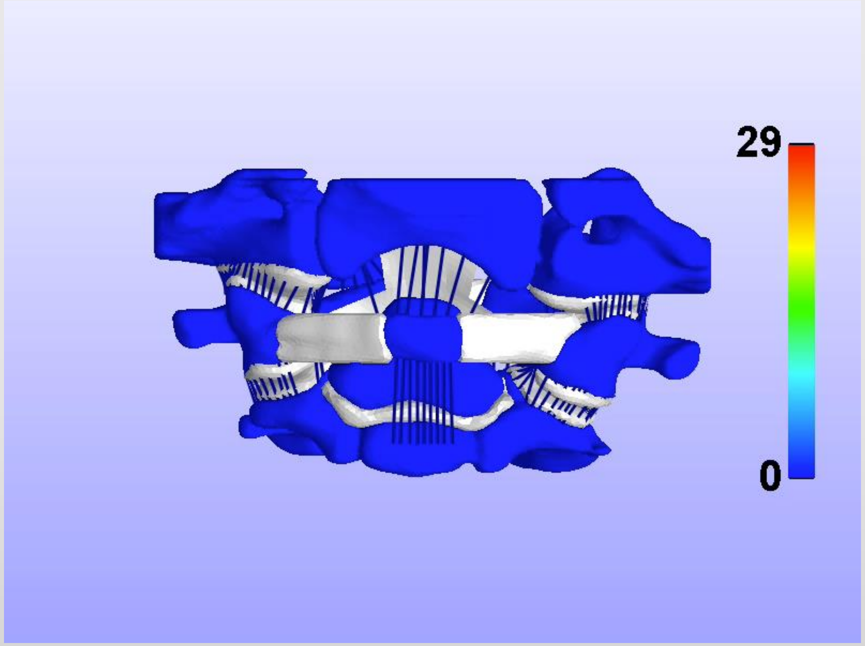
10 Year F

14 Year F

Pediatric AACL Injury – Axial Rotation

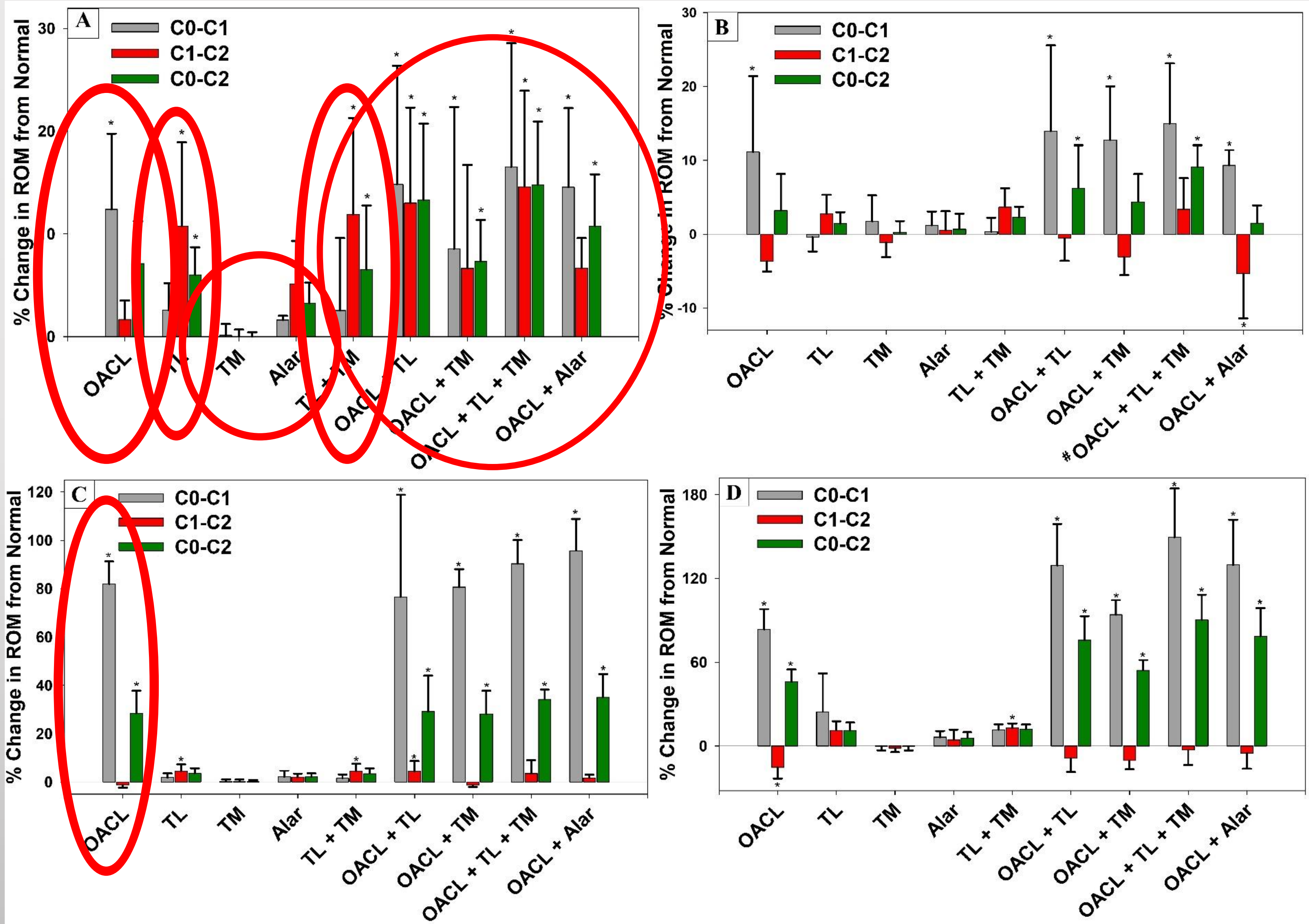


Normal



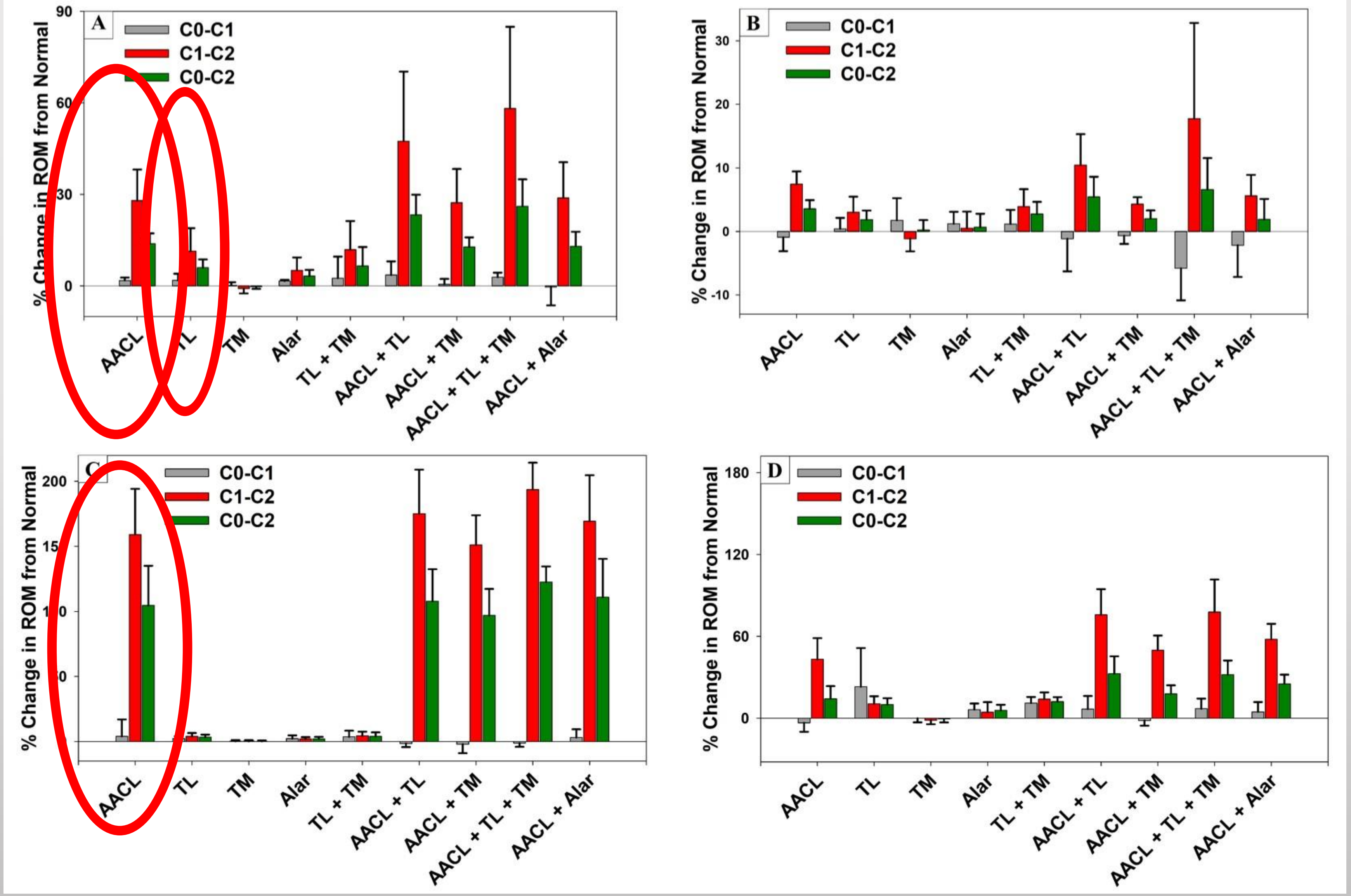
Injured

OACL injury simulation (Averaged 10, 14,29, 59 and 64 YO)



A) Flexion, B) Extension, C) Axial and D) Lateral. *indicates significance # indicates 14 YO model run was not included

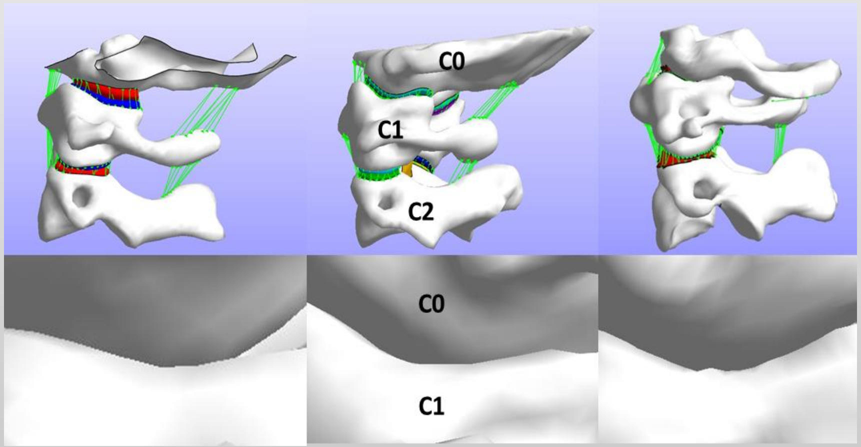
AACL Preliminary Results (10, 15, 29, 59 and 64 YO)



A) Flexion, B) Extension, C) Axial and D) Lateral Bending.

Conclusions

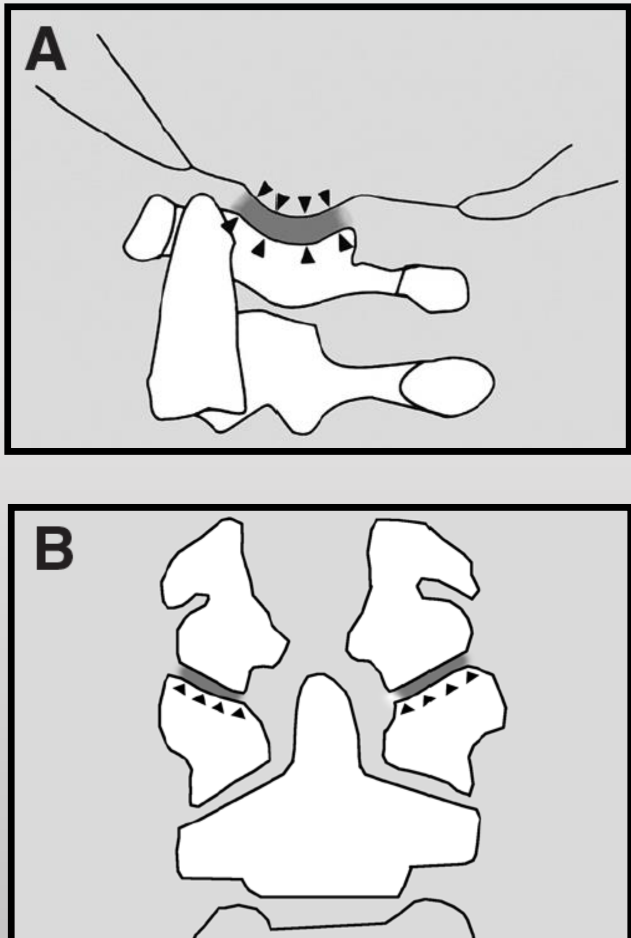
- OACLs are the primary stabilizers of the OA joint*
- AACLs and the TL are the primary stabilizers of the AA joint
- TM and AL do not play a major role in either joint
- Within the FE model, facet geometry plays a role in CCJ stability



*Phuntsok R, Ellis B, Herron M, Provost C, Dailey A, Brockmeyer DL: The occipitoatlantal capsular ligaments are the primary stabilizers of the occipitoatlantal joint in the craniocervical junction: a finite element analysis. JNS:Spine , In final review

Clinical Implications: AOD

CVJ: Condylar-C1 Interval (CCI)



ATLANTO-OCCIPITAL DISLOCATION: PART 1—NORMAL OCCIPITAL CONDYLE-C1 INTERVAL IN 89 CHILDREN

Dachling Pang, M.D., William R. Nemzek, M.D., John Zovickian, M.D.

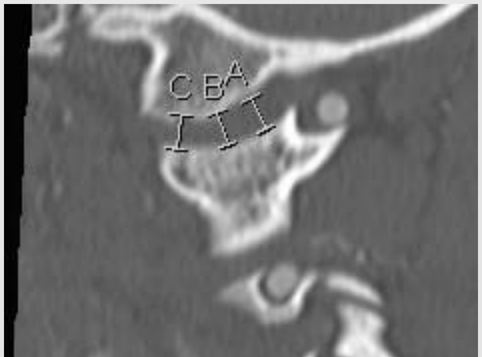
Neurosurgery, Volume 61, Issue 3, 1 September 2007, Pages 514–521,

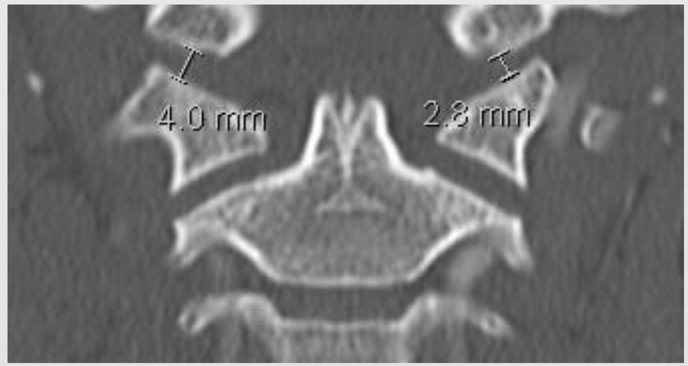
ATLANTO-OCCIPITAL DISLOCATION—PART 2: THE CLINICAL USE OF (OCCIPITAL) CONDYLE-C1 INTERVAL, COMPARISON WITH OTHER DIAGNOSTIC METHODS, AND THE MANIFESTATION, MANAGEMENT, AND OUTCOME OF ATLANTO-OCCIPITAL DISLOCATION IN CHILDREN

Dachling Pang, M.D., William R. Nemzek, M.D., John Zovickian, M.D.

Neurosurgery, Volume 61, Issue 5, 1 November 2007, Pages 995–1015,

Clinical Implications: AOD





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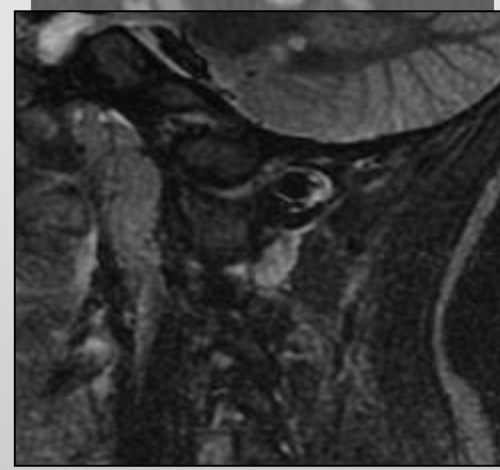



PRIMARY CHILDREN'S
kVp
mA
5.17 mGy
CARM

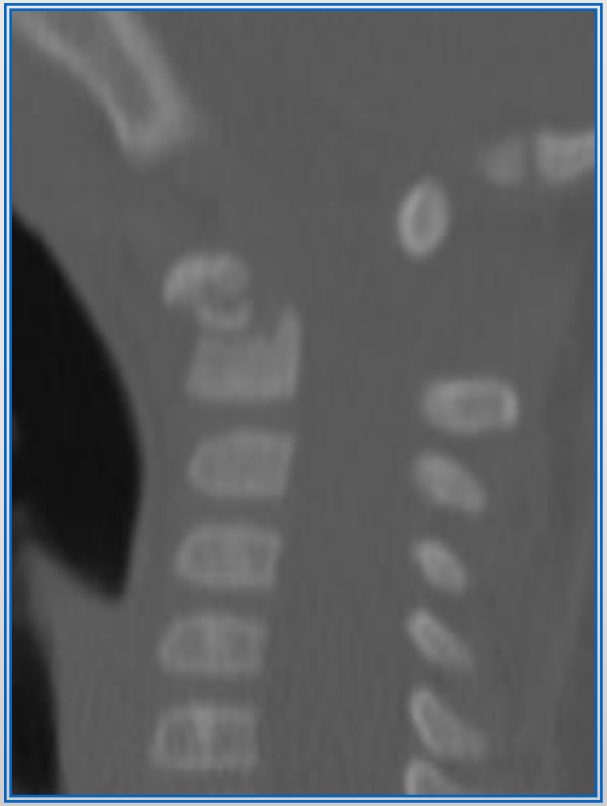
4 y/o Restrained Passenger MVA
O-C1-C2 Combination Injury

Not uncommon

Flexion-distraction mechanism

Requires O-C2 fusion at a minimum

2 y/o Fell Down The Stairs
C2 Synchondrosis Fracture



Brace vs. Halo?

Surgery only for progressive deformity

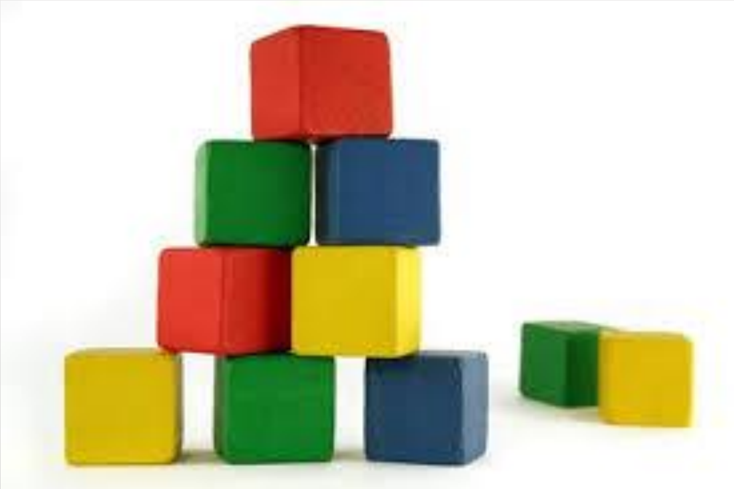
When Do I Intervene at the CVJ:

O-C1

1) Compromise of the bony supportive structures
2) Compromise of the OACLs

C1-2

1) Lack of odontoid integrity
2) Lack of C1 ring integrity
3) Lack of TL integrity
4) Compromise of the AACLs



<u>Supportive Imaging:</u>

1) C-spine x-ray (Neutral, Flex-Ex)
2) Thin cut CT with 2-D recons
3) MRI (T1,T2, STIR)

Gold standard for instability:
1) Flex-Ex CT

When Do I Intervene at the CVJ:

1) Congenital
    - Instability on dynamic imaging
        - Down vs. non-Down syndrome
        - C1 Hemirings/dysplasias
    - Significant sagittal deformity
    - Vertical instability
    - Neuro deficit/compression
2) Trauma
    - CCI > 4.0 mm (relative)
    - Failed halo after synchondrosis fx
3) Tumor
    - Significant C2/condyle removal (far lateral)
4) Post-Chiari decompression
5) Post-odontoid resection

Thank You For Your Attention