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ICEOS 2012

Vertebral growth reductions after spinal hemiepiphysiodesis

Finite element model vs histomorphometry

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DISCLOSURES / Acknowledgments

- Bylski
  - IP, unpaid consultant
    - SpineForm LLC
- Wall
  - IP, unpaid consultant
    - SpineForm LLC
  - Consultant
    - OrthoPediatrics
  - Unpaid consultant
    - Stryker

- Research support
  - UC Computer-aided Engineering
  - Financial
    - UOREF
      - Kumar, MS student stipend

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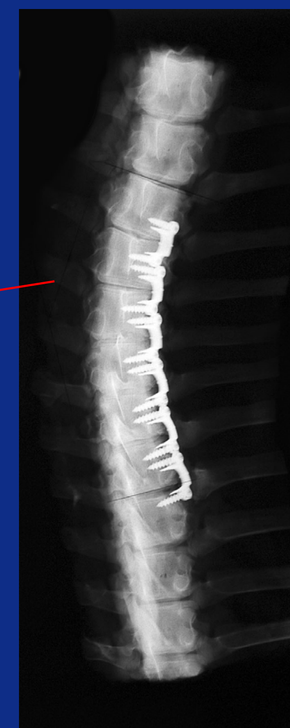
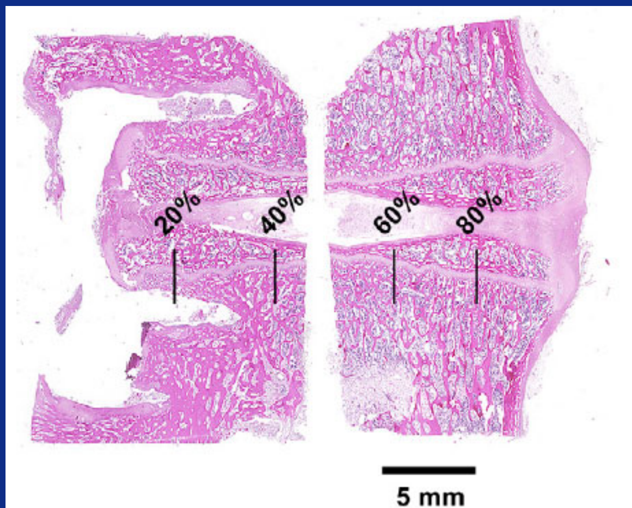
Significance: Clinical trial
Growth modification

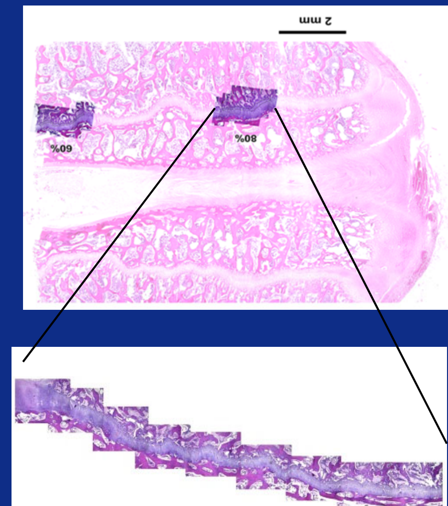
- Prospective clinical safety trial
  - FDA , IRB approved
    - Wall et al ICEOS 2012, #31
  - Late juvenile and early AIS

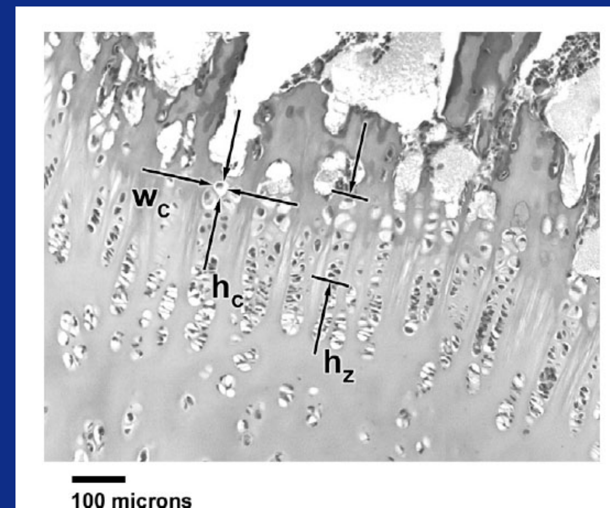


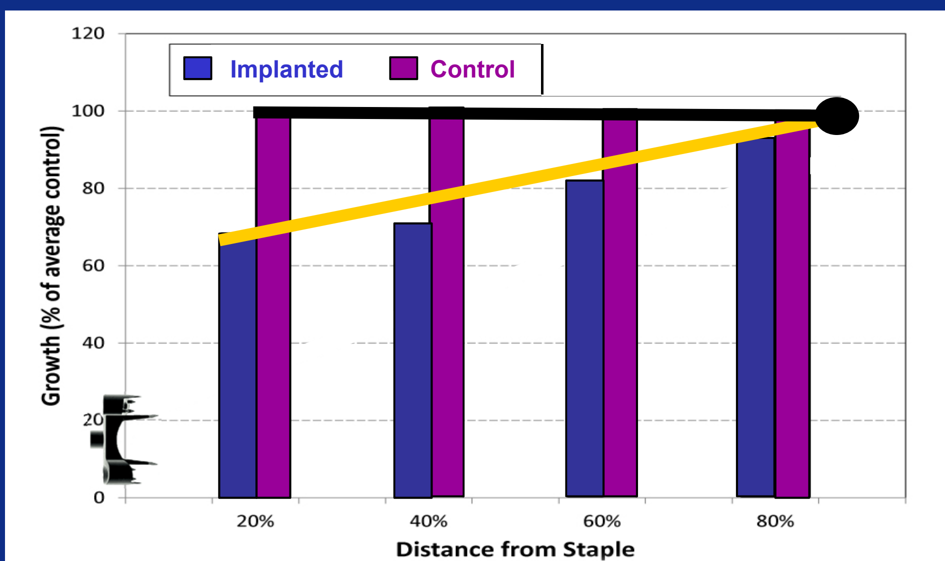
- Pre-clinical studies
  - Curvature 2 mo PO
  - Porcine spines
    - Wall et al ORS 2011

Previous pre-clinical studies





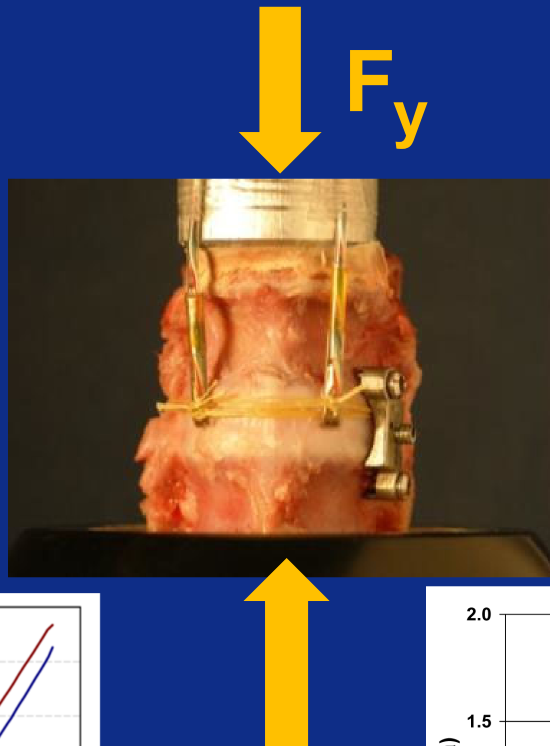


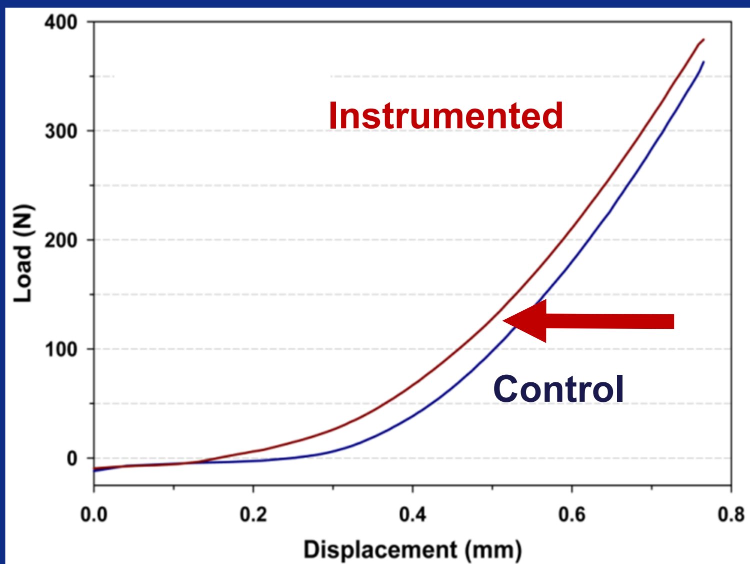


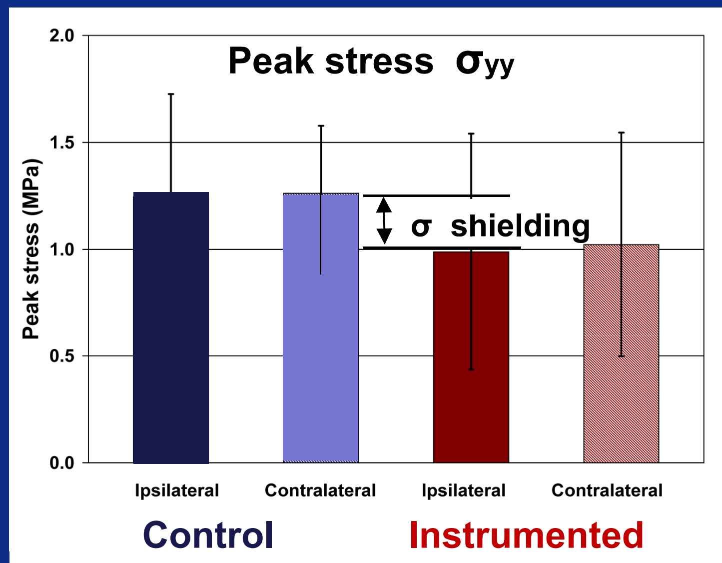
- **Growth plate structure**
  - **Graduated reductions**
    - **Hypertrophic zone height**
      - Bylski-Austrow et al JBJS 2009
  - **Proxy for bone growth rate**
    - Farnum et al 2000

Preliminary biomechanical studies

- Compression
  - *In vitro* disc stresses
  - *In vivo* stresses
    - Glos 2010
    - Bylski 2012

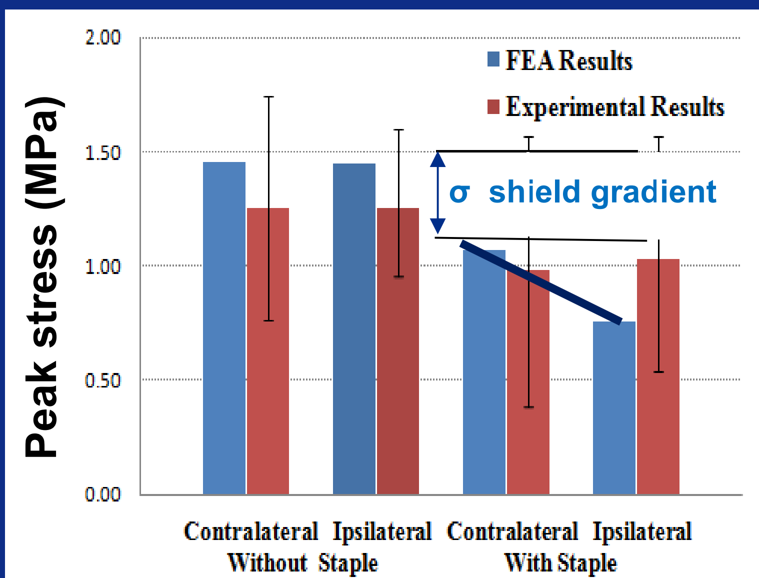


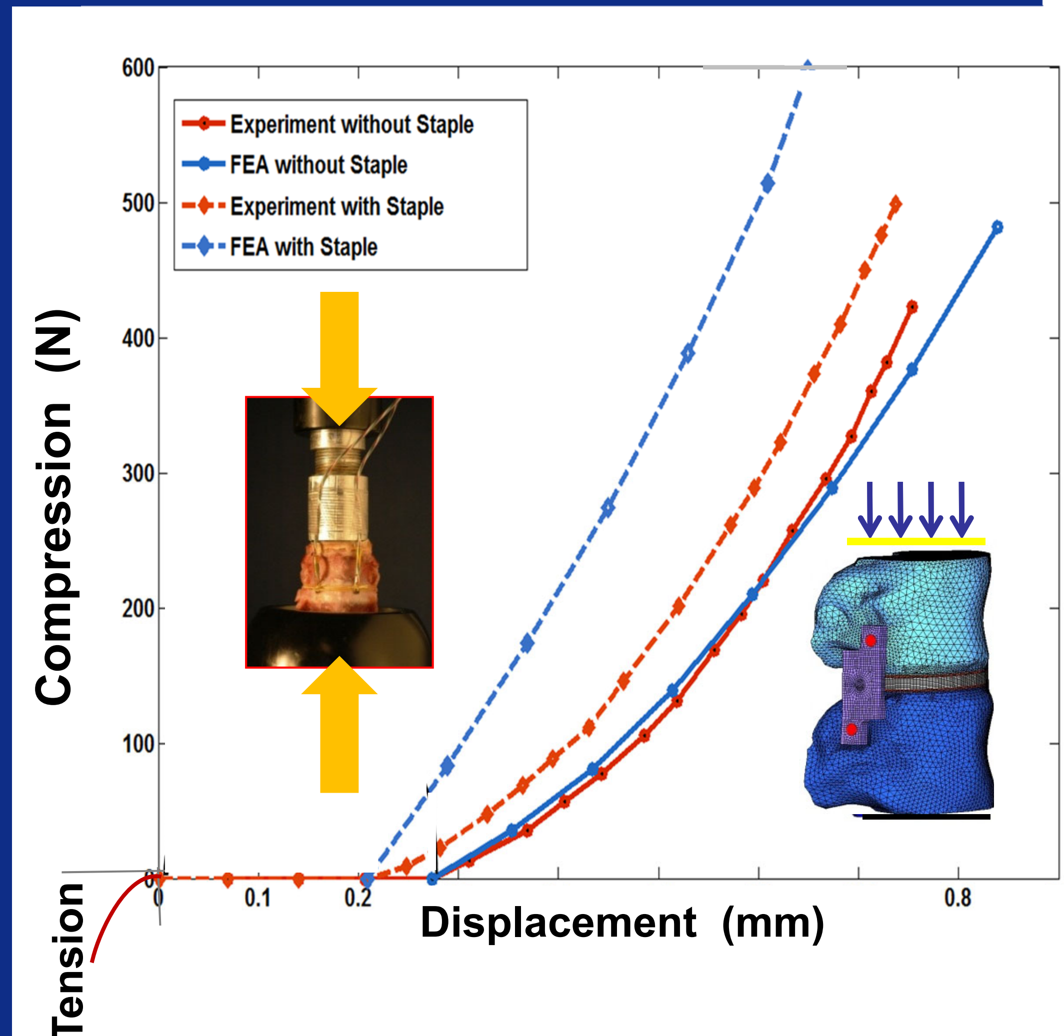




Previous finite element model (FEM)

- FEM vs biomech tests
  - Compressive L-d
    - Kumar ICEOS 2010





Purpose

Determine if

Growth plate hypertrophic zone reductions observed at 2 months PO correlate with growth reductions predicted by a FEM with linear relationship between compressive stress and growth

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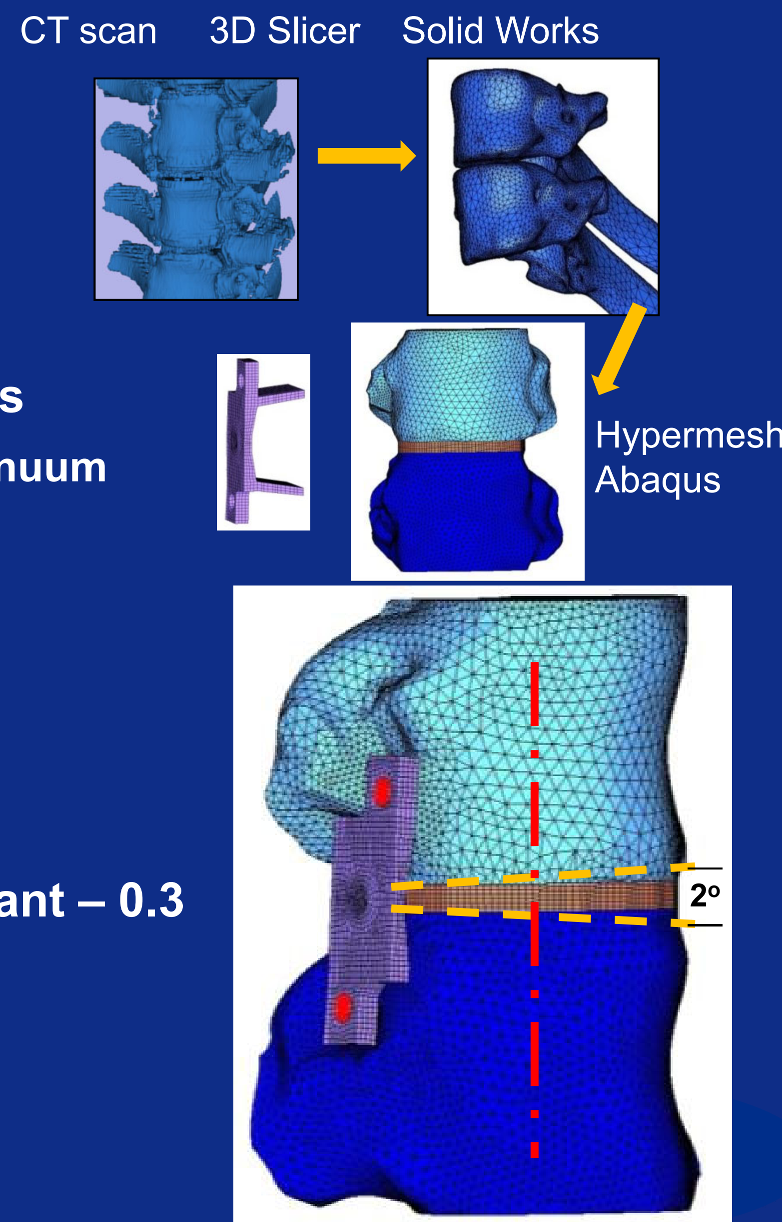
Methods: 3-D FEM

- **Porcine spine, CT scan**
  - **T7-T8**
- **Material properties from lit**
  - **Bone: Cortical, cancellous, end plates**
  - **Annulus: Anisotropic hyperelastic continuum**
  - **Nucleus – fluid inside cavity**
    - **Eberlein 2001**
- **Analysis**
  - **Static, nonlinear, large deformation**
- **Contact conditions**
  - **Coef of friction between bone & implant – 0.3**
- **Initial conditions**
  - **2° tilt w/out initial stress**



FEM Growth model

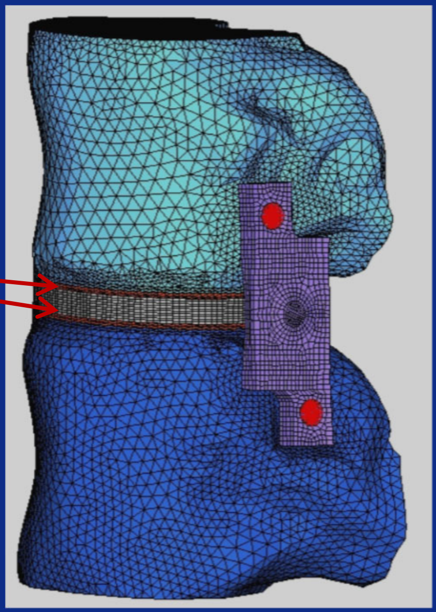
- Growth plate elements added
- Linear growth modulation model

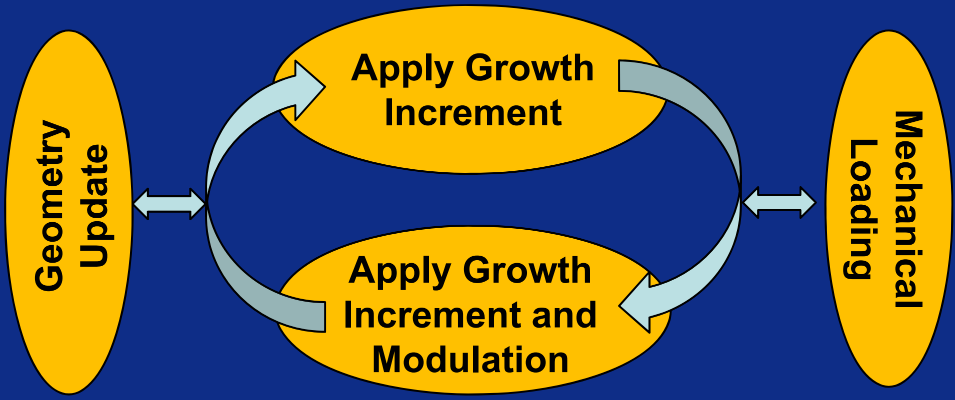
$$\varepsilon_m = \delta G_y + \beta_y \delta\sigma_{yy} \delta G_y$$

β = 1.2 MPa $^{-1}$

— Stokes 1990, 2007

- Villemure, Aubin 2002

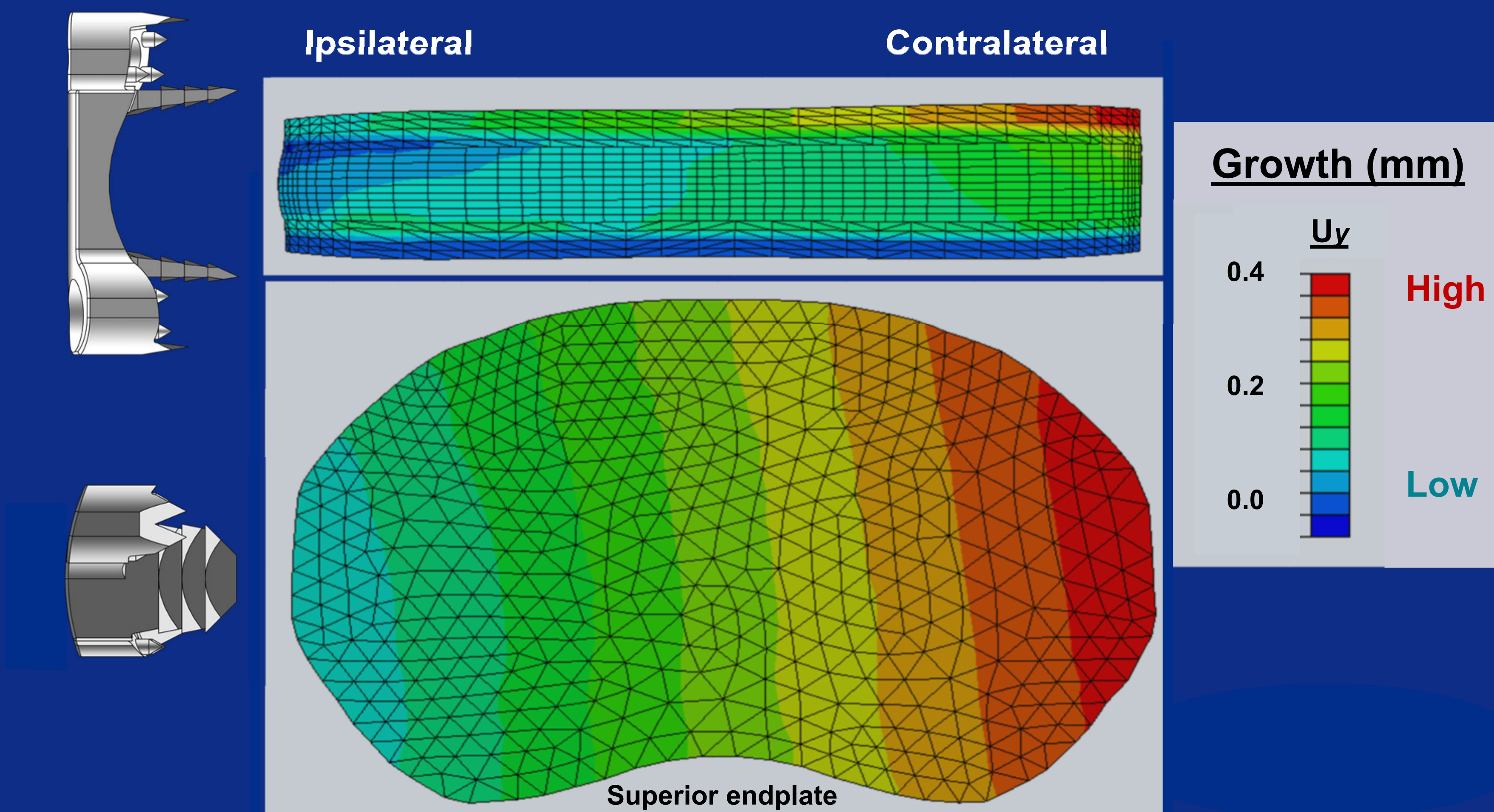




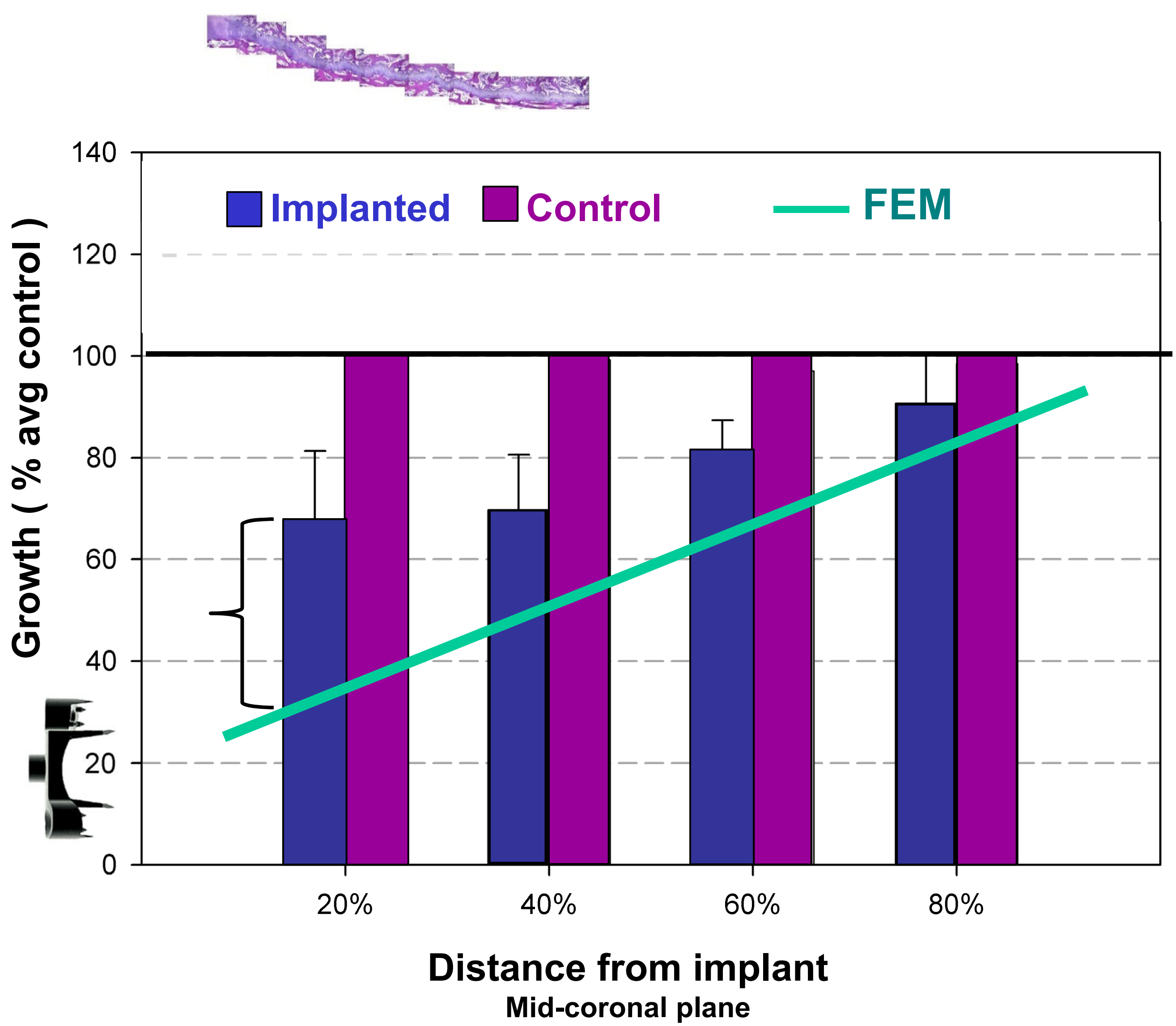
- Initial baseline growth
  - Temperature strain analogy
- 2 month PO time simulated
- Growth modulation strains calculated
  - Applied static compressive stress - 0.5 MPa

Calculated growth after treatment

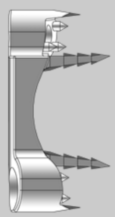
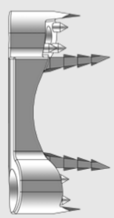
- Reduced across coronal plane compared to calculated control growth after 2 iterations (2 mos)



Histomorphometry vs FEM



Normalized growth (% control)

Location / Method	<u>Ipsilateral</u> *$1/5^{th}$ distance from implant to opposite cortex*	<u>Contralateral</u> *$4/5^{th}$ distance from implant to opposite cortex*
FEM	 **32%**	**81%**
Histomorph	 **69%**	**92%**

Discussion

- Limitations of FEM
  - No viscoelasticity
  - No neutral zone
    - FEM cannot model rigid body motion
  - Sensitivity to many parameters unknown
    - Only one PO time

- FEM useful to assess growth reductions due to compression
  - If & only if developed with in vitro & in vivo tests
    - Parametric analyses within device design type

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Conclusions

- FEM simulated growth reduction gradient
  – Calculated reductions greater than measured
    - Over-estimated treatment efficiency
- Supports concept Hueter-Volkmann ~ linear
  – Compressive stress vs growth rate
    - With methods to modify nearly physiological growth

Conclusion

Vertebral growth reductions after spinal hemiepiphysiodesis as determined by histomorphometry were lower than predicted by this finite element model with linear stress-growth relationship

Thank you

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