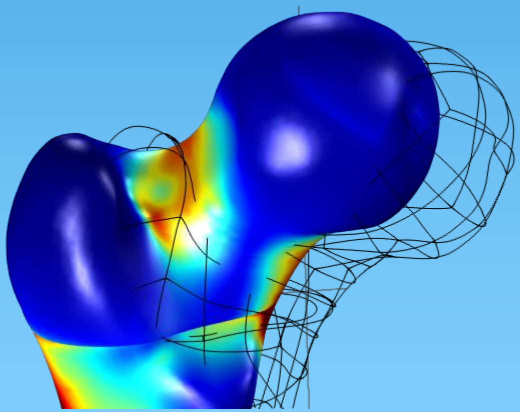
Determination of Mechanic Resistance of Osseous Element through Finite Element Modeling



Luis Enrique Isaza

Luis Carlos Flórez García

Edgar Alonso Salazar

Universidad Tecnológica de Pereira

2013

COMSOL CONFERENCE BOSTON 2013

Excerpt from the Proceedings of the 2013 COMSOL Conference in Boston

Introduction

* The consequences of hip fracture and femoral fracture are widely known. This phenomenon is one of the principal causes of morbidity among elderly.

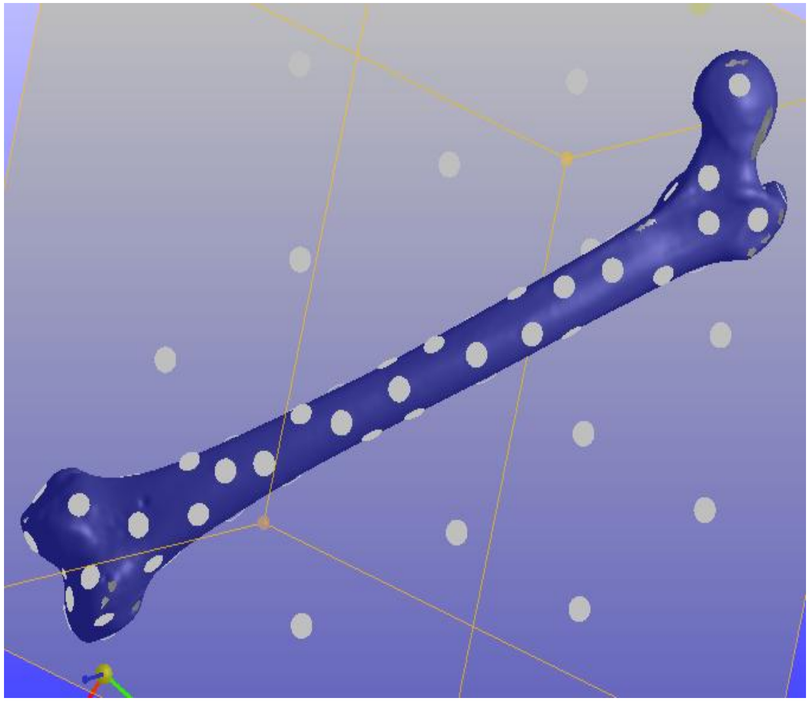
* The mechanical strength of the femur varies in every person, but is possible to predict the mechanical resistance with parameters like density, dimensions and mineral content .

Objetives

* This paper uses different models and empirical studies to determine the mechanical properties of the human femur, developing isotropic and anisotropic models oriented to determine de mechanical behavior of bone.

* This study allows predicting the femur break load in function of one specific individual parameter: the bone density.

Bone Geometry Obtaining

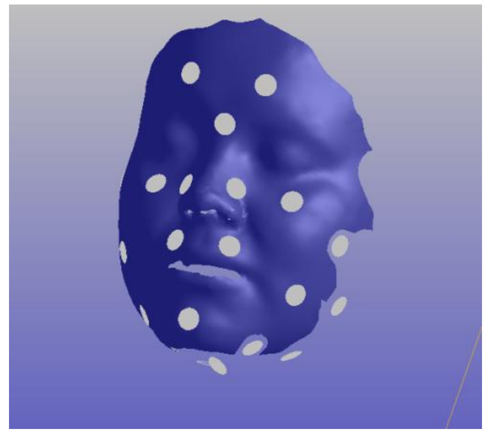


* In this work, the 3D scanning technology was used to obtain the bone geometry.

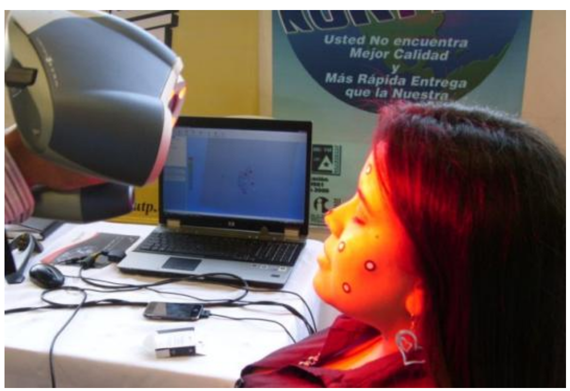
* The 3D scanning technology is widely used to obtain complex geometry, for example in reverse engineering.

Resource

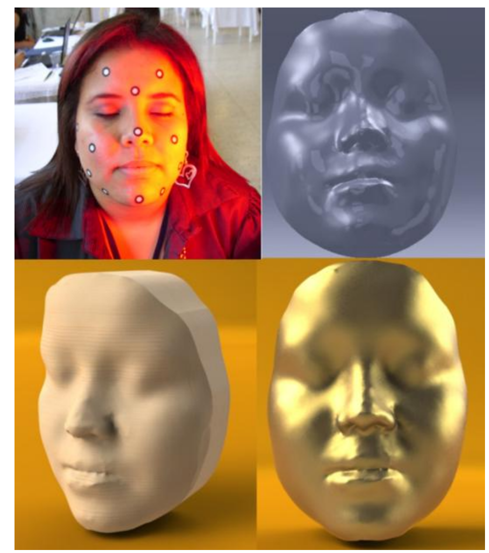
Points Cloud



Scanning Process

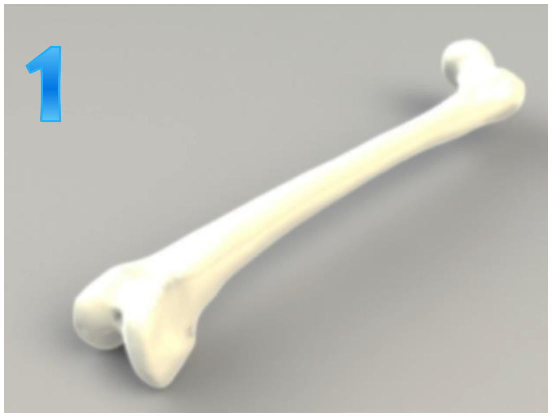


CAD and Physical Model

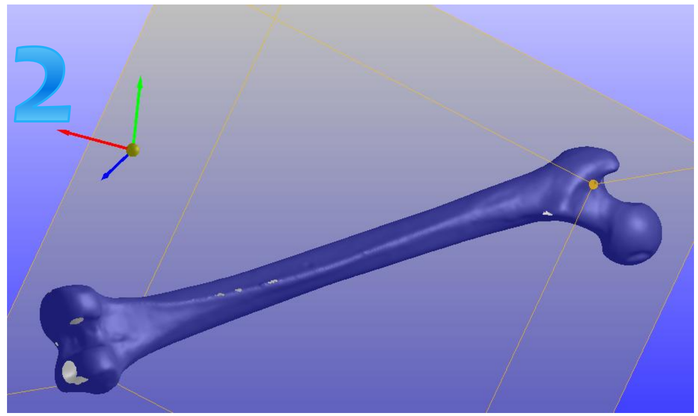


Universidad Tecnológica de Pereira

Human Femur

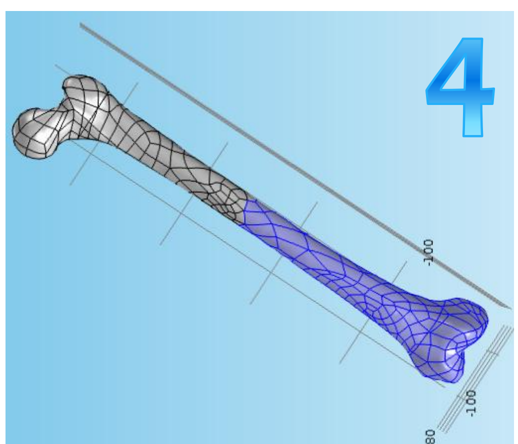


Points Cloud

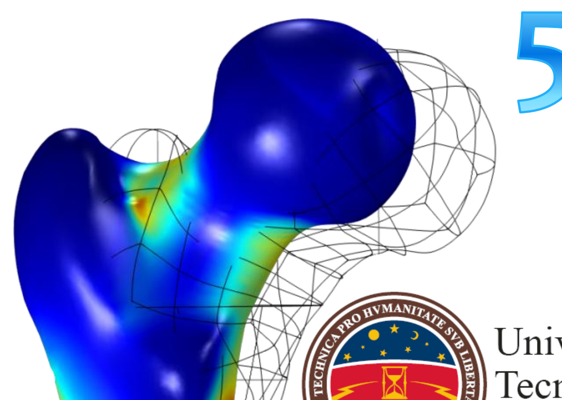


CAD Model

FEM Model



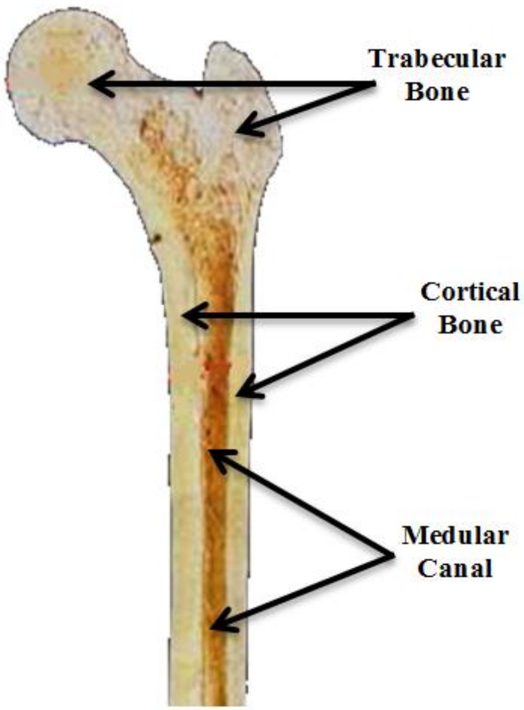
Simulation



COMSOL CONFERENCE BOSTON 2013

Universidad Tecnológica de Pereira

Human Femur Composition



* The human femur is compound by two different materials:
  * Cortical Bone
  * Trabecular Bone
* The mechanical properties of each one are different, and the two materials are anisotropic materials.

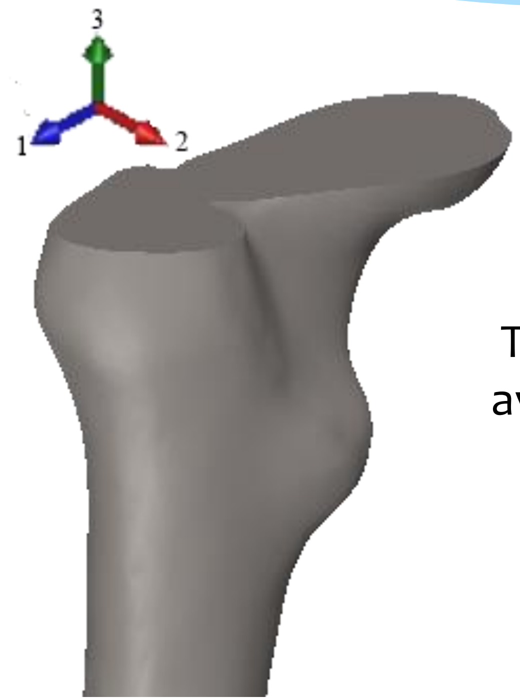
COMSOL CONFERENCE BOSTON2013

Universidad Tecnológica de Pereira

Human Femur Properties

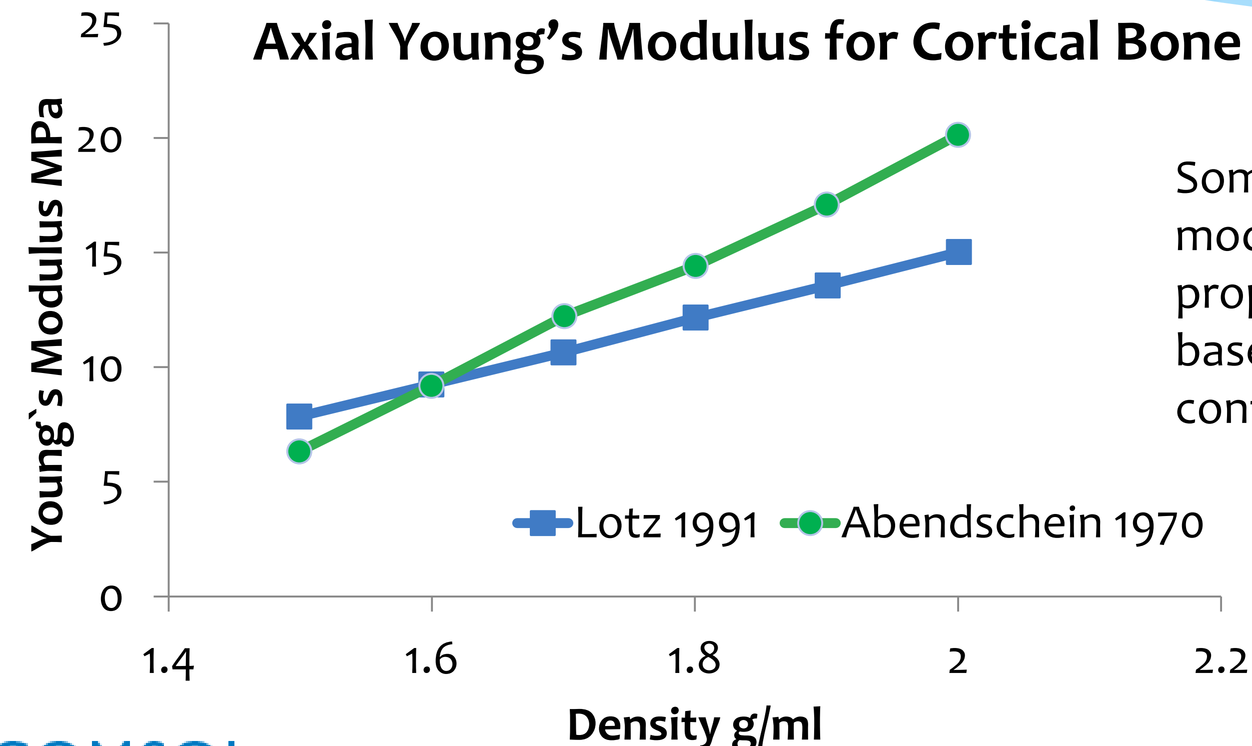
Mechanical Properties of Cortical Bone

Mechanical Property	Ashman 1984	Meunier 1989	Taylor 2002
E_1 (GPa)	13.48	12.41	17.9
E_2 (GPa)	13.48	12.41	18.8
E_3 (GPa)	20.6	20.35	22.8
μ_{12}	0.37	0.41	0.28
μ_{13}	0.22	0.20	0.30
μ_{23}	0.36	0.35	0.31



This properties are average properties, not parametric properties.

Human Femur Properties



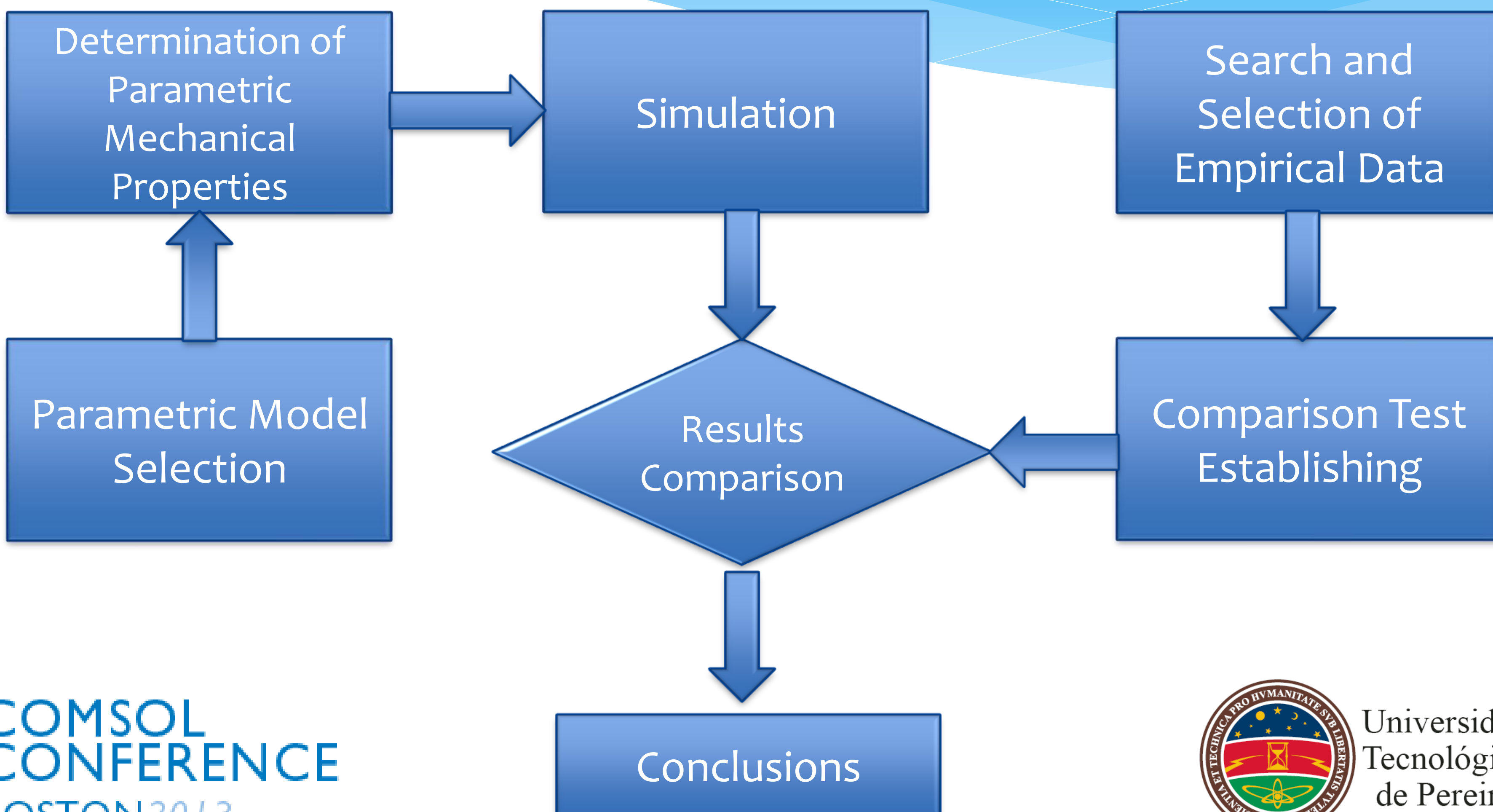
Some authors has developed models for the mechanical properties of human bones based in density or mineral content

COMSOL CONFERENCE BOSTON 2013

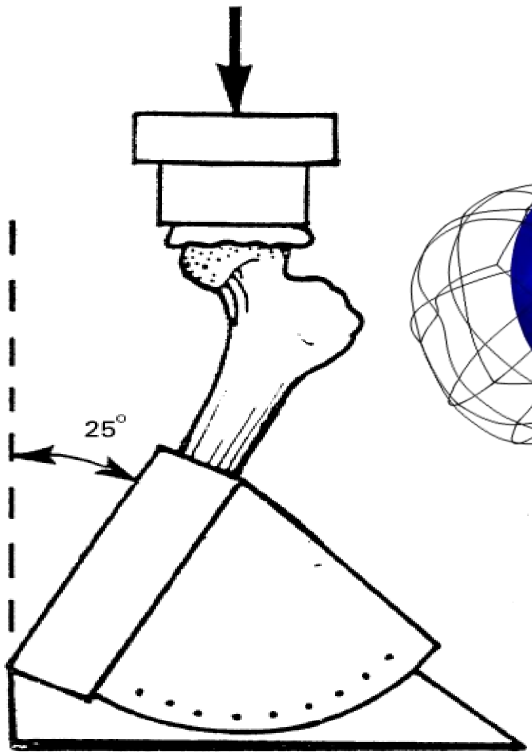
Universidad Tecnológica de Pereira

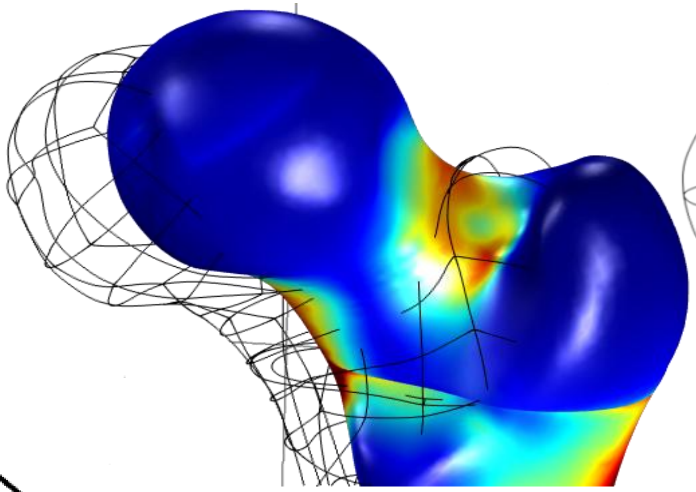
Excerpt from the Proceedings of the 2013 COMSOL Conference in Boston

Modeling Procedure

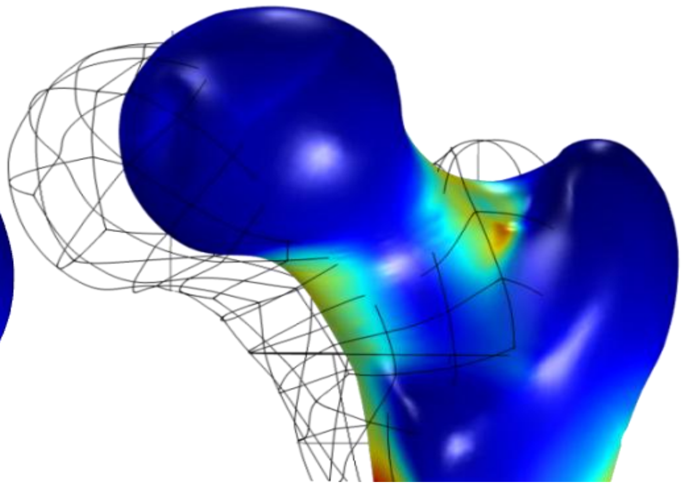


Simulation and Test





Anisotropic Model



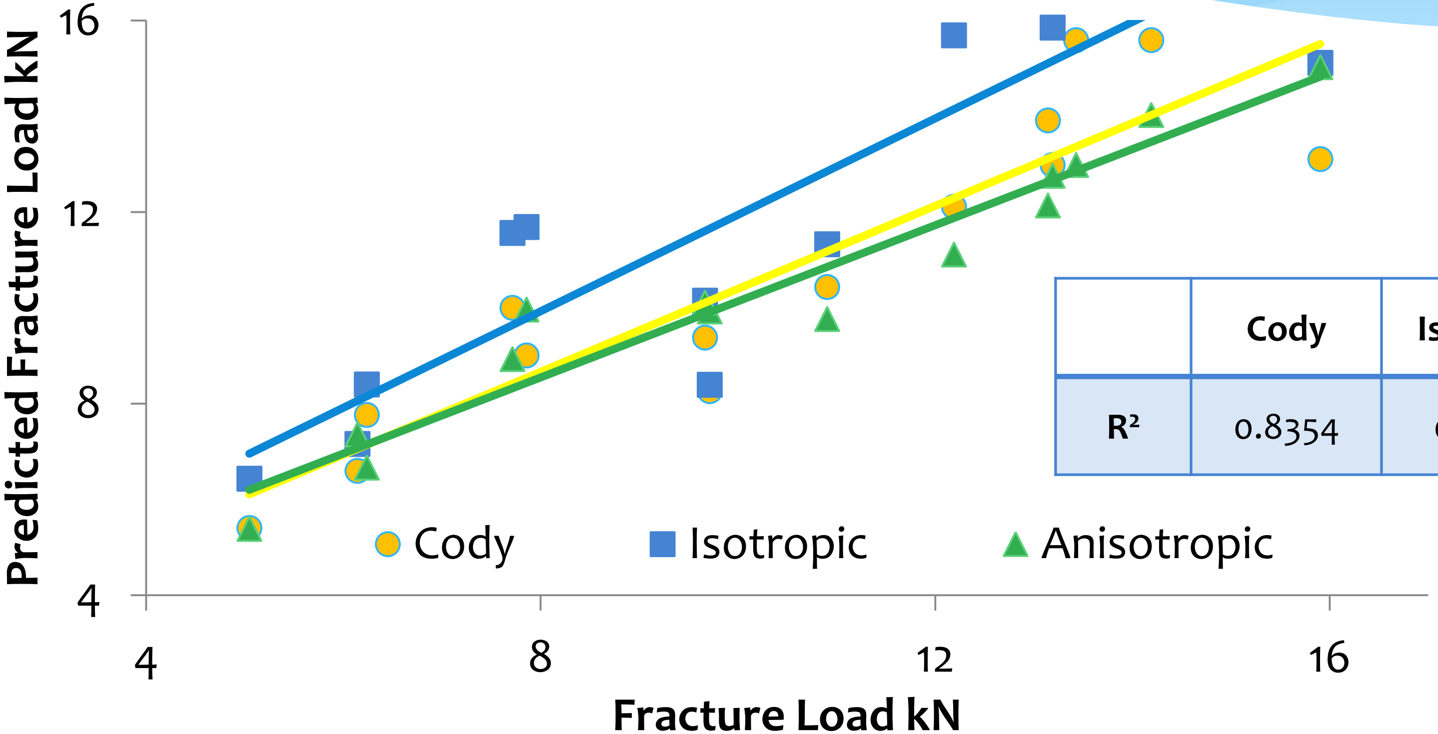
Isotropic Model

COMSOL CONFERENCE BOSTON 2013

Universidad Tecnológica de Pereira

Excerpt from the Proceedings of the 2013 COMSOL Conference in Boston

Results and Conclusions



	Cody	Isotropic	Anisotropic
R^2	0.8354	0.6885	0.9123

COMSOL CONFERENCE BOSTON 2013

Universidad Tecnológica de Pereira

Thanks

References

1. D. Testy, M. Viceconti, F. Baruffaldi, A. Capello. Risk of Fracture in Elderly Patients: A New Predictive Index Based on Bone Mineral Density and Finite Element Analysis. *Computer Methods and Programs in Biomedicice,* **Volume 60**, pp. 23-33 (1999).

2. L. Pérez. *Caracterización Sujeto-Específica de las Propiedades Mecánica del Material Óseo en Femur Porcino.* Pontificia Universidad Católica de Chile. Santiago de Chile. (2009)

3. P. Rubin, P. Leyvraz, J. Aubaniac. J. Angenson, P. Estève, B. de Roguin. The Morphology of the Proximal Femur. *The Journa of Bone and Joint Surgery.* **Volume 70-B No I.** pp. 25-32**.** January (1992).

4. L. Duchemin, V. Bousson, C. Raossanaly, C. Bergot, J. Laredo, W. Skally, D. Mitton. Prediction of Mechanical Properties of Cortical Bone by Quantitative Computed Tomography. *Medical Engineering and Physics.* **Volume 30.** pp. 321-328. (2008).

References

5. D. Wirtz, N. Schiffers, T. Pandorf, K. Randermacher, D. Weichert, R. Forst. Critical Evaluation of Known Material Properties to Realize Anisotropic FE-Simulation of the Proximal Femur. *Journal of Biomechanics.* **Volume 33**. pp. 1325-1330. (2000).

6. E. Rincón, A. Ros, R. Claramunt, F. Arranz. Caracterización Mecánica del Material Óseo. *Tecnología y Desarrollo.* **Volume 2**. pp. 3-27. (2004).

7. R. Huiskes, T. Slooff. Geometrical and Mechanical Properties of the Human Femur. **VI International Congress of Biomechanics, Copenhagen, Denmark.** pp. 57-64. (1977).

8. W. Taylor, E. Roland, H. Ploeg, D. Hertig, R. Klabunde, M. Warner, M. Hobantho, L. Rakotomanana, S. Clift. Determination of orthotropic bone elastic constants using FEA and Modal Analysis. *Journal of Biomechanics.* **Volume 35.** pp. 767-773. (2002).

9. S. Tassani, C. Öhman, F. Baruffaldy, M. Baleani, M. Viceconti. Volume to Density Relation in Adult Human Bone Tissue. *Journal of Biomechanics.* **Volume 44**. pp. 103-108. (2011)

References

10. J.Rho, M. Hobatho, R. Ashman. Relations of Mechanical Properties to Density and CT Numbers in Human Bone. *Medical Engineering and Physics.* **Volume 17.** pp. 347-355. (1995).

11. T. Brown, A. Ferguson. Mechanical Property Distributions in the Cancellous Bone of the Human Proximal Femur. *Acta Orthop.* **Volume 51**. pp. 429-437. (1980).

12. G. Niebur, M. Felstein, J. Yuen, T. Chen, T. Keaveny. High Resolution Finite Element Models with Tissue Strenght Assimetry Accurately Predict Failure of Trabecular Bone. *Journal of Biomechanics.* **Volume 33**. pp. 1575-1583. (2000).

13. A. Nikodem. Correlations Between Structural and Mechanical Properties of Human Trabecular Femur Bone. *Acta of Bioengineering and Biomechanics.* **Volume 14 No. 2.** pp. 37-47. (2012).

14. D. Cody, G. Gross, F. Hou, H. Spencer, S. Golstein, D. Fyhrie. Femoral Strength is Better Predicted by Finite Element Models than QCT and DXA. *Journal of Biomechanics.* **Volume 32.** pp. 1013-1020. (1999).