SCHWEIZERISCHER NATIONALFONDS ZUR FÖRDERUNG DER WISSENSCHAFTLICHEN FORSCHUNG
FONDS NATIONAL SUISSE DE LA RECHERCHE SCIENTIFIQUE
SWISS NATIONAL SCIENCE FOUNDATION
FONDO NAZIONALE SVIZZERO PER LA RICERCA SCIENTIFICA

CO-ME COMPUTER AIDED AND IMAGE GUIDED MEDICAL INTERVENTIONS

Rat der Eidgenössischen Technischen Hochschulen ETH-Rat

Co-Me SAB meeting 2008
Computer assistance in orthopaedic surgery #10

Statistical Finite Element Model for Bone and Implant Modeling

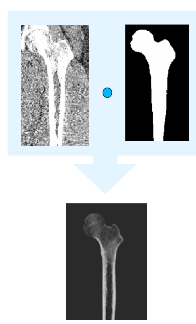
Serena Bonaretti[1], Philippe Büchler[1], Daniel Rückert[2], Mauricio Reyes[1] and Miguel A. González[1]

[1] **MEM-ISTB, University of Bern, Switzerland**
[2] **Visual Information Processing, Department of Computing, Imperial College London, UK**

Introduction

Current implant design is based on clinical experience and trial-error process to find optimal shape and mechanics. Evaluation and optimization of the implant are done on a few cadaver bones.
We aim to develop a *Combined Statistical Model of Shape and Intensity* that will allow the evaluation and optimisation of the mechanical properties of current and future orthopaedic implants. Bone-implant fitting helps to evaluate the current implant shape, while bone density information will help to evaluate the screw positions, orientations and lengths.

Statistical Model



Data Sets

CT and Segmented Femurs:
- *Masked Femurs* delimits ROI femur bone structure.

Registration

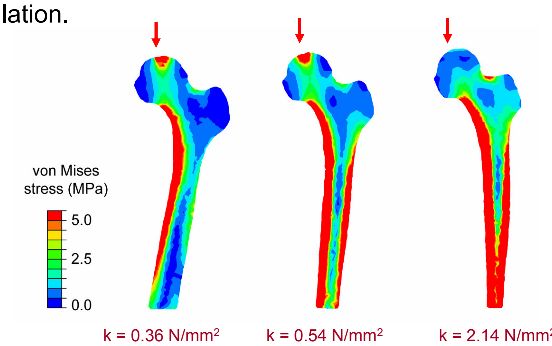
- *Non-rigid*: *Deformation Fields* establish points correspondences.

Principal Component Analysis

- Average and Distribution. $C_i = C_{MEAN} + \Phi b$

Finite Element Modeling

Obtain the average and variation of the stiffness over the population.



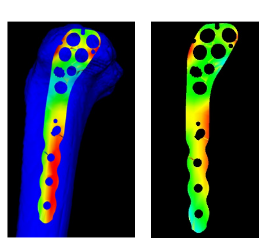
Intensity values → relative density ρ and Young's modulus:

$$E = \begin{cases} 60 + 900\rho^2, & \rho < 0.46\left(g/cm^3\right) \\ 2875\,\rho^3, & otherwise \end{cases}$$

Loading conditions: *1600 N* and diaphyseal maintained fixed.
Bone stiffness *k = F/d*.

Fitting

Statistical analysis of bone-implant fitting:
- Fully automatic
- Anatomical implantation constraints



Discussion

We developed a statistical biomechanical framework [1].
The construction of the model is based on *non-rigid registration* thus no landmarks or parametric representation was required.
PCA combines shape and intensity information, which may help to predict density when only shape is known.
Through fitting and finite element analysis both shape and mechanical properties of bone+implant will be evaluated.

Reference: [1] Belenguer Querol, L., Büchler, P., Rueckert, D., Nolte, L.P., González Ballester, M.A. Statistical Finite Element Model of Bone Shape and Biomechanical Properties. Proc. MICCAI 2006. Copenhagen, Denmark. Springer 2006.

Serena Bonaretti
serena.bonaretti@memcenter.unibe.ch
www.memcenter.unibe.ch
Tel: +41-31-631-5955

MEM-ISTB
Stauffacherstrasse 78
3004 Bern
Switzerland

UNIVERSITÄT BERN