Shape and Biomechanical Models for Population Specific Design of Anatomical Peri-Articular Implants

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Introduction

Current implant design techniques in orthopedics are based on manual fitting and fixation procedures applied on cadaver bones; in this way it is difficult to assess whether implants will fit most of the population.

Here a framework is proposed to evaluate biomechanical performances of an implant across a given population: after the creation of a statistical model that describes bone shape and mechanical properties in a given population, the 41-B1 tibia fracture (A.O. classification) was propagated from the mean bone to each new instance. Subsequently the implant was fitted to the bone in a semi-automatic way and finally biomechanical simulations were performed to evaluate the implant design.

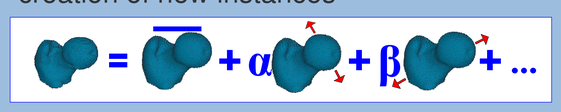
Methods

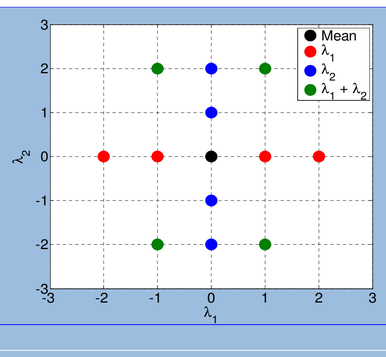
Statistical Shape Model

Dataset: CT images from different populations

Registration: deformation fields

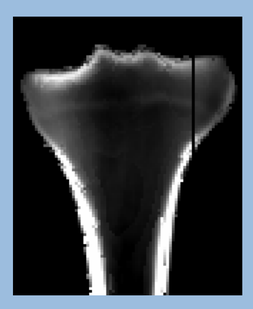
Principal Component Analysis: creation of new instances





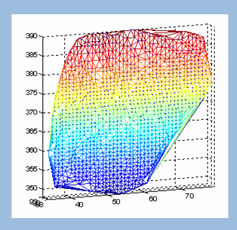
Fracture Creation

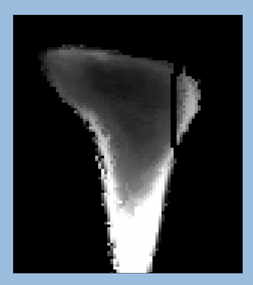
Fracture creation: vertical cut in the mean bone



Registration: fracture propagation to the instances

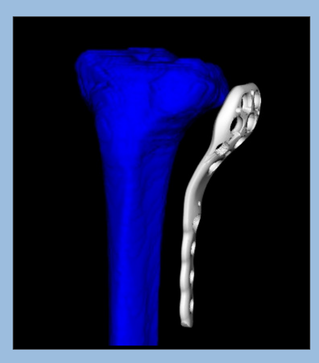
Surface creation:



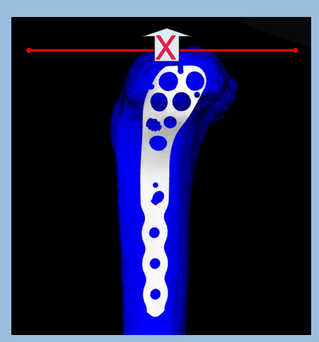


Implant Fitting

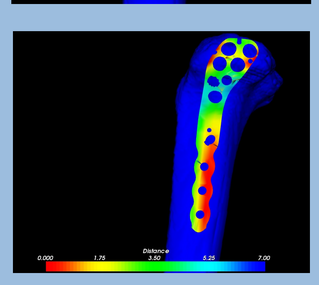
Manual initialization:



Implantation constraints:



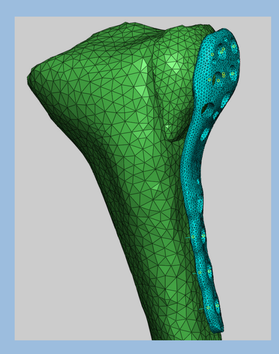
Iterative Closest Point: placement optimization



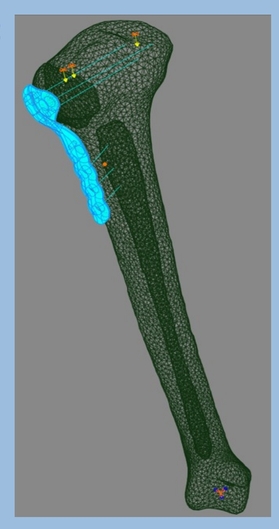
Finite Element Model

Bone:
$E=6.95\rho^{1.49}$
Poisson's ratio=0.3

Implant:
E=110 000 MPa
Poisson's ratio=0.3



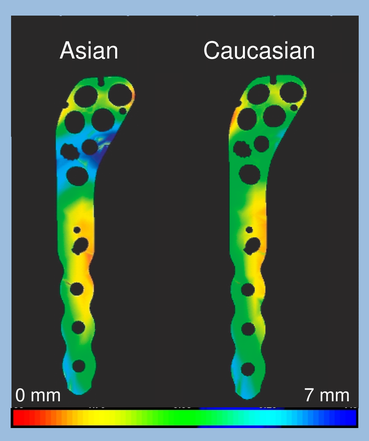
Loading conditions:
1600 N



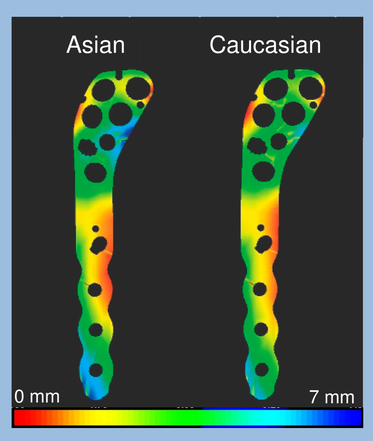
Results

Implant Fitting

Maximum distances:



Average distances:



Finite Element Model

	Caucasian	Asian
von Mises stress in the plate (MPa)	61	69 (+12%)
Max principle stress in the screws (MPa)	61	80 (+31%)

Discussion

We presented a framework for statistical biomechanics assessment including a combined statistical model of shape and finite element analysis. Fitting results showed no statistical differences between Asian and Caucasian, while Finite Element Analysis showed that both plate and screw stresses are significantly higher ($p<0.05$) for Asian than for Caucasian.
Future developments will combine shape and intensity information into the statistical model; moreover different implant positions and loading conditions will be evaluated.

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