15th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
and
3rd Conference on Imaging and Visualization
CMBBE 2018
P. R. Fernandes and J. M. Tavares (Editors)

Abstract ID-207

DEVELOPMENT OF AN IN-VITRO INTRINSICALLY LOADED TEMPOROMANDIBULAR FORCE SIMULATOR AND FAST COMPUTATIONAL MODEL BASED ON METHOD OF EXTERNAL APPROXIMATIONS

Kenneth Ip, Peng You, Nikolas Knowles, Corey Moore, Louis Ferreira

University of Western Ontario, Canada
kip32@uwo.ca, pyou2@uwo.ca, nknowle@uwo.ca, cmoore22@uwo.ca, louis.ferreira@sjhc.london.on.ca

Keywords: In-vitro simulator, In-silico, micro-CT, meshless, craniofacial, biomechanics, strain, muscle loading

Summary: Introduction
The biomechanics of the maxillofacial skeleton are generally described as a system of columns and buttresses through which bone stresses are channeled, and it is important to restore the integrity of these structures during fracture repair or major reconstruction. Ideally, the design and evaluation of surgical techniques and implants, such as fracture plates, should be informed by validated biomechanics models. However, contemporary in-vitro models lack basic physiological intrinsic muscle loading patterns.
Methods
An in-vitro simulator was developed to replicate intrinsic masticatory loads from six individually and simultaneously controlled muscle load vectors. Subject-specific muscle attachments were reverse-engineered from CT scan (isotropic voxel: 0.625 mm) and 3D-printed to produce physiologic lines of action. Ten strain gauges measured bone strains and a load cell measured bite force.
One human cadaveric head was tested with temporalis and masseter muscles simulated. Ten uniaxial strain gauges were cemented to craniofacial bones to obtain in-vitro strain measurements. The head was also scanned using micro-CT (isotropic voxel: 0.108 mm) and the high-resolution model was combined with the clinical resolution model to create a solid model with high resolution in the face, where strain gauges were located. The complete experiment, including bone and actuators, was computer modelled in SIMSOLID and used for cross validation.
Results
Computer simulations required on average 15 minutes. The eight strain gauges away from muscle attachments showed good correlation (R^2=0.833). The two strain gauges near muscle attachments showed poor correlation (R^2=0.231) and strain inflections. A sensitivity analysis revealed that these locations were sensitive to small changes in muscle attachment sites. Pairwise T-test showed no significant difference between in-vitro and in-silico normalised changes in strain between loads levels. The in-vitro bite force correlated with simulation values (R^2=0.987).
Conclusion
The in-vitro and in-silico models revealed complex bone stress/strain distributions as a function of both complex and simple masticatory loading patterns. Locations of stress/strain inflections were found in both models and determined to be sensitive to small changes in muscle loading vectors. The novel application of intrinsic muscle loading to produce complex masticatory load patterns will be useful to simulate in-vivo biomechanics in future studies.