World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:9, No:11, 2015

Computation of Residual Stresses in Human Face Due to Growth

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Abstract : Growth and remodeling of biological structures have gained lots of attention over the past decades. Determining the response of the living tissues to the mechanical loads is necessary for a wide range of developing fields such as, designing of prosthetics and optimized surgery operations. It is a well-known fact that biological structures are never stress-free, even when externally unloaded. The exact origin of these residual stresses is not clear, but theoretically growth and remodeling is one of the main sources. Extracting body organs from medical imaging, does not produce any information regarding the existing residual stresses in that organ. The simplest cause of such stresses is the gravity since an organ grows under its influence from its birth. Ignoring such residual stresses might cause erroneous results in numerical simulations. Accounting for residual stresses due to tissue growth can improve the accuracy of mechanical analysis results. In this paper, we have implemented a computational framework based on fixed-point iteration to determine the residual stresses due to growth. Using nonlinear continuum mechanics and the concept of fictitious configuration we find the unknown stress-free reference configuration which is necessary for mechanical analysis. To illustrate the method, we apply it to a finite element model of healthy human face whose geometry has been extracted from medical images. We have computed the distribution of residual stress in facial tissues, which can overcome the effect of gravity and cause that tissues remain firm. Tissue wrinkles caused by aging could be a consequence of decreasing residual stress and not counteracting the gravity. Considering these stresses has important application in maxillofacial surgery. It helps the surgeons to predict the changes after surgical operations and their consequences.

Keywords : growth, soft tissue, residual stress, finite element method
Conference Title : ICCB 2015 : International Conference on Computational Biomechanics
Conference Location : Paris, France
Conference Dates : November 19-20, 2015