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A 3D FINITE ELEMENT MODEL OF THE FEMALE PELVIC FLOOR FOR THE RECONSTRUCTION OF URINARY INCONTINENCE

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Motivation: In medical science, a progressive development of urinary incontinence in ageing female is not easy to explain. Possible causes for such disorders are the impairment of pelvic musculature and connective tissues which stabilizes pelvic organs, structurally and functionally. Such dysfunctions can be addressed effectively through a surgery with an insertion of an anchoring mesh 'to restore the structure to improve its function', which is the fundamental principle of *Integral Theory* [1]. Enormous effort have been made in order to identify their behaviour, however, exact mechanisms are yet to be found [2], [3]. In recent years, engineers have developed progressive and sophisticated algorithms, to simulate and approximate the pelvic floor anatomy under different circumstances. However, lack of detailed anatomy and realistic simulations has still limited an appropriate behaviour of the models. The aim of this paper is to address the complex anatomy of the female pelvic floor via a realistic computational model in order to examine the interaction between pelvic structures under severe conditions with appropriate fiber oriented material models.

Computational model: As shown in figure 1, a three dimensional geometrical model has been generated from stacks of plastinate images of a 70 years age female cadaver. It consists of pelvic organs, muscles, ligaments, bones and nerves. Based on the topographical anatomy, appropriate thickness information of the pelvic structures, we discretize all of them with 4-noded or 9-noded tetrahedral finite elements, depending on accuracy and contact resolution considerations, see figure 2.

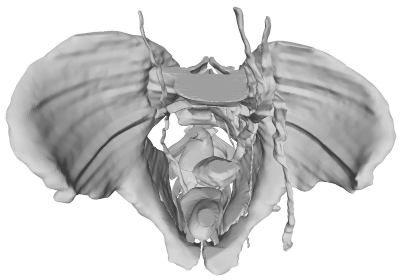

Figure 1: Top view of the geometrical model created from the plastinate surface.

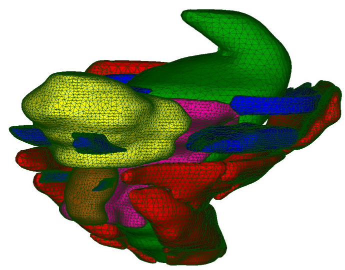

Figure 2: Three dimensional FE mesh of the female pelvic floor showing muscles (red), ligaments (blue), vesica (yellow), urethra (brown), vagina (pink), and rectum (green).

The integrated model consists of pelvic organs (vesica, urethra, vagina and rectum) suspended by ligaments and pelvic musculature (levator ani) attached between pubic symphysis and coccyx. Contrary to current research work which often is focused on the simplification of the models, the three-dimensional model presented in this paper handles the nonlinearities (geometrical and material) and contact problems within the pelvic interfaces.

Constitutive laws: Since most of the biological soft tissues depicts a certain degree of anisotropy, hyperelasticity, incompressibility and fiber families, we choose the HGO-model [4] to simulate the pelvic behavior. The model includes an isotropic (isochoric and volumetric) part and an anisotropic part contributed from different fiber families.

Prospective results: Numerical results have been compared with the MRI behaviour of female pelvic structures. The hypothesis of supporting tissue impairment (fascial stretching and ligamentous laxity) resulting in organ dislocation was supported from 3D simulation, which is close to that measured in prolapsed female [5]. Stress distribution on supporting connective tissues under increased intra-abdominal pressure and corresponding muscle contraction during micturition and active closure of urethra can be issued to compare the phenomena of urinary incontinence. Results obtained from the cadaver based geometrical model can be helpful for the surgeons to treat the incontinent patient.

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