Editorial

Forward to the special issue on biomechanics of breast tissues and its clinical applications

Biomechanical modelling of human breast tissue has been studied for the past 20 years for various medical applications, including surgical training, preoperative planning, diagnosis and clinical biopsy, mammography, image-guided surgery, image registration, and material parameter estimation. By simulating the deformations that occur during various breast procedures, biomechanical modelling of the breast can help clinicians and medical device manufacturers address several challenges. Such applications usually require personalized biomechanical models. Therefore, it is crucial to identify the individual's geometry, mechanical properties of the breast tissues, and boundary conditions to provide reliable and clinically relevant predictions.

The literature has extensively explored the creation of patient-specific geometric models of the breast from MR and CT images based on segmentation of the breast boundaries. Estimating the *in vivo* mechanical properties and loads of breast tissues remains a significant challenge due to their nonlinear, inhomogeneous, anisotropic, and time-dependent behaviors. These properties vary considerably across the population due to factors such as age, physiological conditions (*e.g.* menstrual cycle, pregnancy, and menopause), and pathophysiological state. It is important to note that these evaluations should remain objective and free from bias. The appropriate selection of constitutive laws for each breast tissue and calibration of person-specific parameters has significant implications for numerical simulations. Therefore, it is necessary to conduct suitable *ex vivo* and *in vivo* experimental characterization assessments. Understanding the interplay between the mechanical and biological responses of the system is necessary for developing a high-fidelity patient-specific surgical simulators, such as, for example, specifically a computational model of oncoplastic breast surgery. Similarly, estimating *in vivo* loads, including prestress in tissues, particularly in Cooper's ligaments, and *in vivo* loading due to mammography, remains a significant challenge.

Additionally, practical challenges must be addressed to implement biomechanical models of the breast in a clinical setting. While research workflows prioritize speed and ease of use, clinical workflows prioritize dependability, practicality, and rapid turnaround times. One of the main difficulties in using breast biomechanical models in a clinical setting is obtaining appropriate images to generate patient-specific anatomical models. Technical barriers involve developing cost-effective methods for generating patient-specific biomechanical models of the breast and characterizing the mechanical properties of different breast tissues.

The current issue provides a small yet representative snapshot of current efforts geared towards improved diagnostics and treatments. It comprises both reviews and original studies, with a particular focus on Non-linear Finite Element computational modelling, 3D Imaging, *ex vivo* and *in vivo* tissue characterization, patient-specific model generation, and breast kinematics. The issue begins with a review on how female breasts change over a woman's life span, with implications for breast injuries sustained by females. Limitations of current breast injury research, gaps in knowledge about breast injuries incurred by specific populations, and the lack of breast injury models are highlighted by (McGhee and Steele, 2023). The second paper in the issue addresses the issue of *in vivo* measurement of breast tissue stiffness, which has been poorly addressed to date, with the exception of elastography imaging, which has shown promising results but is still difficult for clinicians to use on a daily basis. In an effort to make progress in the estimation of subject-specific tissue stiffness, (Briot et al., 2022) focus on the development of a light aspiration device to obtain *in vivo* Young's modulus of skin and fibroglandular breast tissue.

The third set of papers concentrates on improving the clinical relevance of biomechanical models. (Ringel et al., 2023) focuse on image-guided surgery, where biomechanical models have been used for prone-to-supine registration to correct for large non-rigid soft-tissue deformations between the imaging and intraoperative positions. The results indicate that biomechanical models that fully incorporate all constitutive complexities of the anatomical structure are likely to achieve the best accuracy, but that a computationally tractable heterogeneous anisotropic model provides a significant improvement and may be applicable to image-guided breast surgery. Similarly, (Pan et al., 2024) tested the hypothesis that different shoulder orientations alter the length-tension of the shoulder girdle muscles to which the breast is attached, and thus the shape of the breast. Their results support this hypothesis and suggest that shoulder girdle orientation should be included in breast biomechanical models used for navigational guidance in breast tumour localisation to improve their accuracy.

The fourth group of papers presents current efforts to make the runtime of preoperative breast surgery planning compatible with the clinical time scale. (Mazier and Bordas, 2024) present a new, fast and simple patient-specific FE pipeline that addresses the challenge of estimating the intra-operative configuration from clinical image acquisition and investigate the importance of breast rheological properties and infra-mammary ligament design on the overall simulation. Likewise, using machine learning models (Said et al., 2023) show that a speedup of factor 240 can be obtained for the estimation of the biomechanical mammographic deformation enabling clinically relevant real-time application.

The last paper of the issue focuses on the development of a low-cost and personalized external silicone breast prosthesis produced by additive manufacturing for women who have undergone mastectomy (Leme et al., 2023). This is a very important challenge in developing countries where only a small proportion of patients undergo breast reconstruction, mainly due to the risk of surgery, complications, prolonged recovery, lack of infrastructure and the small number of surgeons trained and qualified to perform oncoplastic surgery.

The guest editors thank all of the authors for their insightful contributions and the reviewers for their thorough and thoughtful feedback in making this special issue of Clinical Biomechanics on *Biomechanics of Breast Tissues and its Clinical Applications* a success. We hope the field finds these papers stimulating and that they encourage future explorations. Additional thanks to the Elsevier staff of Clinical Biomechanics, in particular Debbie McStrafick for their assistance and to Professor Amit Gefen for encouraging us to develop this special issue. We believe this issue will be an important record of the current state of the field and hope it serves as a meaningful resource for those studying the biomechanics of injury.

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