MODEL-BASED SIMULATIONS OF THE PIERCING PROCESS IN PIEZO INTRACYTOPLASMIC SPERM INJECTION

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ABSTRACT

To develop a piezo intracytoplasmic sperm injection (piezo-ICSI) procedure without using mercury, the real physics behind the zona piercing must be understood. An effort has been made to formulate a three-dimensional model for fluid-membrane interaction with the use of the Material Point Method (MPM) so that the mouse zona piercing process could be better simulated for the piezo-ICSI procedure. It is found from the MPM simulations that the lateral vibration of the pipette leads to the noticeable oocyte deformation and the occurrence of the zona failure but no evident deformation and zona failure result from the longitudinal oscillation of the pipette. This outcome confirms the claim that the lateral vibration of the injection pipette plays a key role in the piercing process, and disproves the argument that the axial displacement of the pipette pierces the zona. The lateral vibration of the injection pipette is also analyzed using the finite element method (FEM) to further investigate the role of mercury in the zona piercing. It is shown that the employment of fluids generally reduces the vibration amplitude of the pipette tip and the amplitude decreases with the increase of fluid density. Moreover, smaller vibration amplitude could be observed as the pulse duration becomes shorter. It can be concluded that the effect of mercury on the piezo-ICSI might yield less oocyte damage due to the reduced amplitude of the pipette tip, and that the development of a piezo-ICSI procedure without using mercury is

possible by changing the dynamic characteristics of the injection micropipette and the piezo-drill controller parameters.