Modelling calvarial development in mice using finite element method

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During the early stages of postnatal development, in concert with the radial expansion of the skull, the mechanical properties of the calvarial bones change and the visible gaps at the sutures reduce to micro/nanometer gaps where the sutures differentiate to bone. Our understanding of the level of loading that sutures experience during the development is limited. The aim of this study was to develop a validated finite element (FE) model of a normal mouse calvarial growth to estimate the level of mechanical strain that sutures undergo during the development and to predict the pattern of bone formation at these joints.

First, a series of *ex vivo* studies based on micro-computed tomography were carried out on wild type mice (*Mus musculus*, C57BL6/J) at 11 postnatal (P) ages from P3-42 to quantify the morphological changes during the calvarial development. Second, mechanical properties of the calvarial bones (frontal and parietal) were characterised in a total of 11 mice (over 3 age ranges) using nanoindentation. Third, the FE method was used to model the postnatal radial expansion of the mouse skull from P3-P10 and to model the bone formation at the sutures using a bone formation algorithm.

Calvarial length, width and height all gradually increased until ~P20. The elastic modulus of the frontal and parietal bones gradually increased from 5.32±0.68 and 4.33±0.18 GPa at P10 to 7.14±0.79 and 6.30±0.47 GPa at P20, and then to 9.4 and 8.7 GPa at P70 respectively (one specimen at P70). The FE models predicted the radial expansion of the skull from P3 to P10 and suggested the calvarial sutures may experience hydrostatic strain in the range of 1.25-2.5% during early postnatal growth.

The validated FE models developed in this study offer significant potential to enhance our understanding of the mechanobiology of the craniofacial system, and further highlight the great opportunities offered by the FE method in predicting morphological changes that occur during musculoskeletal development.