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BIOMECHANICS OF CHIASMAL COMPRESSION: SENSITIVITY OF THE MECHANICAL BEHAVIOURS OF NERVE FIBRES TO VARIATIONS IN MATERIAL PROPERTY AND GEOMETRY

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In the human visual system, the information of the right visual field (VF) is processed by the left side of the brain and vice versa. To achieve this, there is a partial crossing of optic nerve fibres in the optic chiasm. The crossing fibres lie centrally in the chiasm while the uncrossed fibres pass directly back to the tracts in the lateral parts of the chiasm. Compression of the chiasm typically produces a bitemporal hemianopia due to selective damage to the crossed nerve fibres arising from the nasal hemiretina.

In bitemporal hemianopia vision is lost in the temporal half of the VFs of both the right and left eyes. This pattern of visual loss is highly localizing to the chiasm and the most common cause is a tumour of the pituitary gland that compresses the chiasm from below as it grows upwards out of the pituitary fossa (a depression of bone housing the pituitary gland). Although this phenomenon is well recognized, the precise mechanism by which compressive lesions of the chiasm selectively damage nasal nerve fibres is still not clear. This work investigated this longstanding problem by studying the biomechanics of chiasmal compression caused by a pituitary tumour growing up from below the optic chiasm.

Micro-scale models were generated using representative volume elements (RVE) to investigate the strain status in crossed and uncrossed nerve fibres. McIlwaine *et al.* (2005) hypothesised this difference in local anatomy as the reason for distinction between the nasal (crossed) and temporal (uncrossed) nerves due to the concentration of stress in the former. The boundary conditions applied on the RVE were derived from the macro-scale chiasmal compression model. The models are schematically illustrated in Figure 1. As the reported values of the geometric and material parameters used in the RVE model vary largely in the literature, design of experiments (DOE) was used to investigate the impact of uncertainty of these parameters in the output (response) of the RVE model.

The numerical results showed that the distributions of both the von Mises strain and the axonal strain in the crossed nerve fibres were much more non-uniform than those in the uncrossed nerve fibres. DOE analysis results indicated that the crossing angle of nerve fibres in the chiasm is the most significant factor that affects a wide range of outputs (responses) of the model.

The strain difference between the nasal and the temporal nerve fibres may account for the phenomenon of bitemporal hemianopia. This work also highlights the need for more accurate material properties of the tissues in the model and an improved understanding of the microstructure of the optic chiasm.

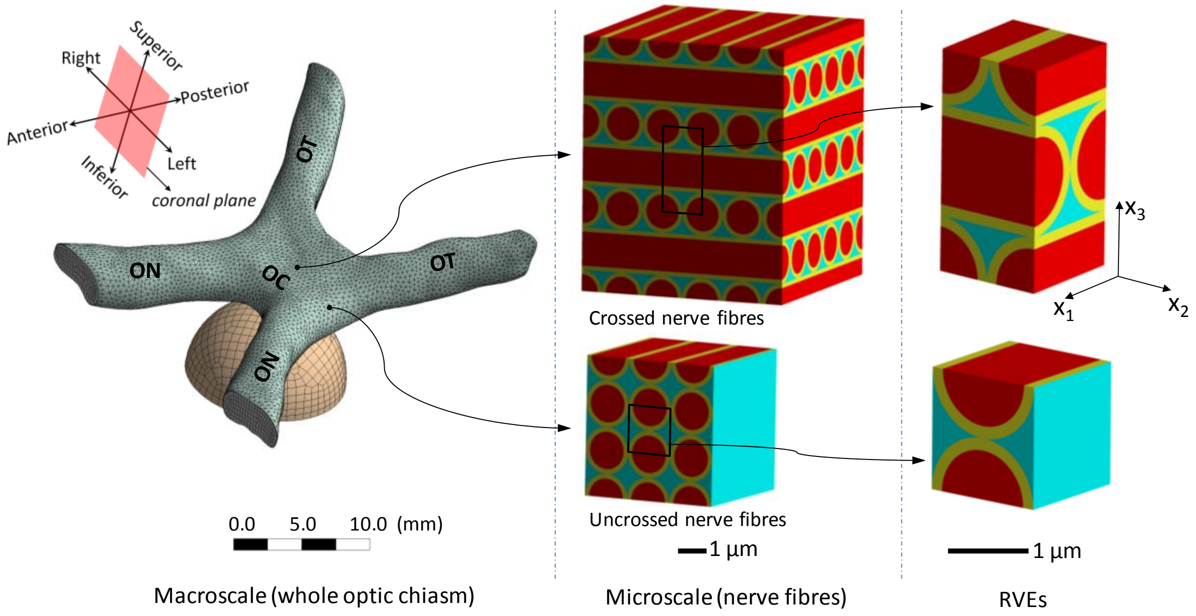

Figure 1. The macroscopic optic chiasmal model and the microscopic RVE models. OC: optic chiasm; ON: optic nerve; OT: optic tract.

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