Numerical material modelling of skull compact bones validated through impact experimental tests

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Bone fractures, and in particular skull fractures, play an important role in determining the severity of an accident.

The development of an accurate and realistic skull compact bone model is a critical step in simulating head impact scenarios and evaluating the performance of protective equipment.

Aim of the present study was to obtain a reliable finite element model of the compact bone tissue, that could predict skull fractures and corresponding forces accurately.

The current work is part of a larger effort made by Politecnico di Milano Laboratory of transport safety (LaST), in collaboration with Ospedale San Gerardo in Monza and Niguarda Hospital in Milan, to obtain an extremely refined and biofedelic model of the human head in finite element software LS-Dyna® by Ansys, starting from medical CT scans of a real patient head, with mesh of the skull entirely made by tetrahedral solid elements.

A traditional material mechanical characterization of human-derived tissues was impracticable due to ethical constraints and the need for an extensive number of samples of sufficient dimensions to be consistently tested. Hence, the response of the model was validated with static and dynamic experimental tests performed on bones derived from a bovine tibia of veal, both in the axial and transversal direction.

Due to the inhomogeneity of the biological samples, microtomography and 3D scanning methods were used, in conjunction with meticulous post-processing, to obtain a high-quality tetrahedral mesh of the specimens.

Stress triaxiality and strain rate dependency criteria were implemented in the material model, averaging values from different literature studies, to obtain a comprehensive behaviour of the failure of bone tissue in impact dynamics.

Results showed promising levels of accuracy of the numerical model not only in the prediction of the measured forces, but also of the fracture patterns compared to experimental tests, as can be seen in Fig. 1.

The current work could represent a step forward in providing a reliable and accurate tool to assess and improve the safety of human protection devices and reconstruct the dynamics of road accidents.

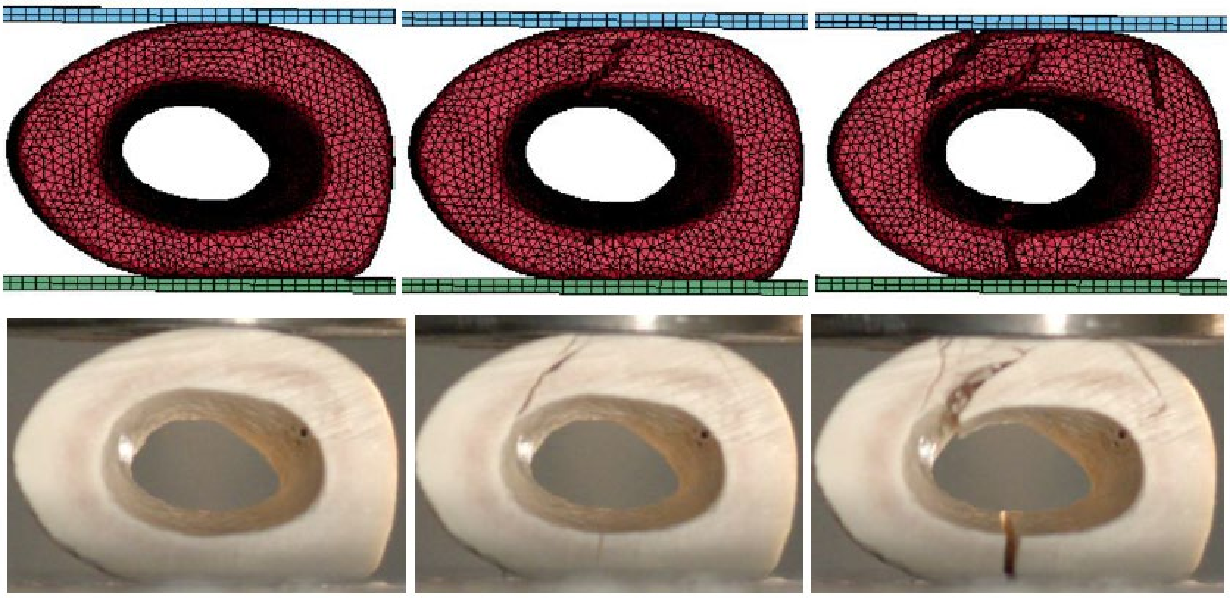

Figure 1: Impact test of bone specimen in transversal direction: comparison between numerical simulations (top figures) and experimental tests (bottom figures)