Quasi-static biomechanics of the human skull : experimental study

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Introduction

Because of the increasing frequency of fatal head injuries (generated by car accidents or other causes) many investigators are involved in head injury research. Biomechanical criteria are used to quantify these injuries. An absolute tolerance could be defined when, after a crash, the pers on is uninjured. The limit tolerance could be the appearance of pain, but it doesn't allow to perfonn comparisons. So the biomechanical criterion usually used is the Head Injury Criterion (HIC) based on linear component of the acceleration. The evaluation of this criterion by automobile equipment suppliers i~ carried out using experimental tests or «crash-tests» where a dummy replaces the human body.

A steel sphere instrumented with an accelerometer is used to simulate the dummy head and allows to test, for example, the aggressiveness of cars interiors. However, these tests are far from being representative of the real human head behaviour. ln order to perfonn more realistic simulations, a representative physical model of the human head, associated to a finite elements model, would be an important tool in the developmentof the vehic1es interior equipment.

Experimental tests were perfonned on skull in order to validate head physical and numerical models.

MateriaIs and Methods

Quasi-static axialloads were applied to four skulls taken from cadavers in order to quantify the mechanica1 response of the global structure. A flat rigid impactor delivered loads to the temporo-parietal region of fixed skulls. The loading surface was a 150 cm2 rectangular plate. The skull' s degrees of freedom were fixed by rigid foam. A load cell was fixed to the plate. The linear loading surface displacement was provided by a laser displacement sensor attached to the test set-up frame. The load velocity was 15 mm/min. Figure 1 shows the initials conditions of a test and the compressive machine.

After each test, the skull mineralization was deterrnined. Rectangular skull pieces were taken from frontal and parietal bones and then were bumt in open air at 700°C. Weights before and after oolcination were noted. Then we deduced the rate of mineralisation.

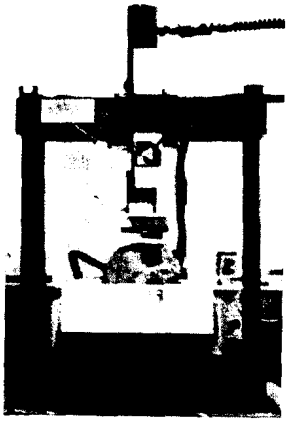

Figure 1 : impact conditions for the quasi-static tests

Results:

The load-displacement characteristics of the skull were established and the fracture force levels were deduced. The quasi-static load caused fracture for an average force level of 430 daN (375-512). The standard deviation is 61 daN. The stiffness was calculated and its average is 830 N/mm (600-1000). The standard deviation is 170 N/mm.

The associated injuries were noticed: fractures were essentially observed in temporo-parietal bones and zygomatique bone.

The morphological and mineral characteristics of skulls are gathered.

Discussion and conclusion

A fracture is not always found in fatal head injuries and, moreover, a patient with a fracture could have minimal clinica1 evidence of brain lesion.

The load-displacement characteristics of the skull were established and the associated injuries were noticed. The results showed different responses from one subject to another but sorne similar experimental results.

The mineralization results showed that age is a poor indicator of bone mineralization and should be discarded in any comparative study using cadavers.

These tests would be used for developing biofidelity requirements for evaluation of existing dummies and as reference for numerical model response analysis, as weIl as for new dummy design. The head physical model will be created and the validation study, using these tests, will be available within a few months.

Reference

Allsop D, Peri T, Warner C (1991): Force/deflection and fracture characteristics of the temporo-parietal region of the human head, *Society of Automotive Engineers* 1991, pp. 269-278.