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Virtual Trauma of Petrous bone fracture under lateral impact : from medical images to fracture process evaluation.

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Introduction

Head trauma, reported in sport injury and road accident analysis, frequently induce complex injury of Petrous bone. Such bone fractures are assumed to occur during lateral or posterior impact on the head [1, 2].

The location of the trauma on head structure, specifically on the Petrous bone area, concerns facial nerves, vestibule, cochlea, internal carotid artery. Over the lethal risk, the pathology associated to these injuries could be very severe from facial paralysis, vestibular trauma, tinnitus, deafness, vascular injuries and high blood pressure in skull [3].

Hence in order to provide a better understanding of this trauma, based on recent advance in medical data processing, a detailed numerical model of the Petrous bone structure was built. Lateral impact simulation was performed, leading to investigate macroscopic damage process of Petrous bone trauma and their anatomical correlation with clinical potential pathologies.

Materials and methods

A CT-Scan of a volunteer without pathology in relation with the Petrous bone was used to build a numerical model. Using Scan2Mesh [6], a tool dedicated to the generation of a mesh from medical data, 169 slices separated by a thickness of 0.6 millimeters were processed, using an automatic detection method based on thresholding. Then an anatomist checked the detected contours of the bone in order to validate them. Once the contours were validated on the whole 3D data, they were processed by the Marching-Octaedra algorithm, a fast and precise 3D reconstruction method [4], which leads to a 3D reconstruction of the bone and its mesh. The 3D Petrous bone mesh obtained is composed by tria/tetra elements, including cortical bone and spongy bone components (Fig. 1).

The bone structure was assumed to be isotropic. Spongy and compact bone material were simulated using an elastoplastic behaviour coupled to a Lemaitre damage model. The bone material set of parameters were obtained from previous works [5] (cf. table 1). Physical failure was simulated by a kill element method.

To investigate damage process on the bone structure, a lateral impact of a 50Kg wall launched at an initial velocity of 7m/s was simulated. In order to take into account the whole head structure effects, the petro occipitalis synostosis (a, Fig. 1) was fully blocked, and outer areas (b, Fig. 1) were only fixed in X directions (b, Fig. 1). Then forces level and stress distribution were recorded up to physical bone fracture process. These data were investigated in order to evaluate Petrous bone fracture mechanism and obtain the map of complete bone fracture.

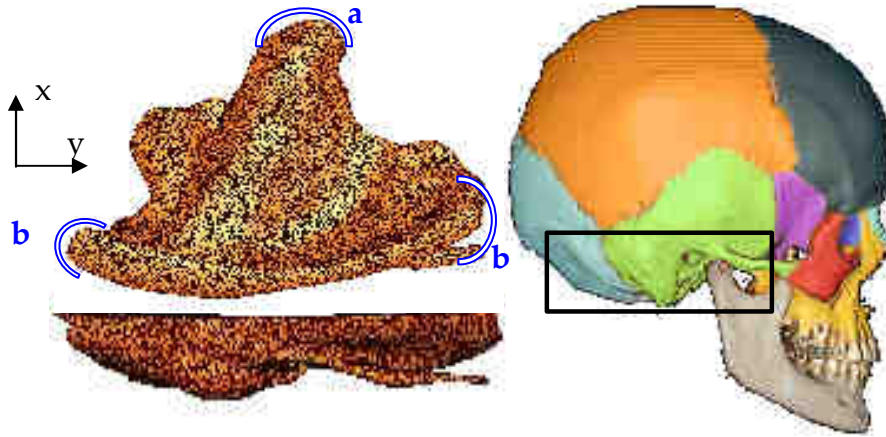


Figure 1 : Petrous bone model overview

Spongious bone		Law 23 (Elastic Plastic law with Damage Material)				
Density	Young's modulus	Poisson's ratio	Plasticity yield stress	Plasticity hardening parameter	Failure plastic strain	Plasticity maximum stress
0.00024	550	0.3	130	20	8%	40
Cortical bone		Johnson-Cook Material Law				
Density	Young's modulus	Poisson's ratio	Plasticity yield stress	Plasticity hardening parameter	Failure plastic strain	Plasticity maximum stress
0.0021	8000	0.3	80	100	3%	125

Table 1 :Material laws used for bone

Results

According to the complex geometry of bone structure (which could be compared to a pyramidal shape with an oblique direction to head centre point), its recruitment process, as recorded through Von Mises stress distribution, follows Petrous bone axes up to be transferred to lateral components.

From forces versus time curves (Fig. 2), the structure failure process spent less than 1.5 ms from impact point. From this time, three peaks were recorded.

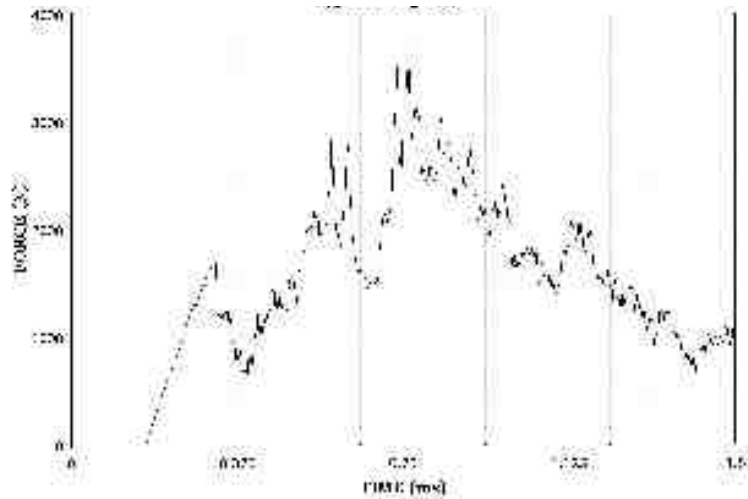


Figure 2 : Impact force

The first peak seems to be correlated to the impact on diploid structure and its related damage (Fig. 3).

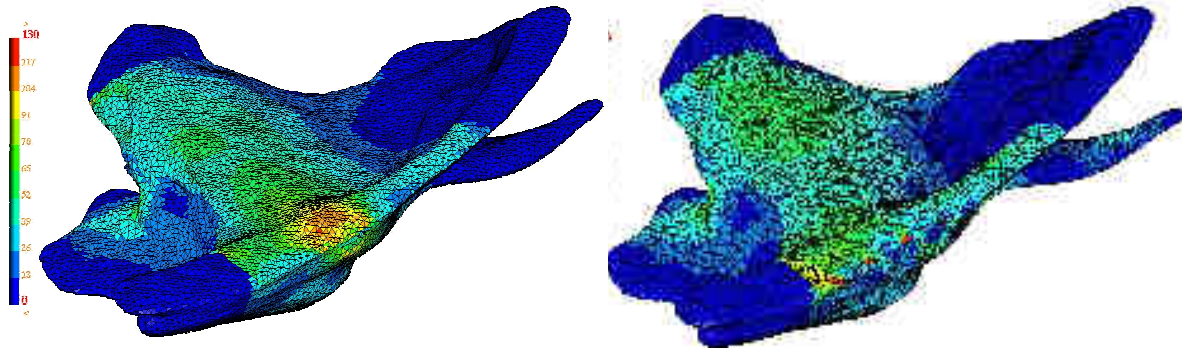


Figure 3 : Stress distribution and damage process at impact time

The two next peaks are in relation with the Petrous bone fracture propagation (Fig. 4).

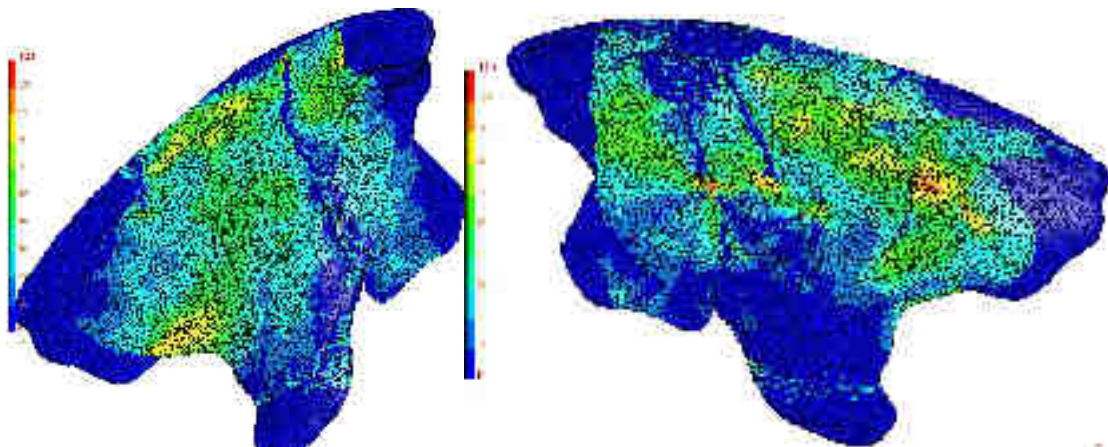


Figure 4 : Overview of bone fracture distribution at complete Petrous bone fracture

The fracture location obtained by simulation is relevant with real fracture longitudinal location. The Petrous bone fracture process converges to tympanal bone, to meatus acusticus externus associated to longitudinal fracture from the mastoid petrous bone joint to the the

vestibule of the internal ear. According to anatomical consideration, bone fracture location is closed to main vascular structure, nerves and hearing structure of the ear area. This fracture location could explain clinically observed trauma.

Discussion – Conclusion

A precise numerical model of the isolated Petrous bone structure was built from CT-scan data and used to investigate the fracture process occurring during a lateral impact. The fracture location on diploid structure, and then across Petrous bone, were evaluated. The fractures convergence is relevant with the longitudinal fracture classification. The fracture location on the mean ear area confirm the severity of induce trauma due to the important vascular and nervous structures being injured.

The fracture process map was reported as relevant with clinical data. These first results should be now completed by taken into account the whole head structure. According to the complex shape of Petrous bone, the numerical simulation seems to show a convergence area of fractures to the area of the external ear and mean ear. Further analysis and reconstruction of medical data, will integrate structure porosity effects and soft tissue component.

Additional work need to be done to investigate sensitivity of fracture process to speed and impact. However this approach could be used to complete existing fracture classification according to the accurate location of fracture and its consequences on surrounding soft tissues.

References

- [1] Ramírez Sabio JB, de Paula Vernetta C, García Sanchís JM, Callejo García FJ, Cortés Andrés O, Quilis Quesada V, Dualde Beltrán D, Marco Algarra J. *Petrous bone fracture. Our experience: 1999-2004*, Acta Otorrinolaringol Esp. 2006 Dec;57(10):450-4. Spanish.
- [2] Chays A, Girard N, Magnan J., *Fracture du rocher en urgence*, In: Tran Ba Huy P. Manach Y (coord.) Les Urgences en ORL. Paris: Société Française d'ORL et chirurgie cervico-faciale. Ed. 2002:365-82.
- [3] Brodie HA, Thompson TC., Management of complications from 820 temporal bone fractures. Am J Otol. 1997 Mar;18(2):188-97.
- [4] Bidal S, Serre T, Kayvantash K, Brunet C, *From organs' 2D contours detection to biofidels finite element meshes generation*, 9th Numérisation 3D - Human Modelling, Paris, 28th&29th of April 2004
- [5] Behr M., Arnoux P.J., Serre T., Bidal S., Kang H. S., Thollon L., Cavallero C., Kayvantash K., Brunet C., A Human model for Road Safety : From geometrical acquisition to Model Validation with Radioss. International Journal on Computer Methods in Biomechanics and Biomedical Engineering. Vol. 6, 4, pp.263, 2003
- [6] Scan2Mesh - Hypercrash Reference Guide, Hyperworks, Altair, www.altair.com