

Letter to editor

Three-dimensional Models Once Again – for research and teaching of early human development

Shiraishi

short title: 3D Models Once Again

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Dear Editor,

Many people – some scientists, others not – are interested in early human development because it is closely related to the basic and important question: What are we and where have we come from?

Classically, histological serial sections were prepared for microscopic two-dimensional (2D) analysis as well as for understanding the three-dimensional (3D) development of external and internal structures (O'Rahilly et al. 1987). 3D plaster or wax models, constructed by technical specialists since the late 19th century, have been indispensable in research as well as teaching (Morgan. 2004). Ziegler's, Blechshmidt's, and Heard's histological models have been world widely famous. The construction process of these models used to be so complicated that a team of scientists, technicians, artists and photographers spent several months to years to complete one model. Then, application of "new" modeling techniques produced much more detailed models and contributed to vivid understanding of early human development.

With the advent of magnetic resonance imaging (MRI), the imaging of embryos has become highly effective, providing a resolution of 40 $\mu\text{m}/\text{pixel}$ or more with long scan times. MRI is a non-invasive and non-destructive method that has many possibilities, not only for precise morphological observations but also for morphometric evaluations of internal structure (Yamada et al. 2006). A beautiful image on the 2D screen can be easily drawn from MRI digital data using computer graphics. However, we think it still fails to illuminate dynamic morphogenesis, particularly spatial changes and anatomical relationships.

A 3D printer is a tool for making 3D solid objects from digital data. Stereolithography was developed in 1986 and attracted much attention (Jacobs 1992). It did not become very popular because it involved very expensive equipment and many other incidental facilities. In recent years, fused deposition modeling (FDM) method has been developed. It has enabled creation of inexpensive 3D models in engineering, medical and dental fields as well as the academic area (Dimitrov et al. 2006)

We constructed a series of 3D precise models of the central nervous system and cerebral ventricle of human embryo from MR data. We created the models according to the

manufacturer's operation manual (BFB-3000, Bristol, UK). These were 3D models of cerebral ventricle of embryos between Carnegie stage (CS) 13 and CS 23. The printed 3D models allowed us to directly visualize the 3D appearance, touch and feel. Comparison of successive specimens enabled us to recognize the dynamic still precise morphological change during development, and to understand the spatial relationship and dynamism of morphogenesis more intuitively, as expected (Fig. 1).

The use of 3D printed models is expected to compensate the fault and limit of computed graphical pictures reconstructed on 2D display. The models are also expected to act as attractive and intelligible tools for teaching. We plan to educate the whole process from MRI data to visible embryonic models.

The plaster model played a substantial role at the dawn of research and teaching of human embryos. We expect that the 3D printed model will be available and play an important role in near future again.

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Figure legend

Fig. 1(A) The 3D model of cerebral ventricles at CS 20 and 23 printed by Fused Deposition Modeling method.

(B) The 3D model of the rhombencephalon at CS17

a) right lateral surface view

b) mid-sagittal section indicating the internal surface

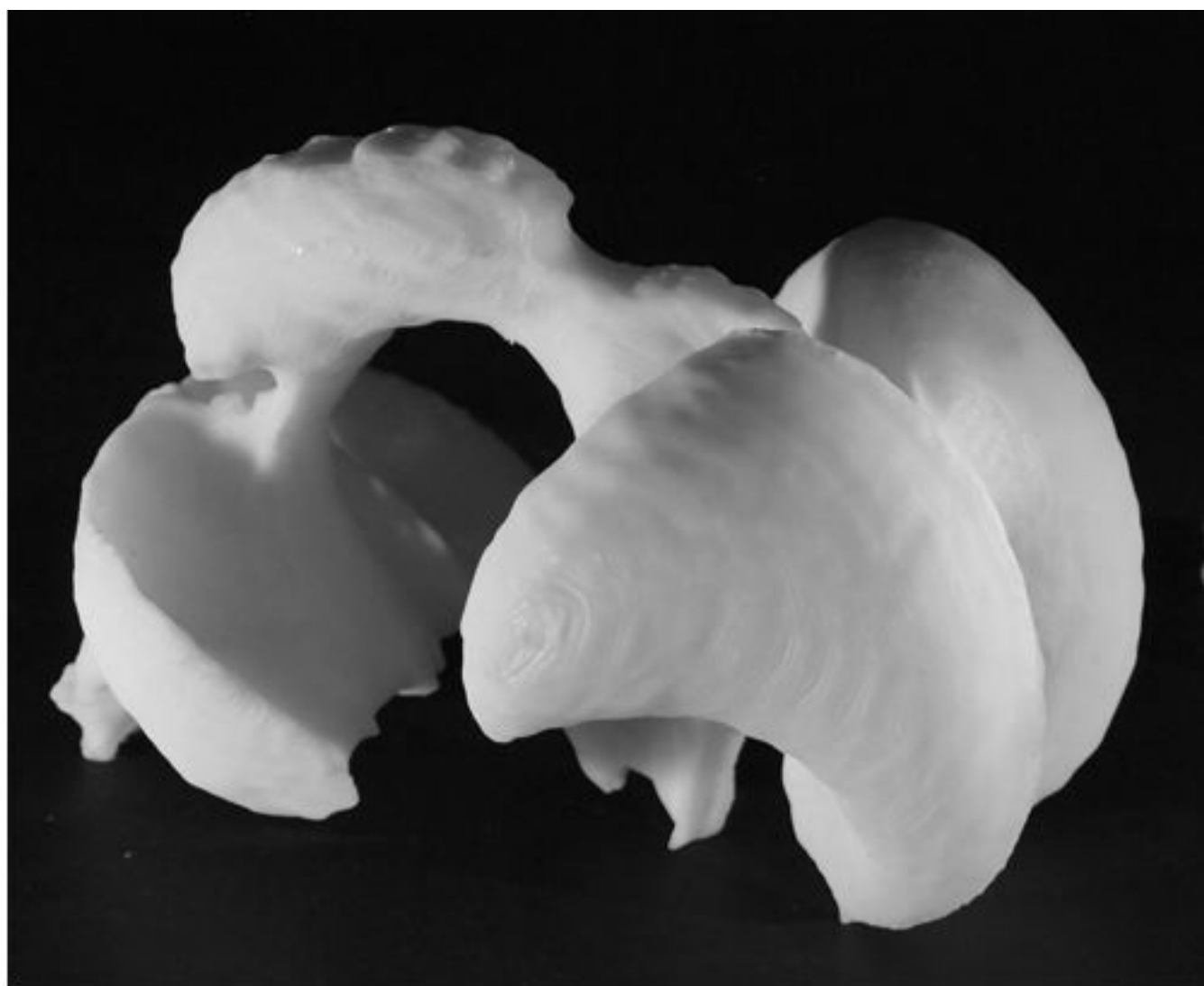
c) The 3D model of the rhombencephalic ventricle with same scale for comparison.

The development of the rhombencephalon will be better understood by touching and feeling.

(C) The 3D model of the rhombencephalon between at CS17 and CS23.

Comparison of successive specimens enabled us to recognize the dynamic still precise morphological change about cerebellum, brainstem and the roof of the rhombencephalic ventricle and those affects on the rhombencephalic ventricle and pontine flexure. Internal cerebellar swelling was arising from the rhombic lip and growing in thickness between CS17 and CS23. The cerebellar hemisphere was conspicuous in CS20. The pons and medulla were growing in thickness rapidly, thereby developing the pontine flexure. The isthmus canal which junction of mesencephalon and rhombencephalon was narrowed by development of medullary velum and pons.

A



B

a)



b)



c)

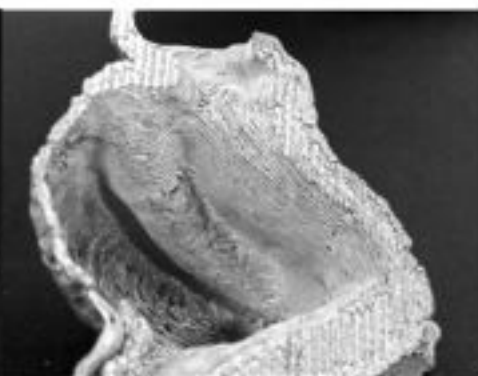
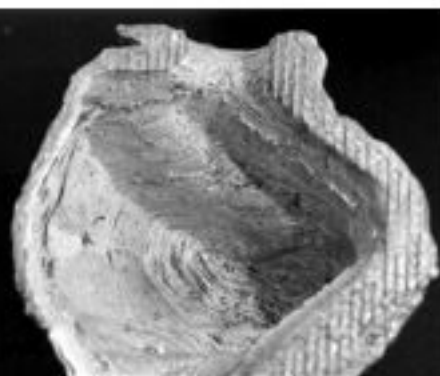
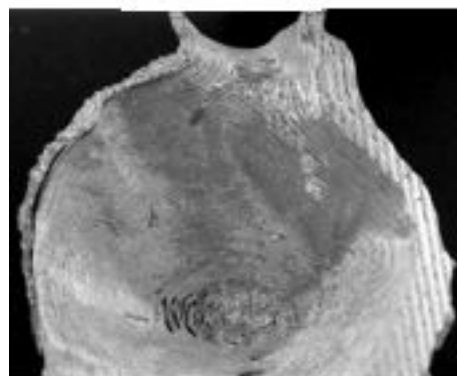


C

CS17

CS18

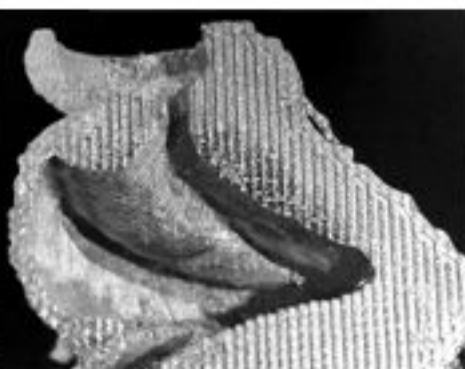
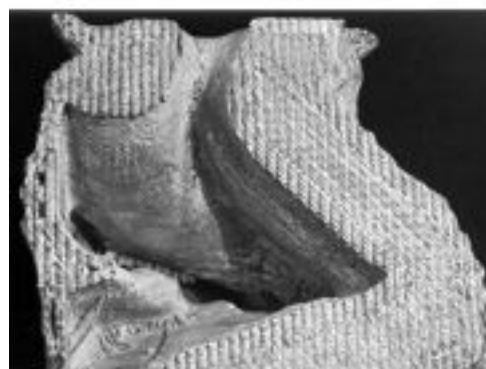
CS20



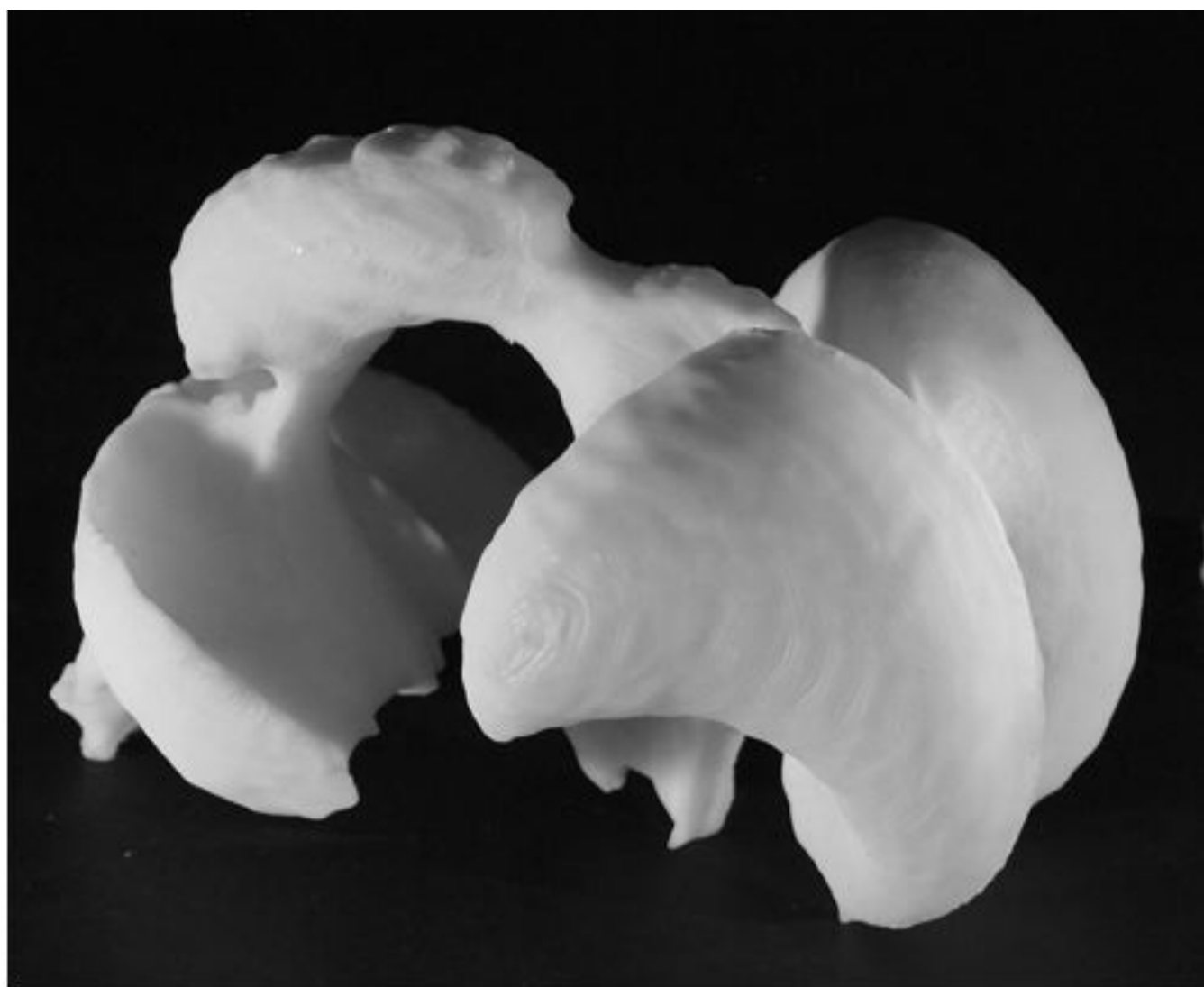
CS21

CS22

CS23



A



B

