Three-dimensional Printing of Models of Cleft Lip and Palate

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Sir:

From the clay models used in Babylonian times for divinatory purposes to the wax sculptures of the Enlightenment era scientific cabinets,[1,2] 3-dimensional (3D) models have been an aid to anatomical studies and surgical training for centuries. As a substitute for real dissection and handling of living tissues, they allow shunning some of the drawbacks and nuisances of cadaveric manipulation. However, these sculptures require a considerable degree of craftsmanship and expertise when related to unusual conditions such as cleft lip and palate. They have been manufactured as expensive "one-of-a-kind" art objects, and their cheap counterparts like the witty origami cleft lip by Boo-Chai[3] have very restricted teaching value.

Recent advancements in additive manufacturing or 3D printing technologies open new possibilities in the delivery and local production of affordable teaching media.

AIM

We offer a free downloadable template for 3D printing of anatomical models of unilateral and bilateral cleft lip. In our age of accessibility (and piracy), we do feel that there is little sense in copyrighting what would be easily replicated.

MATERIALS AND METHODS

Our models stem from an idea of Prof. Yoshiaki Hosaka from Showa University in Tokyo. Prof. Hosaka used painted silicone casts as an aid to describe to parents the surgical procedures he was about to perform. At the same time, trainees in plastic surgery at Showa University Hospital were asked to draw their proposed incisions on a whiteboard on which slides of each patient were projected.[4]

Each of Prof. Hosaka's 3 models (bilateral cleft lip and palate, unilateral left cleft lip and palate, and unilateral right cleft lip and palate) was used as a departure point to shape handmade templates in white plasticine. These plasticine casts were replicated in stable silicone after negative molding in Plaster of Paris. Computed tomography scans of the resulting silicone casts were stored in standard DICOM (Digital Imaging and Communications in Medicine, http://www.slicer.org) file format and transformed into stereolithographic files (.stl extension) by using free access 3D Slicer 4.4 software.

After transferring these files to a standard 3D printing device (Formlabs, Somerville, Mass.), we produced our models from a liquid white photopolymer resin (mixture of methacrylate monomers, methacrylate oligomers, and photoinitiator) provided from the same supplier. Final stabilization of surfaces was obtained after two 10-minute consecutive baths in drying isopropyl alcohol.

RESULTS

Depending on the degree of accuracy, models for bilateral (Fig. 1) and unilateral left (Fig. 2) cleft lip and palate required 4 to 12 hours for printing. Final surfaces are uneven without any marked steps between layers. Screen captures from the MeshLab program (www.meshlab.sourceforge.net) for the unilateral right cleft lip and palate model before printing are available as Supplemental Digital Content 1, 2, and 3 (Supplemental Digital Content 1, see the frontal view for the right unilateral cleft lip and palate model, ***http://links.lww.com/PRSGO/A170***; Supplemental Digital Content 2, see the inferior view for the right unilateral cleft lip and palate model, ***http://links.lww.com/PRSGO/A171***; Supplemental Digital Content 3, see the lateral view for the right unilateral cleft lip and palate model, ***http://links.lww.com/PRSGO/A172***).

Free downloadable files for local printing of each one of the models can be found at: http://www.3dprint.nih.gov/discover. Users are encouraged to tune them according to their tastes and needs.

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Supplemental digital content is available for this article. Clickable URL citations appear in the text.

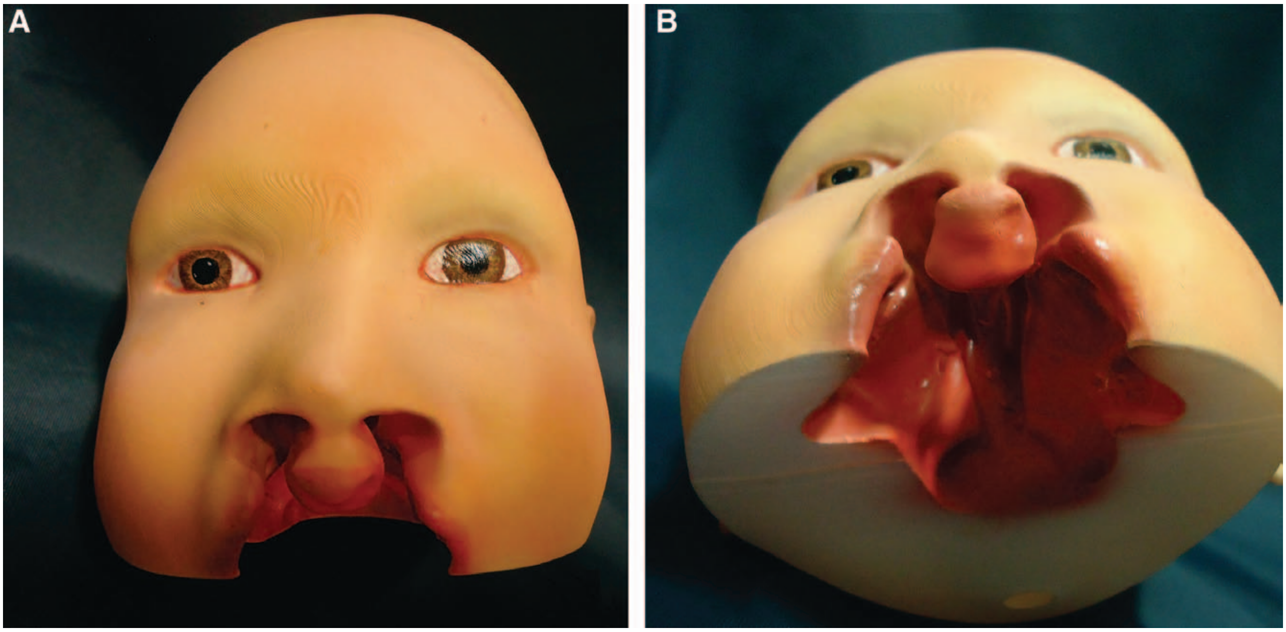

Fig. 1. A printed, painted version of the bilateral cleft lip and palate model. Frontal (A) and inferior (B) views.

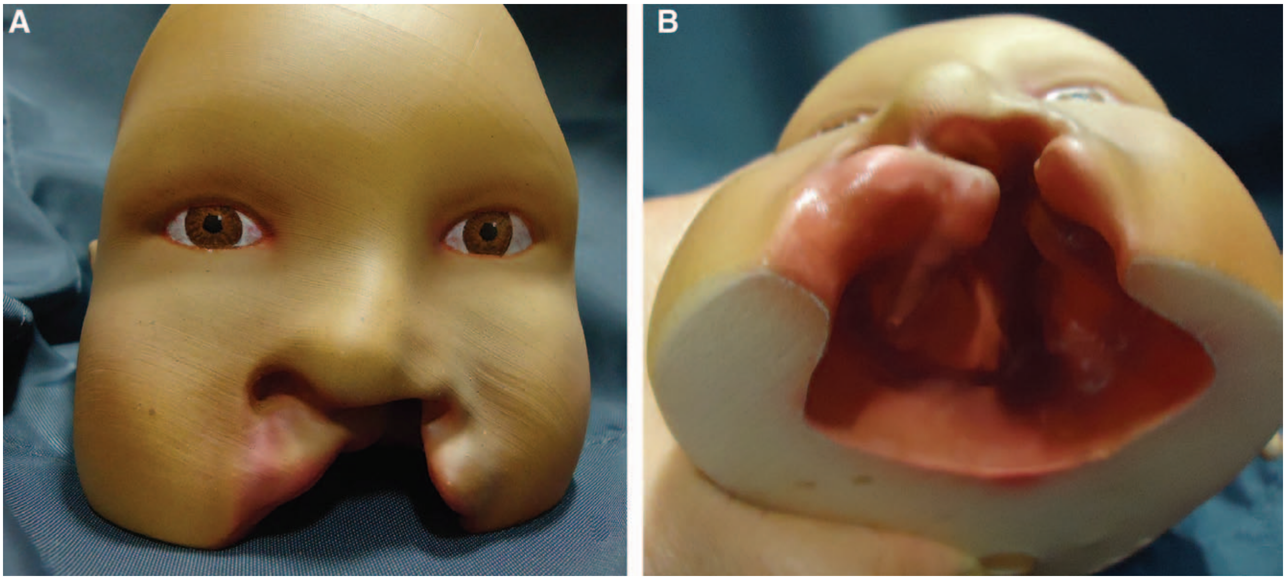

Fig. 2. A printed, painted version of the unilateral left cleft lip and palate model. Frontal (A) and inferior (B) views.

DISCUSSION

The models allow acquiring a first familiarization with the spatial features of the malformation and training of the surgical marking in a standard procedure. Subsequent improvements in printed textures may lead to the possibility of performing mock operations on these casts. This should improve the confidence in surgical trainees. Moreover, pregraduate medical students may better grip what otherwise would have been a remote concept seen in a photograph, sparking a further interest in cleft care. As it has been mentioned, some parents of children born with a cleft could find it easier to understand particular issues at stake, such as feeding, surgery, and speech therapy.

Three-dimensional printed models represent a means to dodge some ethical and cultural scruples. Multiple copies may be delivered to a large audience during the same teaching session. They can be shared across the world in minutes, and their size may be adapted according to the precise needs of the ultimate users.[5–10] Once the novelty factor has withered, the prices of 3D printers should attain affordable levels for any surgical department or individual student. It is not difficult to forecast a popularization of these technologies in the next years to come.

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DISCLOSURE

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