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Letter to the Editor

# Usefulness of the 3D virtual visualization surgical planning simulation and 3D model for endoscopic endonasal transsphenoidal surgery of pituitary adenoma: Technical report and review of literature

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ABSTRACT

The purpose of this research was to investigate the usefulness of three-dimensional print models (3D models) in endoscopic endonasal transsphenoidal surgery (EeTSS) for pituitary adenoma. Eleven patients underwent EeTSS for pituitary adenoma using 3D models. We manufactured a 3D virtual surgical planning image using the patient's Digital Imaging and Communication in Medicine dataset. Based on the image, a life-size model was created by a 3D printer using multi-material acrylic-based resin. Our results suggest that such 3D models could be useful in EeTSS for pituitary adenoma.

## 1. Introduction

In recent years, three-dimensional (3D) printing technology has been advanced to build models of individual pathologies aiming to improvesurgical planning [1–12].

From January 2015, a 3D–printing system (Objet500 Connex3; Stratasys, Eden Prairie) has been introduced in Kagawa University Hospital's Community Healthcare Education Support Center (Fig. 1A). 3D–model technique has been introduced in neurosurgery preoperative simulations; however, it remains in the experimental prototype stage [6,13–18]. In neurosurgical operation, 3D models were created for the preoperative simulation of diseases, such as brain aneurysm or cerebral arteriovenous malformations, meningioma or schwannoma of the skull base, and pituitary adenoma.

In this study, we investigated the usefulness of three-dimensional print models (3D models) in endoscopic endonasal transsphenoidal surgery (EeTSS) for pituitary adenoma. This is the first report on the use of both preoperative 3D virtual images and life-size multi-material 3D resin models created by 3D printers for EeTSS simulations.

## 2. Materials and methods

### 2.1. Patients

This study was conducted in accordance with the institutional review board policy of Kagawa University. Eleven consecutive patients with pituitary tumor (3 men and 8 women; age range, 26–78 years) underwent presurgical evaluation and simulation for endoscopic transnasal pituitary tumor resection; virtual simulation and 3D model created by 3D printers were employed. The characteristics of the patients are shown in Table 1. All patients were candidates for endoscopic transnasal pituitary tumor surgery after assessment of image inspection. All diagnostic examinations and treatments were performed at Kagawa University Hospital from January 2015 to October 2015.

### 2.2. Data acquisition methods

The patients' imaging data were acquired preoperatively by various modalities, such as computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA).

CT scans were acquired using a 64-row multi-detector CT scanner (Aquilon, Toshiba Medical Systems Corp., Tochigi, Japan) with 0.5-mm

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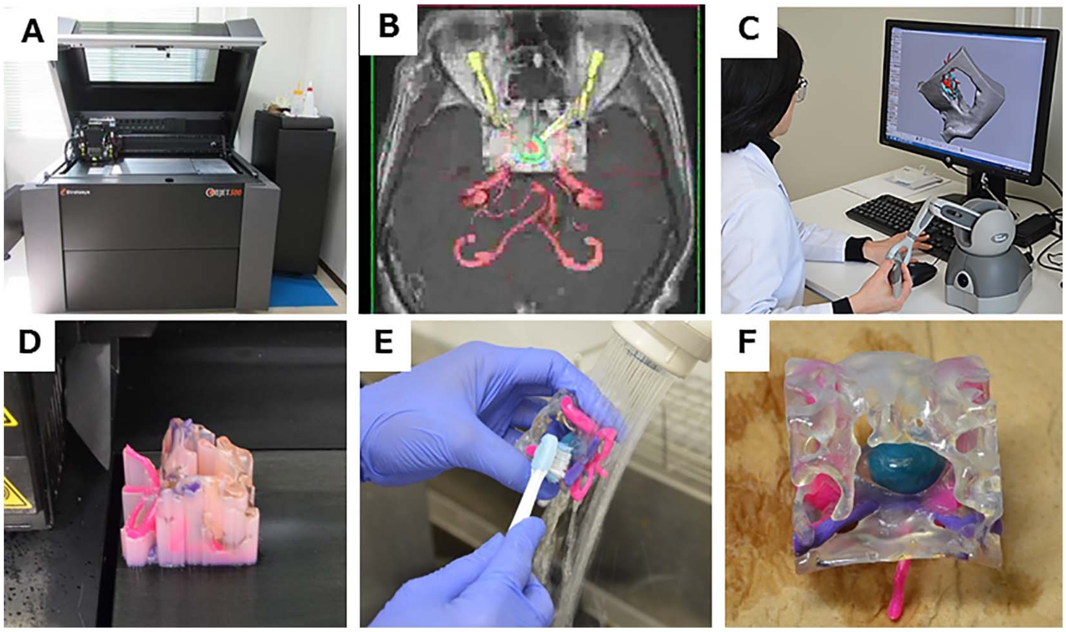


**Fig. 1.** (A) Objet500 Connex3 (Stratasys, Eden Prairie, MN) printer. (B) The steps of data processing on image-analysis software (ZedView,LEXI Co. Inc., Tokyo, Japan). (C) The virtual simulation was performed using the design software Geomagic® Freeform® and the haptic accessories device of Geomagic Touch® (Geomagic Free FormV2014.0 with Touch, 3D Systems, Rock Hill, SC). (D) The Printed 3D model by Objet500 Connex3. (E) The support material was removed with the hand or the water jet burst device. (F) Finished 3D model.

slice thickness. The MRIs were acquired using the 3-T system (Skyra, Siemens AG, München, Germany) or two kinds of 1.5-T system (Achiva, Royal Philips, Amsterdam, Netherlands, and Sigma, GE Healthcare, Milwaukee, WI) with 1–3-mm slice thickness. To clearly identify the nerves, heavily T2-weighted images were acquired by constructive interference in steady state sequence on a 3.0-T MR system with the following parameters: TR 1300 ms, TE 96 ms, flip angle 120°, FOV 180 mm, $320 \times 320$ matrix, and slice thickness 0.3 mm (144 slice). Moreover, fast imaging employing steady-state acquisition sequence was also employed on 1.5-T MR systems. For visualization of vascular anatomy, 3D–TOF MRA was performed.

DSA images were acquired using a DSA system (Allura Xper FD20, Royal Philips) with arterial administration of an iodine-containing contrast medium. All CT, MRI, MRA, and DSA image data were stored in the standard format according to Digital Imaging and Communication in Medicine (DICOM).

### 2.3. Data processing

For protection of personal information, anonymization in a linkable fashion was employed when extracting imaging data of the patients. An informed consent was obtained from the patients with respect to the creation of 3D–lesion models using a 3D printer. We have created 3D computer graphics (CG) models consisting of all structures required for EeTSS simulation. DICOM data were processed on image analysis software (Zed View, LEXI Co., Inc. Tokyo, Japan).

First, we extracted the region of interest, separated it from the other structures, and removes noise data (Fig. 1B). During extraction, the brightness value of the original images was a problem (e.g., CT value and the strength of the nuclear MR signals). For the region of interest with distinct brightness values compared with other areas, the operation was easy. By contrast, if the value was similar to that of other areas, the extraction was difficult and time-consuming.

Subsequently, we transformed stereolithography (STL) data to make a 3D model from the voxel data of DICOM. While the extracted areas from the voxel data hold an appropriate data volume and accuracy, are converted into STL format that is a general-purpose output format for the 3D–models, as triangular polygon mesh by surface image-rendering technique automatically.

The coordinates of the extracted data from various imaging techniques were adjusted manually on the reconstructed virtual multidirectional planes to fit in the individual anatomical structure. Finally, we made each 3D–model data written in the binary STL format, of skull, pituitary, arteries, and optic nerves onto the equivalent virtual multidirectional plane.

### 2.4. Virtual simulation

The 3D CG models reconstructed from the data saved in binary STL format on the virtual space were corrected or modified and were optimized using the design software Geomagic® Freeform® and the haptic accessory device of Geomagic Touch® (Free Form Modeling with Touch v.2014.0, 3D Systems, Rock Hill, SC). The medical image data of the 3D models were evaluated in relation to the anatomical structures based on a surgical viewpoint. We performed virtual preoperative simulation using the final virtual 3D CG model of the combined data (Fig. 1C).

In the virtual preoperative simulation, we confirmed the positional relationship between pituitary tumor, normal pituitary gland, and bilateral ICAs through observation of the sphenoid sinus and sella turcica from the nasal side along the surgical direction for the endonasal transsphenoidal approach.

The 3D CG models displayed the inside view of the sphenoid sinus. We ensured the position of the sphenoid septum in the sphenoid sinus and eliminated the septum leaving the part. Subsequently, we made the bony parts of the models translucent by image processing to confirm the location of the tumor, normal pituitary gland, and bilateral ICAs or optic nerves. We identified the margin of safety of the fenestration of the anterior wall of the sella turcica for the surgical approach.

### 2.5. Printing the 3D model

We selected the appropriate model data for the 3D models and saved the data to binary STL format. After confirming the integrity of the final STL data, the data were converted to tool path data for printing by dedicated software (Objet studio™). We output the data to the 3D–printing system (Objet500 Connex3) after setting the data attributes, such as that color and hardness of the resin. A full-sized individual model was printed by the Object500 Connex3 using acrylic