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Single-Step Resection of an Intraosseous Meningioma and Cranial Reconstruction: Technical Note

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■ OBJECTIVE: Simultaneous tumor resection and cranial reconstruction can be a challenging task. Surgical navigation is an indispensable tool in making this single-step procedure possible. In this technical note, we describe a new technique for this procedure to ensure a precise resection and optimal fit of the implant in a patient with an intraosseous meningioma.

■ METHODS: We generated a 3-dimensional (3D) model of the patient's skull based on a computed tomography scan and created a digital "resection line" object using 3D Studio Max 2016 software. Based on this object, the patient-specific implant was generated and printed with a 3D printer. Before surgery, the digital object was transferred to the neuronavigation system to enable a navigated resection of the lesion to ensure maximum precision. During surgery, the craniotomy was performed, and the custom-made implant was fitted in a single step.

■ RESULTS: The planned resection was achieved, and the implant could be fitted without need for further adjustments to the resection border.

■ CONCLUSIONS: We provide a simple technique to digitally define a planned resection site and create a custom-made implant using specialized software and 3D printing to enable single-step resection of a skull lesion and cranial reconstruction, thereby reducing surgical time and costs and ensuring a good cosmetic result.

INTRODUCTION

Intraosseous meningiomas of the calvarium present as a firm and painless mass on the skull and may be detected incidentally, as neurologic signs and symptoms usually are absent.[1] They can, however, become cosmetically disturbing. Wide surgical excision is potentially curative[2] but also leaves the patient with a skull defect for which a reconstruction is required. The rapid evolution of imaging techniques, simulation software, computer-aided reconstruction techniques, and surgical navigation have made it possible to perform a resection of the tumor and cranioplasty in a single procedure. However, precise definition of the resection site to ensure an optimal fit of the implant remains a challenge. We describe a new technique using specialized software to facilitate this process.

CASE REPORT

History

A 68-year-old woman with a history of diabetes, alcoholic hepatitis, and Barrett esophagitis was admitted to the neurologic department with diplopia. Analysis showed a vitamin B1 deficiency, and complaints resolved with substitution. Imaging also had shown a lesion of the left frontotemporal skull (**Figure 1**). Further analysis ruled out a primary tumor elsewhere as well as metastases. A biopsy was scheduled in our center because a malignant lesion was suspected. Biopsy showed a World Health Organization grade I intraosseous meningioma, and a watchful waiting strategy was chosen because the patient was without symptoms. Two years later, progression of the tumor was shown on magnetic resonance scan (**Figure 1**), and she opted for surgical resection.

Key words
- 3-Dimensional printing
- Cranioplasty
- Intraosseous meningioma
- PMMA
- Single-step procedure
- Skull lesion

Abbreviations and Acronyms
3D: 3-Dimensional
CT: Computed tomography
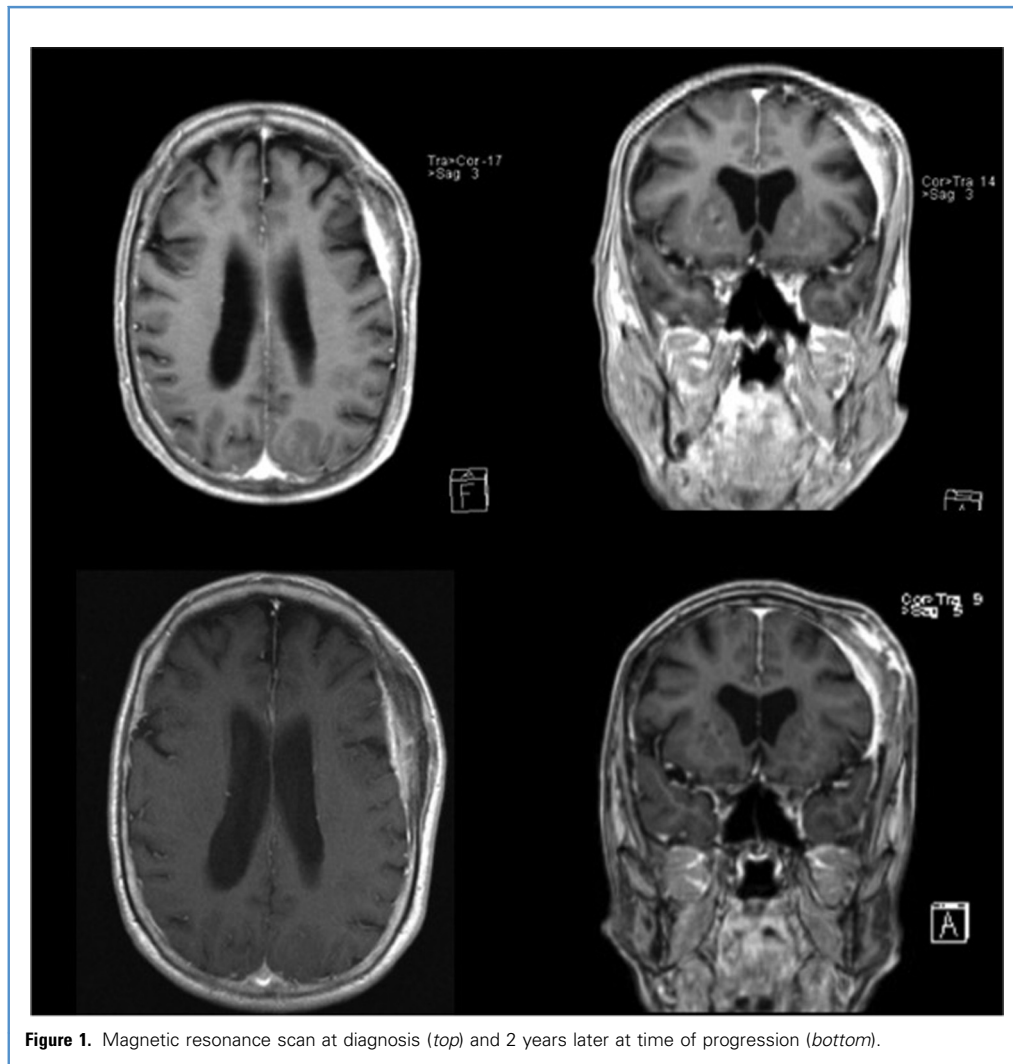**PMMA**: Polymethyl methacrylate

Figure 1. Magnetic resonance scan at diagnosis (*top*) and 2 years later at time of progression (*bottom*).

Preoperative Planning

A resection and reconstruction in one session was planned. First, a computed tomography (CT) scan (0.5-mm slices) was taken (**Figure 2**). Digital Imaging and Communications in Medicine images were exported to Maxilim, version 2.2.2.1 (Medicim NV, Mechelen, Belgium) software, and a 3-dimensional (3D) model was reconstructed. In 3D Studio Max 2016 (Autodesk Inc., San Rafael, California, USA), the surgeon drew a digital resection line on the 3D model, which was used to generate a "resection line" object. All 3D data within the resection line were excluded from the model; the model was then copied and mirrored. The mirrored and original models were fused (excluding resection), and the 3D data from the projection in the previously defined resection area on the right side of the skull were used to generate a 3D model of the implant.

Both the model (with the lesion resected) and the implant design were 3D printed with a FormLabs Form 2 3D Printer (Formlabs Inc., Somerville, Massachusetts, USA). The implant was then made from polymethyl methacrylate (PMMA) by copying the 3D-printed implant design in wax. The wax model was embedded in plaster and burned out after which the space inside the plaster was filled with hot cured PMMA. The PMMA implant was polished, cleaned by brushing with soap, and plasma sterilized.

The day before surgery, a new magnetic resonance scan was performed, which was loaded into iPlan Brainlab software (Brainlab AG, Munich, Germany) and fused with the thin-slice CT. The 3D images of the implant and resection line were imported into the software as well (**Figure 3**).

Surgical Procedure

During surgery, a reference star was fitted on a sterile marker and registered with the Brainlab system. Via the use of this navigated sterile marker, the preoperatively defined resection border could be drawn onto the patient's skull during the surgery (**Figure 4A**). The craniotomy was performed following this