Stereolithography Model
in Presurgical Planning of Craniofacial Surgery

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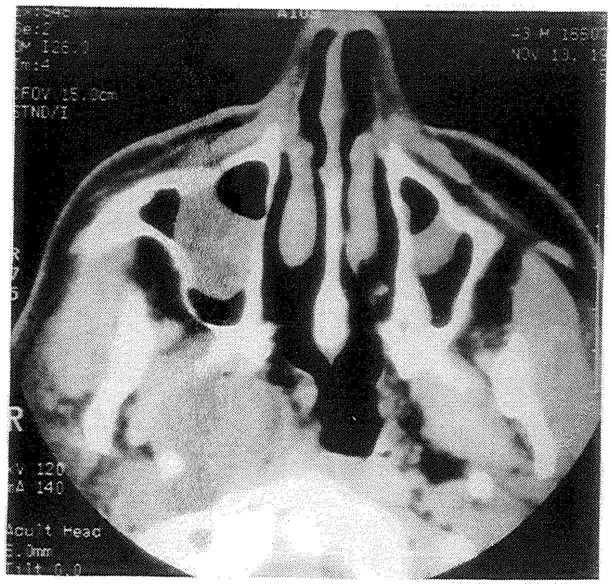
Introduction

A rapid prototyping technique, which was originally used in mechanical engineering, has found applications in medicine. Recently stereolithographic models have been used in complex craniofacial surgeries for visualization, presurgical planning and implant design[1-4]. There are some advantages of model fabrication when preparing for surgery: more accurate evaluation of the patient's condition/deformities, better informed consent for surgery and better-fitting artificial body parts. This paper is a case report in which a sterelithographic skull model was used in the presurgical planning of a complex craniofacial tumor resection.

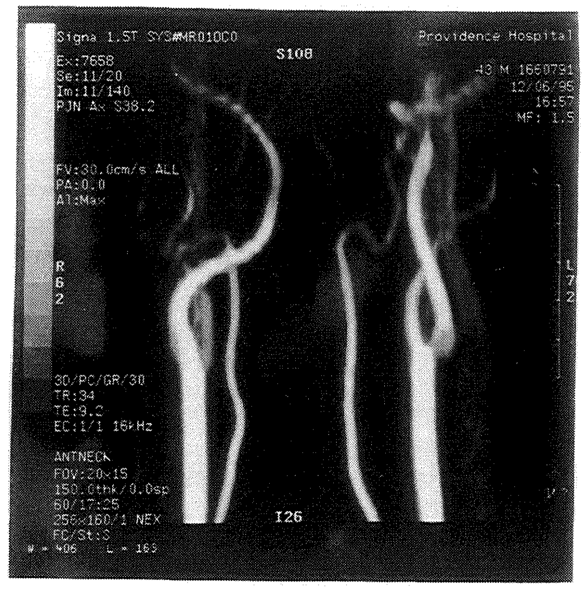
Case Report

The patient presented with a mass (neurofibroma) in the right infratemporal fossa. MRI scan examination revealed that the mass was wrapped around the internal carotid artery and was high up in the skull base area. Since the mass was in the infratemporal fossa which contains significant vessels and nerves, it was very important to fully study the relationship between the lesion and the surrounding structures in order to decide which surgical approach would be best.

2D and 3D imaging analysis was performed first [Figure 1], following this two solid models were made for further surgical planning, these were based on CT and MRI scans, respectively. The CT data was obtained on a GE HighSpeed Advantage Helical Scanner with 5mm thickness slices. It can be noticed that the lesion was not well shown on



(a)



(b)

(c)

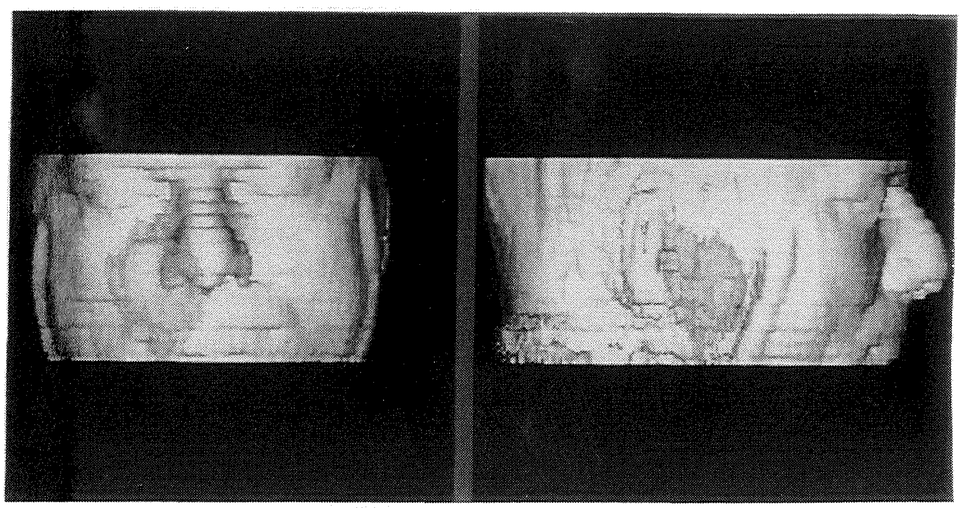


Figure1. 2D and 3D imaging analysis. (a) One cut of CT scan. Notice that the lesion is not shown clearly on CT image. (b) MR angiography of the interested region. (c) 3D profile of the patient's MRI. Lesion was measured as 33cc.

the CT images. The MR scan was done on a GE Signa with contrast and 4mm thickness slices with 2mm spaces between. The skeletal model [Figure 2] was manufactured based on the CT scan by Stereolithography Laboratory in Troy, Michigan. The dual color stereolithography [Figure 3] was fabricated by Materialise Inc., in Belgium, based on the MRI scan, this combined both skin and tumor information. The color stereolithography was to differentiate different structures in one model. All of work of CT and MRI imaging processing were done by Materialise's medical software. Since both scans were originally for diagnosis purposes, the slices were thicker and the models look a little rough.

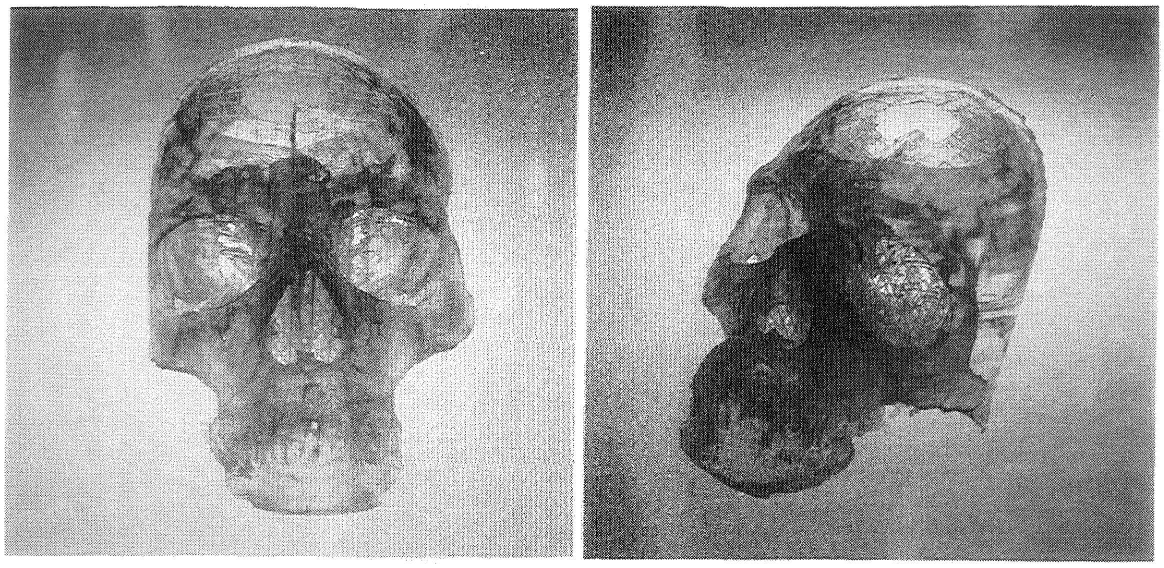


Figure 2. Stereolithography model based on CT scan.

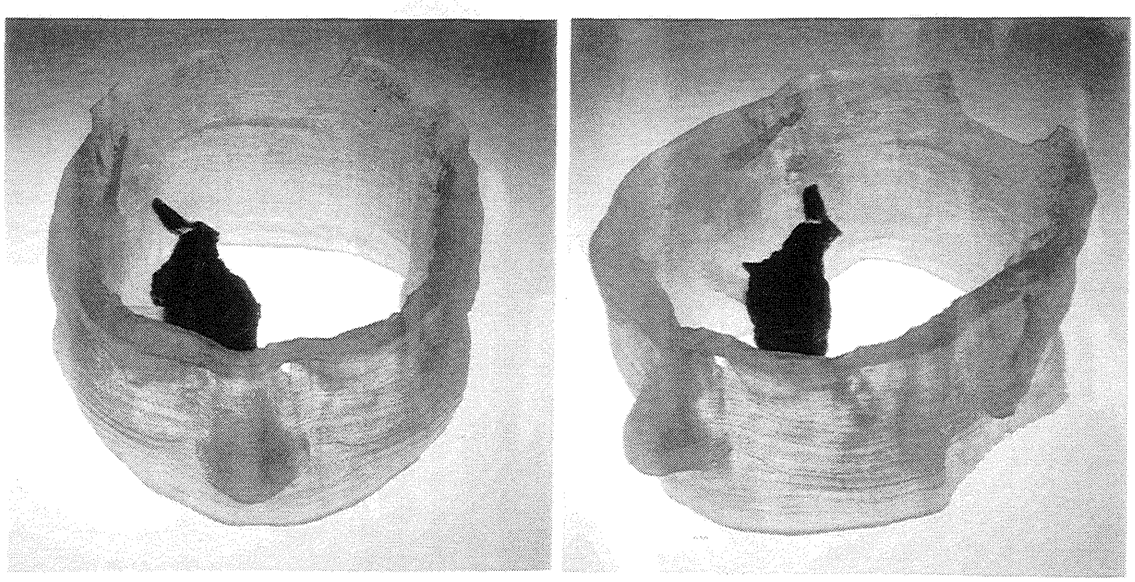


Figure 3. Dual color stereolithography model based on MRI with contrast.

The MRI data were segmented with the MIMICS software with the use of thresholding and 3D region growing. The skin of the patient was selected to serve as reference, the lesion was selected semi-automaticly. The sterelithography machine of Materialise was equipped with a special resin (Zeneca, UK). This resin has the ability to color if additional energy is applied to the resin. A first pass of the laser produces curing, with a second pass of the laser, the desired zone is selectively colored. The resolution of this coloration is the same as the building resolution.

This case was the first real case in which selective coloration was used for pre-surgical planning. The total time of making this dual color stereolithography model was 7 hours, which including less one hour for the segmentation and additional editing, one and half hours for calculating complete model and supports, and less than five hours for final fabrication of the model.

The possible approaches to resect the mass were considered. The models helped to show exactly where the lesion lay in relation to the ascending ramus of the mandible. Presurgical planning of the procedure on the sterelithography model enabled us to decide the best approach, this was the mandible swing procedure. In addition, the life-size models of the patient's head, sitting in the operating room during the procedure, gave the surgeon an intuitive view of patient's condition. The mass which measured 5x4.5x2.5cm was resected completely. The patient did very well during the procedure, which lasted two and half hours, and did not require a blood transfusion. He has made an excellent recovery from surgery.

Discussion

Presurgical planning based on 3D CT and MRI has been routinely used in the Institute for Craniofacial and Reconstructive Surgery, Providence Hospital, over the past five years. Advanced graphic technique has allowed the mimic 3D image to be displayed on a two-dimensional surface. As compared to the stereolithographic skull model, it can never be truly three-dimensional. Thus for some complex cases such as the one presented, to visualize the special relationship of the complicated skeletal areas to soft tissue complexes is difficult. Our preliminary experience with a 3D solid model indicates that a stereolithographic skull model provides the surgeon with additional comfort in planning prior to a complex craniofacial surgery. It is possible to perform real simulation surgery, resulting in significant reduction of operation time and stress on the patient. With the cost continuously decreasing, we hope that this technique can be used more routinely in the clinical setting.

Concerning the quality of the srtereolithogphy model, there are two aspects involved. One is the data acquisition. The reduction of slice thickness and slice distance will result in a fabricated model with greater accuracy. Another is data processing, including properly interpolating imaging data between the single slices and correctly segmenting object of interest (e.g. tumor). In addition, for this particular case, if we can build a model, including the skeletal, tumor and arteries, that combines the information obtained from CT, MRI and Angiography, it will be very helpful. We believe that advances in computer design techniques and enhanced software will solve this problem.

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