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Technical Note
CAD-CAM

A novel digital workflow to manufacture personalized three-dimensional-printed hollow surgical obturators after maxillectomy

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Abstract. Partial or complete resection of the maxilla during tumour surgery causes oronasal defects, leading to oral-maxillofacial dysfunction, for which the surgical obturator (SO) is an important treatment option. Traditional manufacturing of SOs is complex, time-consuming, and often results in inadequate fit and function. This technical note describes a novel digital workflow to design and manufacture a three-dimensional (3D)-printed hollow SO. Registered computed tomography and magnetic resonance imaging images are used for gross tumour delineation. The produced RTStruct set is exported as a stereolitography (STL) file and merged with a 3D model of the dental status. Based on these merged files, a personalized and hollow digital SO design is created, and 3D printed. Due to the proper fit of the prefabricated SO, a soft silicone lining material can be used during surgery to adapt the prosthesis to the oronasal defect, instead of putty materials that are not suitable for this purpose. An STL file of this final SO is created during surgery, based on a scan of the relined SO. The digital workflow results in a SO weight reduction, an increased fit, an up-to-date digital SO copy, and overall easier clinical handling.

Key words: computed tomography (CT); magnetic resonance imaging (MRI); Cad-Cam; 3D printing; obturator; maxillectomy.

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Partial or complete resection of the maxilla during tumour surgery causes oronasal defects which leads to functional impairment, disruption of deglutition, aspiration, inadequate speech and reduced quality of life[1,2]. After resection, the surgical obturator (SO) remains an important treatment option for rehabilitation of oral-maxillofacial function, in addition to reconstruction with a flap[1].

Traditionally, the SO is fabricated on a preoperative cast of the maxilla. Directly after ablative surgery, the SO is adapted to the defect manually. Due to the nature of this method and the materials used, the

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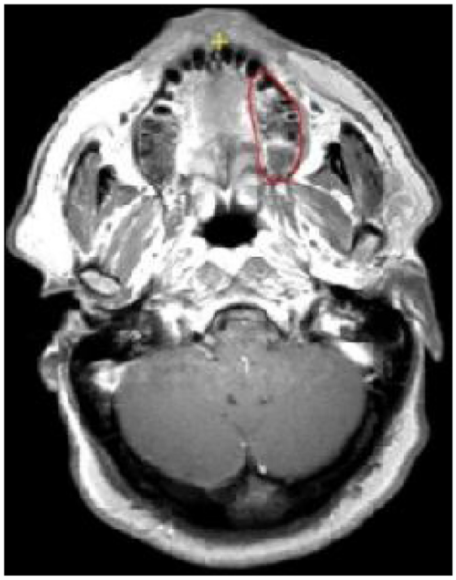

Fig. 1. Tumour delineation based on computed tomography and magnetic resonance imaging.

clinical procedure is complicated, with a bulky and unpredictable SO fit. This results in inadequate function, pain or loss of retention. Digital planning of the SO may overcome these limitations. Using three-dimensional (3D) imaging techniques, the expected defect can be visualized preoperatively, which facilitates planning of the surgical and prosthetic treatment. Previous studies have described computed tomography (CT)-based methods to prefabricate SOs[3,4]. For identification of soft tissue and tumour expansion, however, magnetic resonance imaging (MRI) is preferable[5]. In addition, fusion of CT and MRI images further enhances digital planning[6].

This technical note demonstrates a novel digital workflow to design and manufacture a personalized 3D-printed hollow SO, based on registered CT and MRI images.

Materials and methods

A 46-year-old female was diagnosed with a pT1cN0M0 maxillary gingival carcinoma for which a partial maxillectomy was scheduled. Before surgery, CT and MRI data were obtained. To ensure the quality of the registration, both images were registered using a rigid-registration method with an intensity-based method matching algorithm using an in-house developed software program (Volumetool, Department of Radiotherapy, University Medical Center Utrecht, Netherlands[7]). With this tool, CT and MRI images were displayed in their original form. After the rigid-registration and manual verification, the tumour contours were manually delineated by the physician based on the MRI images. Next, using the rigid registration, the delineations were converted to the same coordinate system of the planning CT (Fig. 1). Finally, we constructed a 3D closed mesh of triangles from the stack of contours (RTStruct) using a parallel slice reconstruction algorithm. The produced RTStruct was exported as a stereolitography (STL) file[7]. The planning CT, and STL of the delineated gross tumour volume were subsequently imported to Synthes ProPlan CMF Orthognatics software (Synthes ProPlan CMF 3.0, Materialise, Leuven, Belgium). Using this program, the images were matched with the patient's dental status (derived from a dental impression), based on the anatomical position of the teeth. Subsequently, a hollow digital SO was designed (without clasps and connectors) using 3 Matic design software (MIS Medical and research 20.0, Materialise, Leuven, Belgium) (Fig. 2), taking into account the expected tumour resection (and its margins). The

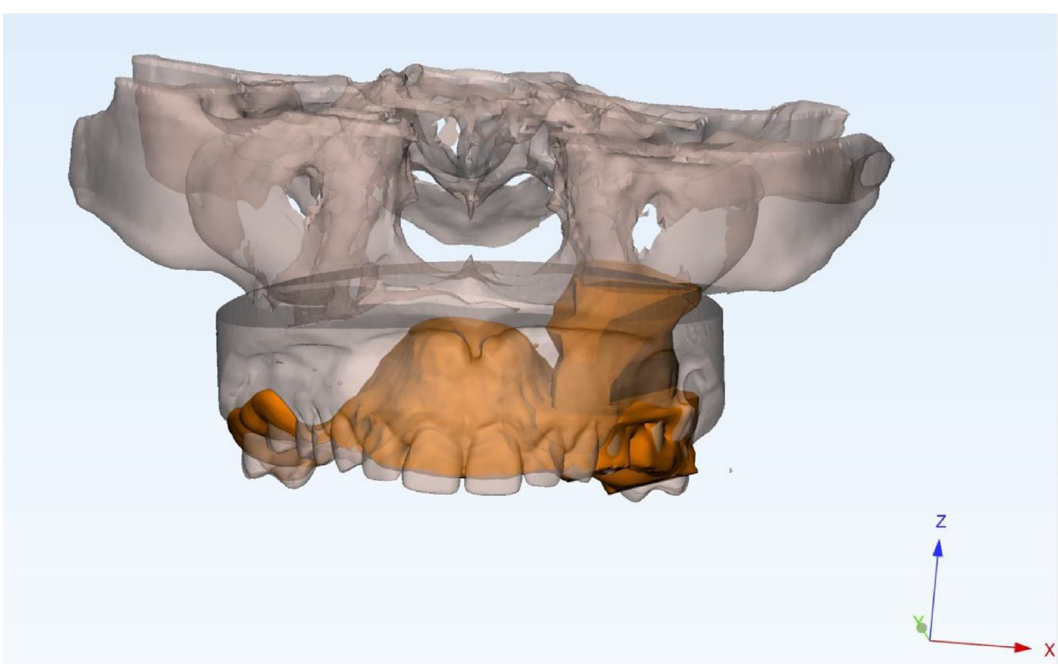

Fig. 2. Digital surgical obturator design imported dental arch, skull and tumour.

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