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Accuracy of virtually 3D planned resection templates in mandibular reconstruction☆

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ABSTRACT

Objective: Since reconstruction of composite defects in the head and neck region is a challenging and demanding problem for head and neck surgeons, surgical aids have been sought for decades. The purpose of this study was to evaluate the accuracy of prefabricated surgical resection templates used in mandibular segmental resections in comparison to the virtual surgical plan.

Materials and methods: A prospective study was performed in 11 consecutive patients, with a primary T4 oral squamous cell carcinoma or osteoradionecrosis of the mandible. Preoperatively, a CBCT scan was acquired to delineate the size and extension of tumor invasion; a virtual patient-specific resection template was designed based on this information. Intraoperatively, the resection template was positioned on the mandible and secured using four fixation screws.

Postoperatively, a CBCT scan was acquired. This scan was superimposed on the preoperative scan. Positioning of the resection template and inclination of the resection planes were evaluated on the virtual head model. In order to test the interobserver reliability of these new measurement methods, two different observers executed all measurements.

Results: The mean shift of the proximal resection templates was 3.76 mm (standard deviation [SD] 3.10 mm). For the distal resection templates, the mean shift was 3.06 mm (SD 1.57 mm) with no significant interobserver difference (ICC = 0.99). An absolute mean deviation of 8.5° (SD 5.3°) was found for the proximal resection angle and 10.4° (SD 5.0°) for the distal resection angle. Again, no significant interobserver differences were found (ICC = 0.98).

Conclusion: The resection templates used in this study proved reasonably accurate. Although the concept of virtual surgical planning aids significantly in mandibular reconstruction with microvascular free flaps, further improvement of resection accuracy is necessary for further improvement of reconstruction accuracy.

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Products and devices used in this study

- i-CAT® 3D Imaging System (Imaging Sciences International Inc, Hatfield, PA, USA).
- Maxilim® version 2.2.2.1 Medicim NV, Mechelen, Belgium.
- Matlab version 2012b, The Mathworks Inc., Natick, MA, USA.
- 3D Studio Max 2014, Autodesk Inc., San Rafael, CA, USA.
- Selective Laser Sintering, 3D Worknet BV, Ede, The Netherlands.
- Level One Fixation Screws, KLS Martin Group, Tuttlingen, Germany.

1. Introduction

Head and neck surgery can result in the absence of various types of tissue, with serious aesthetic and functional impairment, leading to physical and social disability. Reconstruction of these composite defects is a challenging and demanding problem. To improve true to anatomical reconstructions, surgical aids for composite defect reconstruction have been sought and explored in the last decades (Rose et al., 1993). Over the past few years, three-dimensional (3D) virtual planning has gained popularity in the planning of tumor resection as well as the reconstructive aspect of surgery (Coppen et al., 2013; Tsai and Wu, 2014).

Nowadays, preoperative virtual surgical planning (VSP) is a widely accepted concept to improve surgical reconstruction in the head and neck region (Zheng et al., 2012; Metzler et al., 2014; Kääriäinen et al., 2016). However, data regarding the accuracy of this concept are scarce (Zheng et al., 2012; Foley et al., 2013; Metzler et al., 2014). The VSP concept used in this study consists of three separate steps (Coppen et al., 2013). In the first step, a resection template is designed preoperatively and used intraoperatively, to achieve resection at the planned anatomical location and with the planned angulation of the resection plane. Accuracy of the resection templates is critical, since it defines the surgical margin of radicality if used in oncological surgery. Positioning errors of these resection templates will introduce errors, yielding inferior functional and aesthetic outcomes. In order to obtain optimal results in surgical resection and reconstruction of a defect, the position of the resection template as well as angulation of the resulting resection plane is of the utmost importance.

The purpose of this study was to evaluate the accuracy of prefabricated surgical resection templates used in mandibular segmental resections in comparison to the virtual surgical plan. The primary outcome measure was the similarity between the planned and realized positions of the templates. The secondary outcome measure was the difference in degree of angulation of the planned and realized resection planes.

2. Materials and methods

2.1. Data acquisition

A prospective study was performed in 11 consecutive patients with a primary clinical T4 oral squamous cell carcinoma or osteoradionecrosis of the mandible. All patients were treated between March 2012 and July 2013. Patients with oral squamous cell carcinoma were treated with a curative intention.

Prior to surgery, a cone-beam computed tomography (CBCT) scan was acquired to delineate the size and extension of the mandibular infestation. CBCT data sets were obtained by scanning the patients in natural head position, using a standard CBCT scanning protocol (i-CAT, 3D Imaging System, Imaging Sciences International Inc, Hatfield, PA, USA) in "Extended Field" modus (field of view: 16 cm diameter/22 cm height; scan time: 2 × 20 s; voxel size: 0.4 mm) at 120 kV and 3- to 8-mA pulse mode. Radiation dose for the patient was given as 136 μSv for a single scan. The CBCT dataset was exported in DICOM format.

2.2. Resection templates

A 3D virtual head model was reconstructed from the DICOM data in Maxilim software (v2.3.0, Medicim NV, Mechelen, Belgium). A virtual 3D planning for the resection and reconstruction was performed according to the triple template technique, described in detail by Coppen et al. (Coppen et al., 2013). The CBCT scan of the head and neck, combined with all available clinical and radiological information (e.g., magnetic resonance imaging [MRI] findings) were used to plan the optimal resection planes, with a 10-mm margin around the tumor. A resection template was designed for both the proximal and distal sides of the mandibular segment to be resected, based on the optimal resection planes.

Each resection template contained four fixation boreholes to rigidly fixate the template to the mandibular bone (Fig. 1). In the reconstructive phase of surgery, the boreholes of the fixation

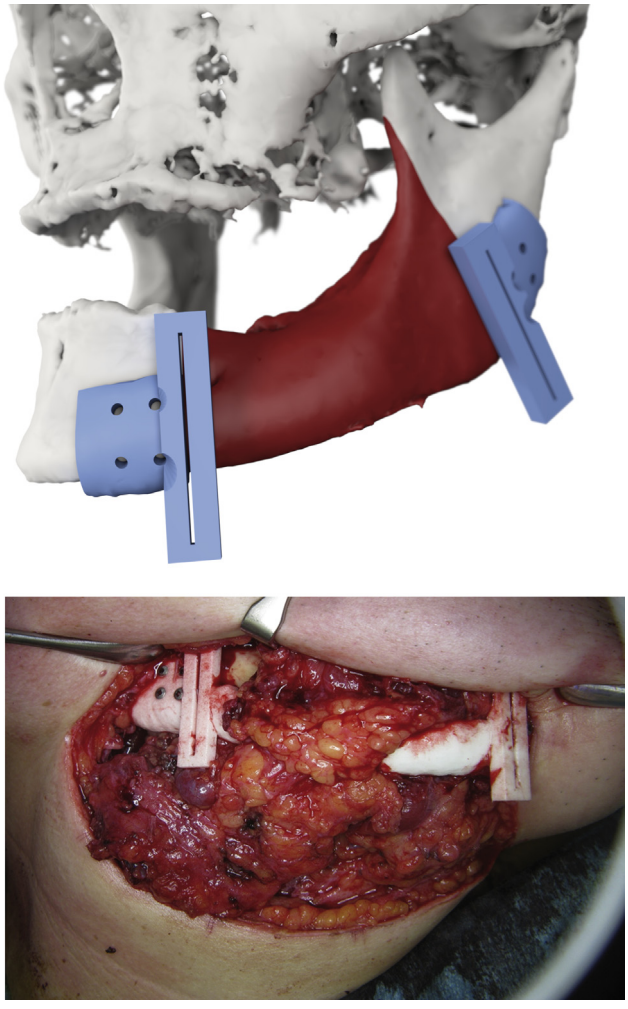

Fig. 1. Virtual design of a resection template with four screw holes to fixate the resection template to the mandibular bone and a saw slot to guide the oscillating saw during surgery (left). The resection template was produced using selective laser sintering.