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# Secondary surgical management of osteoradionecrosis using three-dimensional isodose curve visualization: a report of three cases

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*Abstract.* Osteoradionecrosis is defined as bone death secondary to radiotherapy. There is a relationship between the radiation dose received and the occurrence of osteoradionecrosis of the jaws, with the risk increasing above a dose of 60 Gy. In cases of class III mandibular osteoradionecrosis, a segmental resection can be indicated. Current practice is to completely remove the affected bone up to the point where the bone looks healthy and is bleeding. Exact resection planning and the use of guided surgery based on imaging of the bone changes have not been reported so far. This article describes a method whereby the radiotherapy dose information is incorporated into the imaging of the affected bone in order to plan a three-dimensional (3D) virtual guided resection and reconstruction of the mandible in osteoradionecrosis. The method enables 3D visualization of each desired dose field in relation to the 3D model of the affected bone. Two types of application – for resection and reconstruction – are described.

Key words: 3D planning; isodose; data fusion; osteoradionecrosis.

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Osteoradionecrosis (ORN) is defined as bone death following radiotherapy (RT), characterized by a non-healing area of exposed bone[1,2]. The deleterious and disabling side-effects of head and neck cancer radiation on bone are amongst the hardest to treat. The progression of ORN in the jaw can be difficult to control, resulting in the development of large osseous defects[3]. There is a pathophysiological relationship between the occurrence of ORN in the jaw and the radiation dose, i.e. the radiation dose is reported to be a risk factor for the development of ORN. The risk of developing ORN with a dose of 40–60 Gy is considered medium, whereas the risk at 60 Gy is frequently reported as high[4–7]. ORN often occurs within 3 years after the completion of RT and is related to trauma to the bone (tooth extractions prior to or post RT), the tumour volume treated, and the patient's health status.

This study focused on the category of patients who require surgery as a result of developing severe, or class III, ORN[8,9]. This surgical intervention includes removal of the affected bone and possibly a free-flap reconstruction as well. Determination of the resection margins of the affected bone is at present based mainly on preoperative interpretation of imaging, including computed tomography (CT) and technetium bone scans, in combination with intraoperative tissue exploration. Exact margin planning, and thereby also planned reconstruction of the defect, is not possible using these methods. Reconstructions are mostly performed without pre-treatment and exact size planning. Currently, the actual resection area of the affected bone is determined intraoperatively: the resection is continued until healthy bleeding bone is visible at the margin[10,11]. Nevertheless, as described by Zaghi et al.[12], histopathological confirmation that the necrotic bone margins have been completely resected does not always tally with the progression of ORN.

Exact intraoperative determination of the affected bone area, and thereby resection margin planning, is challenging and makes reconstruction planning unpredictable and thus suboptimal. In contrast to mandibular resections in cases of malignancy, no three-dimensional (3D) planned resection and guided surgery has been described to date for cases of ORN-related resection. Recent studies of primary oncological resections have reported successful integration of both resection planning and reconstruction based on 3D virtual planning[13–15], which might be applicable to ORN cases as well.

In order to make 3D virtual plans for the resection, the tissue affected by ORN or the tissue at risk requires adequate delineation. However, it is more difficult to derive exact margins from routine imaging in severe ORN cases. This case study introduces a method for resection planning based on 3D information of the causative radiation dose received. During 3D resection planning, the dose received can be visualized at each location of the affected bone. Moreover, this visualization technique can be applied to plan the drilling of screw holes for osteosynthesis plate fixation outside the high dose field in those cases requiring secondary reconstruction. Both applications are described below.

## Materials and methods

### Workflow

In order to plan and evaluate resections in relation to a selected isodose curve, a workflow was developed using a combination of radiation oncology planning software (Mirada Medical, Oxford, UK) and surgical planning software (ProPlan CMF 3.0; Materialise, Leuven, Belgium). Visualization and 3D planning requires access to the CT dataset showing the patient's current situation, as well as the RT planning, including the isodose curves.

This workflow was applied to three example cases, which are described below. In all cases, after consulting the radiation oncologist, the correct isodose lines of the planned target volume (PTV) (e.g. 56 Gy) were selected and exported as a radiotherapy structure set (RTSS) together with the CT dataset of the RT. The CT and RTSS were combined using a conversion method described by Kraeima et al. 2015[16]. In short, a conversion tool written in MATLAB (MathWorks, Natick, MA, USA) introduces a voxel highlight on the CT image for every coordinate corresponding to the RTSS file. In short, the RTSS is projected onto and combined with the CT, resulting in an enhanced DICOM file containing both the CT and isodose information.

The combined RT dose and CT information was imported into the 3D surgical planning software ProPlan 2.1 (Materialise, Leuven, Belgium). The isodose information was segmented into a 3D model, as well as all relevant bony structures. This combined 3D visualization was then used to discuss and determine the osteotomies for the resection of the affected bone. The workflow is described and presented in Fig. 1, including an example image for each software step.

In the case of previously performed surgical resections (for example patient 1A described below), the 3D model was supplemented with 3D visualizations of the osteotomies performed in the earlier surgical intervention. These were derived from the postoperative imaging of the previous intervention.

### Patient 1A—retrospective analysis of resection vs. radiotherapy field

The first patient (patient 1A) was treated using conventional methods, as the 3D visualization methods were not available at that time. A retrospective analysis of the ORN in relation to the 3D visualization of the RT field was performed.

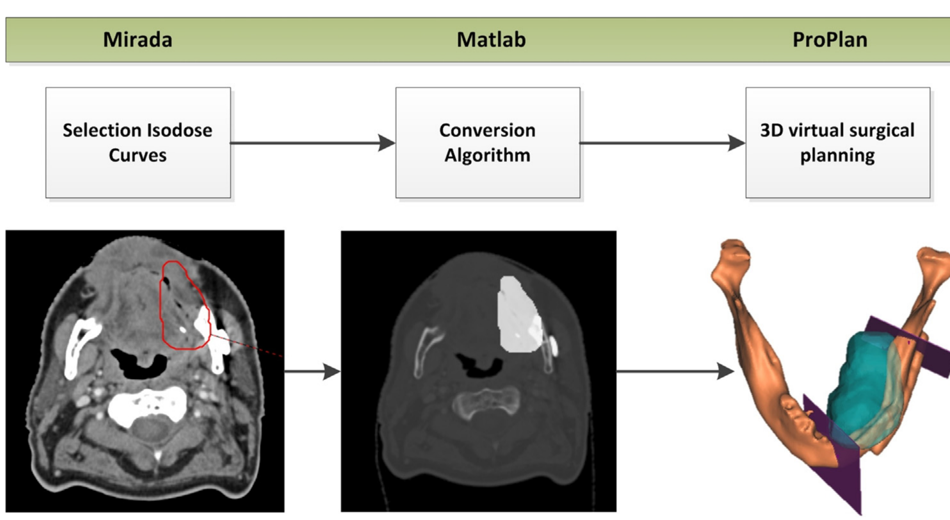


*Fig. 1.* Schematic overview of the workflow from isodose curve selection to 3D visualization and surgical planning.