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CLINICAL REPORT

Individual 3-dimensional printed mold for treating hard palate carcinoma with brachytherapy: A clinical report

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ABSTRACT

This clinical report describes the use of a 3-dimensional (3D) printer to create an individual mold for delivering high-dose-rate interventional radiotherapy for hard palate cancer. The maxillary teeth and palate were scanned with an intraoral scanner (3Shape TRIOS 3). The scan was transformed into a mesh using the standard tessellation language (STL) format and aligned with Digital Imaging and Communications in Medicine (DICOM) computed tomography (CT) images using free Blue Sky Plan 4 planning software. A mold was generated by tracing a guideline around the gingival margins of the maxillary teeth and palate on the scan mesh in accordance with established parameters. All data were imported into computer-aided design (CAD) software. For this patient, 3 parallel 2.2-mm-diameter ducts were placed 10 mm from each other in the mold mesh. A CT scan of the patient's mouth with the mold in place was used for treatment planning. Treatment was delivered by means of microSelectron digital afterloading. (J Prosthet Dent 2019;121:690-3)

The prognosis of hard palate carcinoma varies with the disease stage at diagnosis. To increase local tumor control, high-dose-rate interventional brachytherapy (HDR-IRT) with custom molds is used for some head and neck cancer sites, especially in the oral cavity. It delivers a higher radiation dose locally and reduces the irradiated area, thus efficiently treating superficial tumors; it is associated with low toxicity and excellent cosmesis.[1-17]

Mold making requires time, experience, and skill, as the mold must conform to the patient's anatomy. The mold room experience which the patient must undergo is rarely well tolerated, particularly for a face shell. Furthermore, handmade custom molds are difficult to make for small area lesions, those with irregular surface contours, or those in difficult anatomic sites which need multiplane and multidirection catheter geometries.[17] Three-dimensional (3D) printing[18] may offer a solution for these difficulties. Automation could reduce fabrication time compared with hand molding, and computer optimization of catheter positions could improve dosimetry.[19] In radiotherapy, 3D printing has been used for boluses,[20-25] phantoms for quality assurance,[26-29] compensator blocks,[30] and proton range compensators.[31] In HDR-IRT,[32-38] 3D printing has been used to make superficial molds,[39] gynecological applicators,[40,41] and custom templates for guiding interstitial insertions.[42-50]

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This clinical report describes how 3D printing was used to make an individual mold for delivering HDR-IRT treatment for hard palate cancer. No events during this short-term follow-up preclude identifying the specific features of patients at risk of relapse and illustrate the need for performing a large database analysis of treatment results of these types of cancer.[51,52]

CLINICAL REPORT

A 43-year-old woman presented with a dyschromic hard palate lesion (Fig. 1). Biopsy findings indicated a poorly differentiated mucoepidermoidal malignancy of the central hard palate. A computed tomography (CT) scan was negative for nodal and distant metastases. The multidisciplinary team, which included 2 dental surgeons (S.P., S.C.), 5 radiation oncologists (V.L., C.A., G.K., L.T., V.V.), a medical oncologist, and a radiologist opted for HDR-IRT with 40 Gy in 4 Gy fractions delivered twice daily for 5 days from Monday to Friday. HDR-IRT treatment was delivered by means of a 3D printed mold. The dental surgeons (S.P., S.C.) scanned the patient's maxillary teeth and palate with an intraoral scanner (3Shape TRIOS 3) which provided a certified RealColor 3D dental model accurate to within micrometers. The scan was transformed into a mesh, using the standard tessellation language (STL) format. The mesh STL file was aligned with the Digital Imaging and Communications in Medicine (DICOM) CT images using free Blue Sky Plan 4 planning software.

A custom-made mold of light-polymerizing resin (Dental SG Resin; Formlabs) was generated by tracing a guideline around the gingival margin of the maxillary teeth and the palate on the scan mesh; the software automatically produced the mold in accordance with the preestablished parameters. Given the longest diameter of all tooth surfaces, the lower area was removed, as otherwise the mold would not have fitted into the patient's mouth (Fig. 2). Under the supervision of the radiation oncologist (V.L.), a company (TRIOS3; 3Shape, A/S) technician imported the diagnostic CT images on to the Mimics Innovation Suite by using, as required, RealColor images from the intraoral scanner. The radiation oncologist identified the lesion and indicated the intercatheter and catheter-lesion distances. The mold STL file and measurements were imported into computer-aided design (CAD) software. For this patient, 3 parallel 2.2-mm diameter catheter ducts were placed at a 10-mm distance from each other in the mold mesh. The ducts started in the anterior portion of the mold and ended on the posterior edge of the lesion, centrally and left and right laterally at 14 mm and 16 mm, respectively. The posterior mold edge was raised by 2 mm to prevent the catheter button from touching the palate (Fig. 3). Finally, the mesh was optimized for 3D printing. This palate radiotherapy mold was produced by the Formlabs Form 2, 3D printer by using stereolithography technology and Formlabs Dental SG Resin, which is approved for use in dental biomedical devices. After the mold was inserted into the patient's mouth, a CT scan (2.5-mm slices) evaluated its placement and was used for treatment planning. A European Union-wide patent was recently requested for the device and its production.

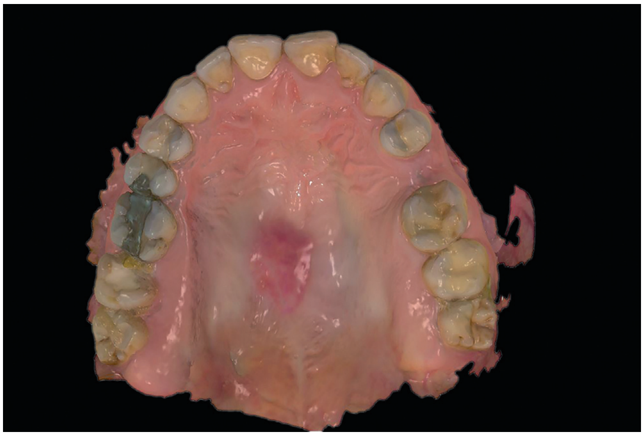

Figure 1. Dyschromic hard palate lesion diagnosed as carcinoma.

The intended treatment was to deliver ≥95% of the prescribed dose to the planning target volume (PTV), accepting 90% as satisfactory. The mold was ready for use within 5 hours. The 3D-printed mold provided effective dose coverage in the PTV with V95%=99.01%. HDR-IRT treatment using the 3D mold was well tolerated with no patient discomfort reported.

DISCUSSION

As far as the authors are aware, this is the first description of a process for creating an HDR-IRT 3D printed mold to treat intraoral carcinoma. This patient's outcome suggests that because individual 3D printed molds have the potential to replace commercially available materials with handmade molds, their use may well become standard for oral cancer treatment with HDR-IRT. Although the use of handmade HDR-IRT molds for intraoral tumors has been described,[43-50] a comparison with these reports is not possible. The immediate advantage of intraoral scanning with a contactless surface scanner and 3D-printed mold was that patient discomfort was greatly reduced. The process is much less invasive and less time-consuming than a conventional polymeric dental impression and a scanned cast. The intraoral scanner did not contact the lesion and reduced the number of steps that could lead to errors.[47] Because catheter positioning and number were based on the patient's CT data, CT-based planning ensured tumor coverage. Treatment was efficiently delivered by means of the 3D-printed mold with effective dose coverage in PTV.

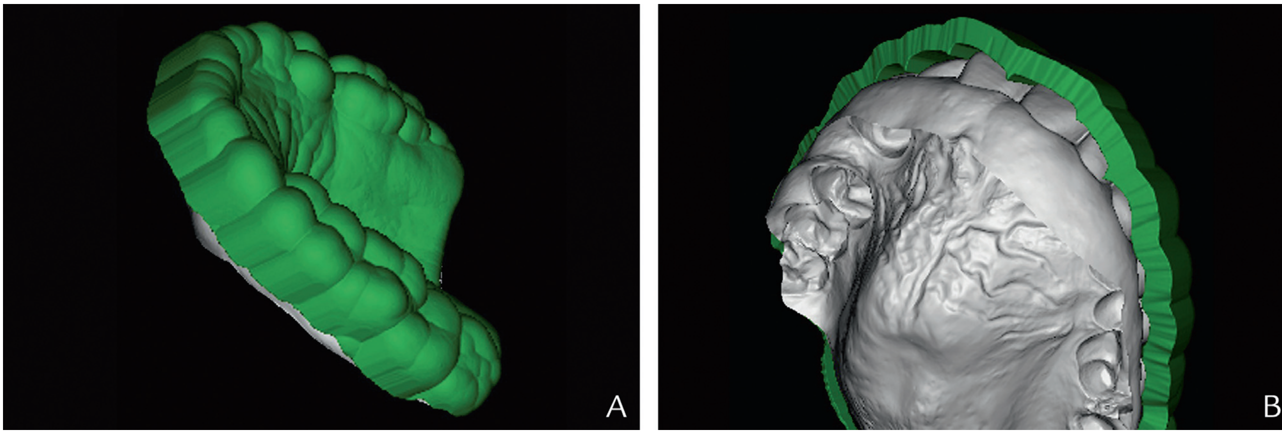

Figure 2. Mold generation. A, Maxillary left panel. External surface of mold showing maxillary teeth, hard palate. B, Intaglio surface of mold showing lesion.

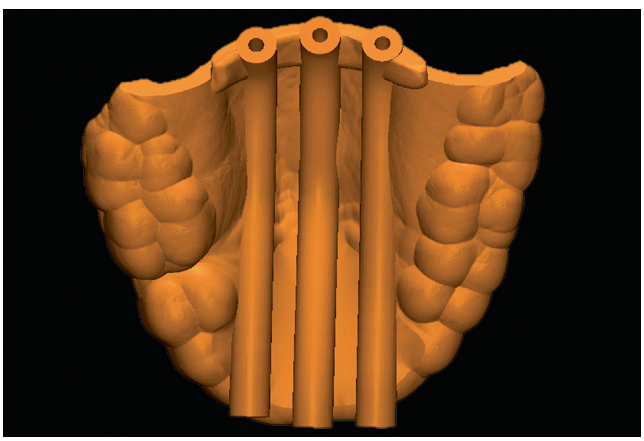

Figure 3. Catheter ducts.

The mold was accurately positioned at each treatment session by contact with the teeth. Furthermore, consistent placement provided dosimetric advantages. This patient received each fraction of the planned dose in full, as CT images showed no air gap between the 3D printed mold and palate surface. Indeed, a significant drawback with handmade molds is their impact on dose delivery as they may not adapt perfectly to the patient, particularly for superficial tumors, and may even need to be remade if gaps are found. Improper mold fitting may lead to an unwanted air gap between the mold and the surface, which might be unavoidable, and which could affect therapy as the surface dose is significantly affected by air gaps greater than 5 mm.[46,50] Unfortunately, with handmade molds, the depth of the air gap cannot be anticipated and calculated during treatment planning and may cause a discrepancy between planned and delivered doses.

The main limitation of the 3D printing used was the need to engage specialized staff who were not employed by the local hospital or university, thus raising costs. No events during this short-term follow-up preclude identifying specific features of patients at risk of relapse and suggest the need for performing a large database analysis of treatment results of these types of cancer.[51,52] Furthermore, studies are needed to validate dosimetry and characterize printing materials before 3D printing can be fully implemented in clinical practice.

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