Custom-designed mouthpiece for HDR brachytherapy of embryonal rhabdomyosarcoma of the soft palate

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Abstract

This paper describes the design and fabrication of the mouthpiece used for high-dose-rate (HDR) brachytherapy of a cancerous lesion in the soft palate of a pediatric patient. A custom mouth guard made with Thermo-forming material (Clear – Mouthguard) similar to those used by athletes, with a bite section, alveolar sulcus, hard and soft palate sections was made. Markers were placed around the lesion using a color transfer applicator and the impression transferred to the mouthpiece. Ten catheters arranged in a plane were placed on the inferior side (concave part) of the mouthpiece, and held in place by stitching each to the mouthpiece. Two pieces of lead (Pb) sheets with total thickness of 5.7 mm were placed beneath the catheters. Wax was used to create additional distance between the tongue and the catheters, and the entire assembly was covered with wax.

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Key words: HDR brachytherapy, mouthpiece, rhabdomyosarcoma, soft palate.

Purpose

Rhabdomyosarcoma is a cancer thought to arise from skeletal muscle progenitor cells; it is the most common type of soft tissue sarcoma in children. Rhabdomyosarcoma accounts for about 3% of all childhood cancers. Embryonal rhabdomyosarcoma, as opposed to alveolar rhabdomyosarcoma, is the most common type of rhabdomyosarcoma that usually affects infants and young children. These cancers tend to occur in the head and neck area, bladder, vagina, in and around the prostate and testicles.

Treatment of this disease involves surgery, chemotherapy, radiation therapy, and combination therapy. Radiation therapy to the soft palate using external beams will give extraneous dose to the surrounding structures. Late effects associated with this technique include severe fibroses of surrounding normal tissues, asymmetric facial growth, zerostomia, trismus, mandibular osteoradionecrosis, and visual and dental abnormalities. Another unwanted long term result is the small but increased risk of secondary cancer induction [1]. Intensity-modulated radiation therapy (IMRT) has been extensively used for the treatment of soft tissue sarcoma and reports indicate excellent local control can be achieved while minimizing late effects [2-13]. Intensity-modulated radiation therapy has been shown to achieve better sparing of normal structures than conventional 2D planning or 3D conformal planning techniques [4,9]. Proton therapy has been reported for the treatment of soft tissue sarcomas [14-16]. Substantial normal tissue sparing was observed with proton therapy dose distributions compared to either three-dimensional conformal radiation therapy (3DCRT) or IMRT plans.

Brachytherapy has also been routinely used for the treatment of rhabdomyosarcoma [17-22]. The overall survival is similar to that reported for external beam irradiation without the severe fibrosis and asymmetric growth problems. Given these reports in the literature on differing methods to treat rhabdomyosarcoma, an opportunity was identified to make a brachytherapy applicator that was less invasive than interstitial brachytherapy, yet permitted pre-implant imaging and treatment planning. In this manner, the dosimetric advantages of brachytherapy over external-beam methods could be utilized while being practical for use on pediatric patients. To our knowledge, there are no other reports in the literature on the use of such applicator in the pediatric population.

Material and methods

A custom designed mouthpiece was designed and included the following components: a clear mouthguard, 4 French catheters, a lead shield, and wax material. The dental hygienist, having selected the correct size of the bite impression tray, made a dental impression of the patient that includes the teeth, alveolar sulcus, hard and

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soft palate. Using a color transfer applicator, the radiation oncologist delineated the surgical margins on the soft palate and these in turn transferred to dental impression. Dental stone was subsequently poured into the dental impression and allowed to set. Figure 1 shows the positive impression of the patient's mouth with the surgical margins imprinted on the mold.

Thermo-Forming Material (Clear – Mouthguard, Henry Schein Company, Melville, NY, USA), 3.8 mm thick with a density of approximately 1.007 g/cm^3 , was heated until it became soft, then formed around the teeth model (Fig. 2). This resulted in the mouthguard thickness of about 2.5 mm. Next, ten catheters were sewn into a single plane into the mouthguard with about 2 mm extending distally beyond the mouthpiece (Fig. 3).

Two layers of lead, total thickness of 5.7 mm, were fashioned to fit the concave part of the mouthpiece and placed over the catheters, and extended about 5 mm beyond the ends of the catheters. The easily pliable lead pieces were held in place by also stitching them to the mouthpiece. The ^{192}Ir half-value layer (HVL) of lead is 2.5 mm [23], and the above lead thickness will give approximately 21% transmission of the dose to the underside of the mouthpiece. To further extend the distance between the catheters and the tongue, 20 mm of wax was used to fill the concave part of the mouthpiece, thereby holding the various components together as one piece (Fig. 4).

Prior to using the mouthpiece by the patient, the entire assembly was wrapped with saran-wrap. The patient, a 15 year old football player, tolerated the mouthpiece

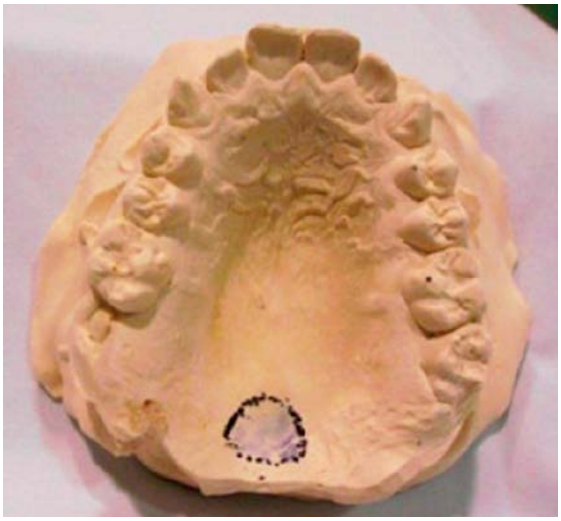

Fig. 1. Positive dental impression with surgical margins delineated

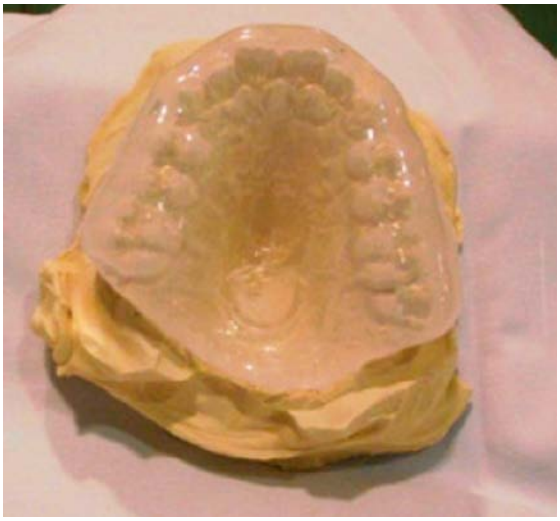

Fig. 2. Clear-Mouthguard superimposed on the positive dental impression

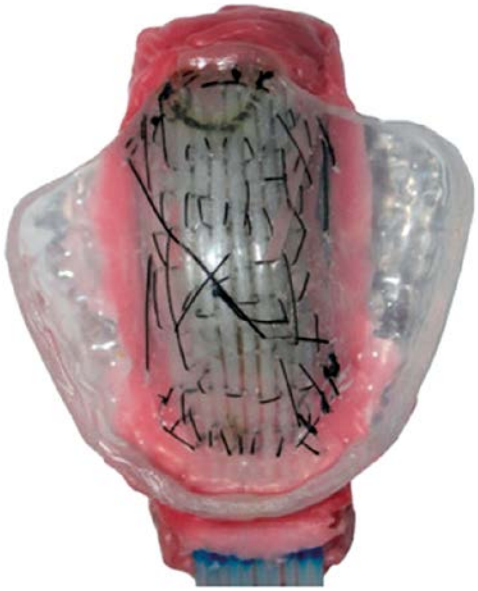

Fig. 3. Mouthpiece view showing stitching of catheters to the Clear-Mouthguard

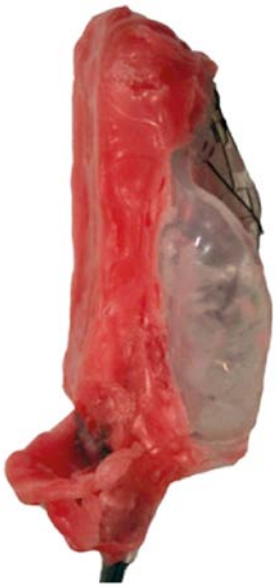

Fig. 4. Mouthpiece view showing the thickness of wax used

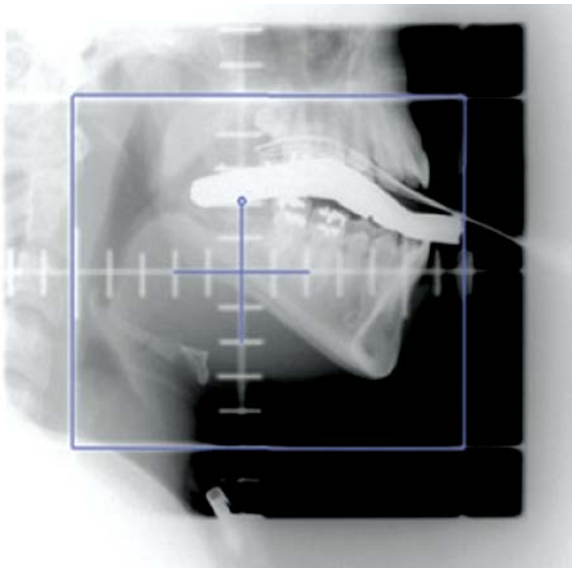

Fig. 5. Fluoro verification of mouthpiece placement

very well and had no gagging reflex. The positioning of the mouthpiece inside the patient was verified with a Nucletron Fluoro simulator located in the same high-dose-rate (HDR) suite (Fig. 5).

Using a second mouthpiece similar in shape and size as the first mouthpiece, but with the lead shield replaced with a thermoplastic bolus of the same thickness, the supine patient received a CT scan with 3 mm slice thickness. Clinical target volumes (CTV) was delineated by the radiation oncologist and treatment planning was completed using Oncentra Treatment Planning System (TPS) v.4.3. Only a few dwell positions around the tip of the catheters were activated since the CTV is located towards the end of the catheters. A total dose of 36.0 Gy was prescribed at 2.0 Gy daily dose to a lesion depth of 5 mm. The total treatment time was 66.5 seconds for fraction one with the Nucletron microSelectron HDR ^{192}Ir brachytherapy source (21.95 mGym^{2}h^{-1} or 5.4 Ci).

To evaluate the delivered dose, optically stimulated luminescent dosimeters (OSLDs) were fastened *in vivo* to the mouthpiece to measure doses to the tongue and the soft palate surface at locations determined by the TPS to be maximum dose. The OSLDs were mailed to Landauer Special Dosimetry Services for readout.

Results

Figure 6 shows the axial, sagittal, and coronal views through the CTV with 2.0 and 3.0 Gy isodose lines displayed. It also shows the DVH for CTV and the organs-at-risk (i.e., right and left mandibles). OSLD report shows that the dose to the soft palate surface was 3.65 Gy, consistent with the 3.75 Gy TPS result. The dose to the tongue as measured with OSLD was 0.308 Gy compared to the 0.28 Gy TPS result.

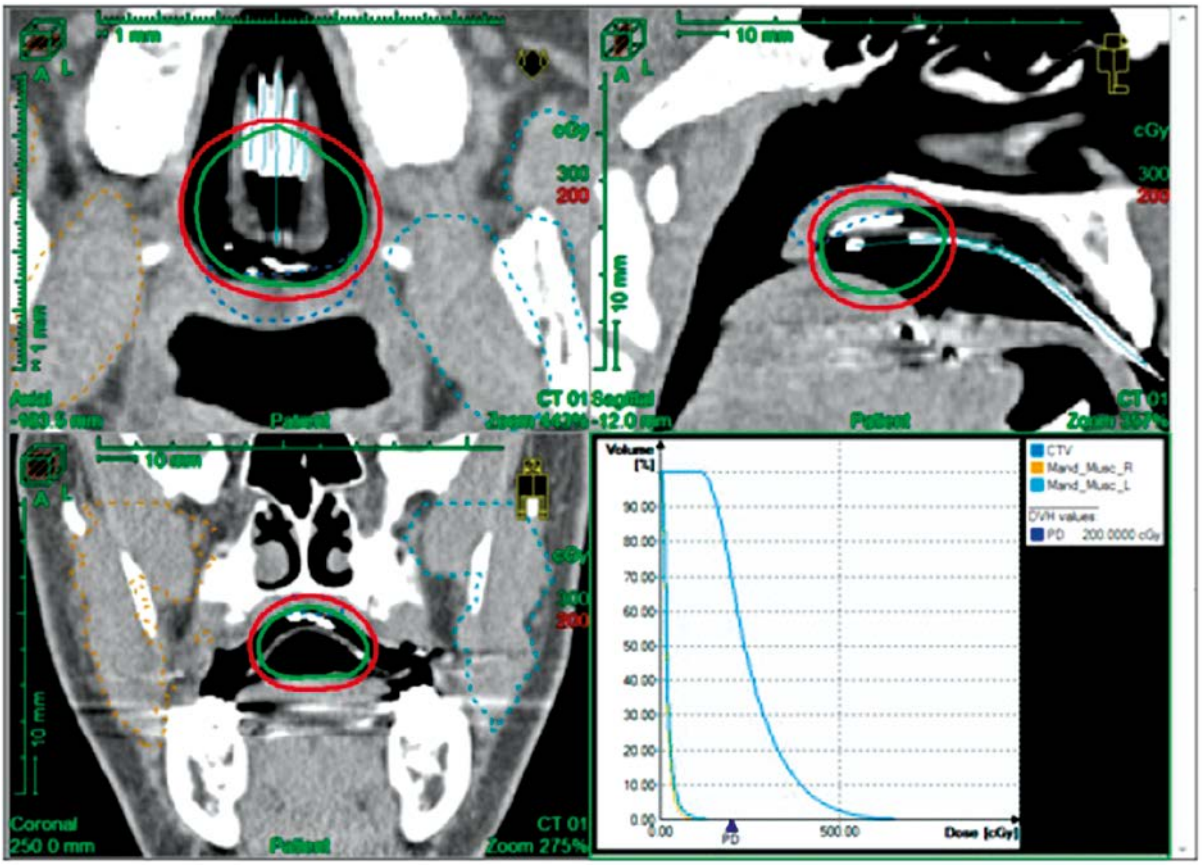

Fig. 6. Axial, sagittal, and coronal views through the CTV and the DVH

Discussion

The patient's soft palate lesion was surgically resected and pathology report confirmed embryonal rhabdomyosarcoma with no metastasis. Subsequently, he received three cycles of chemotherapy prior to this radiation component of local control. The primary reason for using brachytherapy was to reduce dose to normal tissues while providing a conformal therapeutic dose. However, one of the late effects of using brachytherapy for STS is trismus and osteonecrosis [20]. Ulcerations around the hard palate were noted at fraction number ten, and this was resolved by giving the patient a nine-day treatment break. The measured doses using OSLDs were within 0.1 Gy of the dose calculated by the TPS results for a given treatment fraction. This level of agreement was considered good given the differences in OSLD calibration (i.e., using ^{60}Co, whereas the treatment used ^{192}Ir), prediction of lead attenuation, and differences in radiation scatter conditions between that assumed in the TPS and that present during the patient treatment [24].

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Disclosure

Authors report no conflict of interest.

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