

# Wax Tissue Compensator for Head and Neck Radiotherapy - Fabrication and Dosimetric Evaluation

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## Abstract

Thickness and contour variations in head and neck regions introduce non-uniformity of radiation dose delivery leading to severe hot spots. Tissue compensation is achieved sometimes using square non-divergent aluminum metal pieces in 'Ellis type' compensators. We developed Divergent Wax Tissue Compensator (DWTC) and tested their efficacy in tele-cobalt treatments.

For a photon field of size 20x20cm in a telecobalt machine with 'Source Diaphragm Distance (SDD)' of 45 cm, DWTC is designed to provide compensation at 'source skin distance (SSD)' of 80 cm. A jig stand with 3 acrylic perforated sheets kept together at specified gaps allow required radial divergence of the metal spokes on equally spaced grid. Dose compensator could be fabricated by a tray mounted on the top side of the jig, using molten dental wax by measuring patient anatomy created by a positive of 'Plaster of Paris' (POP).

Accuracy of fabricated DWTC is tested using 3-dimensional semi-spherical and wedge shaped contours, and measuring transmitted radiation flux using EDR-2 verification film and evaluation by Vidar scanner. The uniformity of the dose in the treatment region with compensator is well within 3%, 3mm dose evaluation criteria.

These wax compensators are simple, accurate and they could be adopted in linear accelerator treatments also retaining the dose build up advantage.

**Key words:** Megavoltage radiotherapy; Tissue compensation; Dose uniformity; Head and neck regions

## Introduction

External Beam Radiotherapy (EBRT) remains the mainstay for radical treatments, for malignancies in head and neck regions. Inter-field thickness variations and irregular contour variations are encountered in these patients affecting uniformity in radiation dose delivery. Adverse reactions are encountered because of skewed isodose curves seriously affecting the volume dose variations in treatment planning. This complex situation results in dose inhomogeneity resulting in painful reactions in the head and neck region often discouraging the patient from taking full course of treatment. There are issues relating to adjuvant surgical management when the texture integrity of skin in neck region is not preserved. Non-uniformity of dose in the planned treatment volumes also ad-

versely influence normal tissue reactions, affecting effectiveness of the treatment and therefore deter the Quality Of Life (QOL) in the follow up period.

Ever since deep x-ray era, various compensation methods have been reported in literature for such treatments[1-11]. Tissue Compensators (TC) in the shadow tray level of megavoltage beams are implemented to preserve the shape of the isodose curves accounting for tissue beam obliquity, preserve dose build up advantages, and to improve dose delivery. Ellis type compensator[1,2,5] use aluminum (Al) square pellets to construct compensator plates for individual radiotherapy portals. Tissue deficiencies are addressed by fixing small thickness Al rods taking density factor. Commercially available jigs for fabrication of aluminum tissue compensators do not account for beam divergence at the collimator level[12,13]. Effect of tissue compensation has been studied for sites other than head and neck regions and also use of other metals for such work[14-16]. Presence of metal during

transit of x-ray photons induce low energy scattered x-rays, add recoil electrons increasing surface dose.

In India, around 40% of head and neck cancers detected are oral malignancies. In addition, there are patients with cancer of nasal cavity, nasopharynx, paranasal sinuses and the oropharynx, where treatment involves the oral cavity as well as neck area[6]. Radiotherapy (with linear accelerators and telecobalt machines) is increasingly being used as an adjunct form of treatment in the management of head and neck cancers. Because of small inter-field separations, there are no specific advantages of linacs over cobalt machines in these treatments. To overcome treatment related morbidity in these treatments, we investigated[17] efficacy of wax tissue compensators accounting for beam divergence, mounted away from the patient on the path of the beam. The dosimetric adequacy in the application of these compensators in clinical situations is highlighted.

## Materials and Methods

### Fabrication of jig

An iso-centric Theratron tele-cobalt machine (Theratronix, Phoenix) with isocentre at 80 cms has been used for delivering head and neck treatments with parallel opposing lateral fields. The shadow tray distance (Source-Diaphragm Distance 'SDD') is 45 cms. To simulate radial diverging beam with a field size of 20 x 20 cm at isocentre, a special jig was prepared using three perforated Perspex sheets mounted at fixed intervals. Metal spokes pass through all the 3 Perspex sheets through equally distributed holes drilled, in square matrix form. The divergence of pencil beams, with calculated decrement factor at different planes with respect to 80 cm SSD ensures correct reproducibility in compensator fabrication. This system can estimate contour variations when placed on a 3 dimensional object. Figure 1 and 2 shows the design of the developed jig, the method of taking the impression of semi-spherical and wedge object and the diminished size of fabricated tissue compensator.

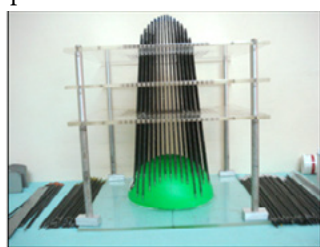


Figure 1

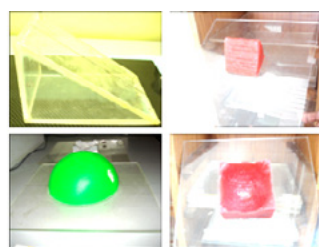


Figure 2

Figure 1: Design of jig for preparation of divergence based wax tissue compensator demonstrated on a semi-spherical phantom object.

Figure 2: Wedge and semi-spherical object and their wax compensator impressions with diminished sizes.

Dental Modeling wax (a tissue equivalent material of density,  $\approx 1.00 \text{ gm/cm}^3$ ) commercially available in standard sizes 9 x 16 cm plates, having thickness ranging from 0.2 cm to 10.0 cm was used as compensator material. Water equivalence is confirmed by measurements carried out in a water phantom (Model WP30) of size 30 x 30 x 30 cm, using 0.6  $\text{cm}^3$  ionization chamber connected to an electrometer (CD-SSD-92).

### Film dosimetry

Verification of the obtained water equivalent wax compensa-

tor thickness was carried out with Kodak therapy verification film (Extended Dose Range: EDR-2) with and without TC, to confirm improvement in flatness of horizontal radiation beam profiles. (Figure 3 and 4). The films are exposed under these phantoms to a dose of 2 Gy on Phoenix telecobalt unit using SAD technique keeping in a sagittal plane at a depth of 2 cm with and without TC. Intensity Modulated Radiotherapy Omni Pro film dosimetry software (Wellhoffer Scanditronix, Uppsala, Sweden) was used to evaluate film response with VXR-16 vidar scanner. Flatness, symmetry, uniformity in radiation intensity were checked with the available software.

### Clinical use of DWTC

For patients planned for bilateral curative radiotherapy for head and neck tumors were taken for tissue compensation. These patients were immobilized with appropriate mould sheets. A positive Plaster of Paris (POP) mould is prepared for the head and neck together, in the mould room. This was kept under the jig and the metal spokes were run to obtain the shape at the tray level accounting for beam divergence. Diminished size wax impression mould is obtained incorporating the 'decrement factor  $45\text{cm}/80\text{cm} = 0.563$ '. Separate divergent TCs were prepared for left and right sides of treatments. The fabricated TCs were fixed on a Perspex tray maintaining correct positioning with respect to central axis of radiation treatment portal. The two compensators showing their orientations and treatment execution in the presence of compensator in shadow tray of cobalt machine is seen Figure 5 and 6.



Figure 3



Figure 4

Figure 3: Geometry of taking fluence pattern on the EDR-2 film for the semi-spherical object at SSD and corresponding compensator in the tray level.

Figure 4: Geometry of taking fluence pattern on the EDR-2 film for the Perspex wedge object at SSD and corresponding compensator in the tray level.

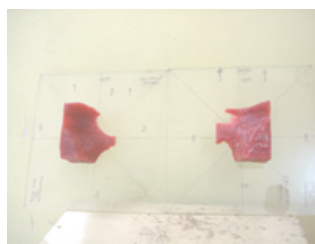


Figure 5



Figure 6

Figure 5: Wax based divergent compensators made for left and right halves of the neck portion of a patient

Figure 6: Wax compensator of the left lateral field fixed on the shadow tray along with patient in treatment position.

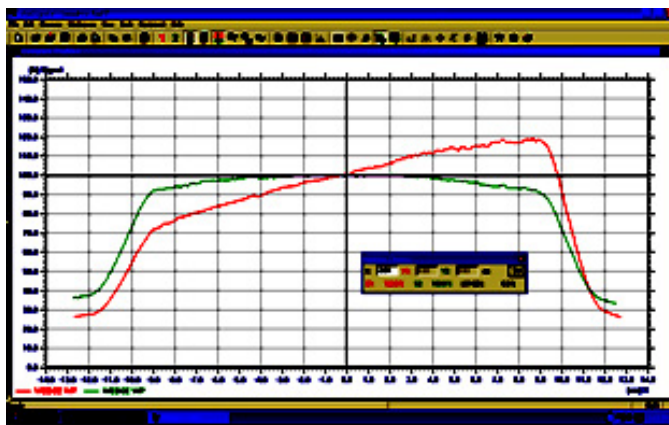


Figure 7

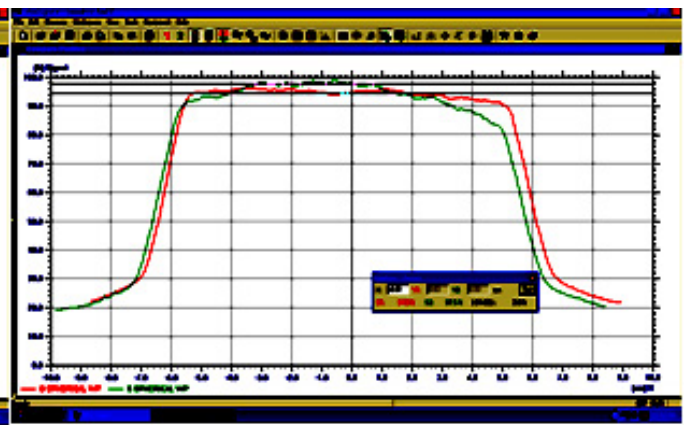


Figure 8

Figure 7: EDR-2 measured intensity profiles with and without compensator for wedge shaped Perspex phantom  
 Figure 8: EDR-2 measured intensity profiles with and without compensator for semi-spherical object

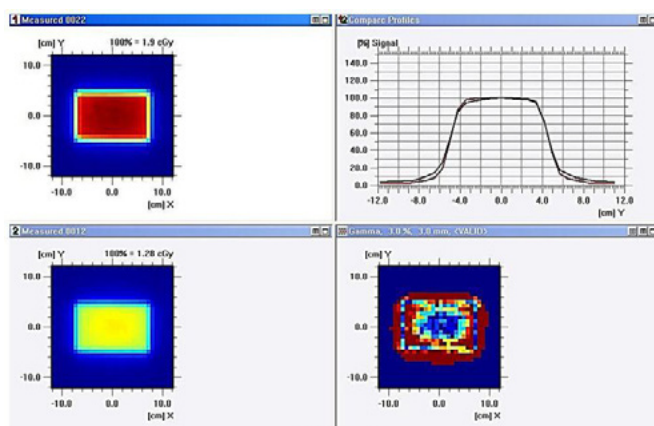


Figure 9

Figure 9: Uniformity of compensated intensity pattern checked with 3mm, 3% dose evaluation criterion.



Figure 10



Figure 11

Figure 10: Uniformity of patient's skin reaction during treatment (seen in Antero-Posterior view) treated with presence of tissue compensator during treatment.

Figure 11: Uniformity of patient's skin reaction during treatment (seen in Right Lateral view)

## Results

Water phantom measurements of beam transmission gave broad beam attenuation coefficients for water and wax showing good equivalence within 2 – 3 % ( $\mu_{\text{water}} = 0.048 \text{ cm}^{-1}$  and  $\mu_{\text{dental wax}} = 0.049 \text{ cm}^{-1}$ ). Flatness of horizontal profiles as obtained with TC is found to be within  $\pm 1\%$  without any spikes showing homogeneity in the fabricated wax impressions. The wedge and semi-spherical wax impressions gave the required shapes (Figure 7 and 8) as confirmed from the profile plots with the scanner. The uniformity of the dose in the region with compensation is well within 3%, 3mm dose evaluation criteria (Figure 9).



Figure 12

Figure 12: Sequential clinical photographs of another patient indicating minimum radiation sequelae at completion of treatment and in the follow up period.

In Figure 10 and 11 the AP and Lateral views of the irradiated patient, shows the uniformity in radiation reaction indicating the efficacy of designed DWTC for clinical applications. Figure 12 illustrates sequential clinical photographs of a treated patient indicating minimum radiation sequelae at the end of treatment and in the follow up period.

## Discussion

This study has systematically presented the clinical implementation of a wax-compensator based radiotherapy treatments at our center. It is brought out clearly that any shape of the contour could be corrected for tissue obliquity. For the quality assurance aspect we have shown regular objects like wedges and semispherical shapes checked with water phantom and film dosimetry. These wax based divergent tissue compensator is superior in reducing hot spots to improve overall dose homogeneity, without introducing additional corpuscular stray radiations like metal filters. The safety of their applications and optimal dose delivery were well demonstrated.

Enormous irregularities in patient geometry in the superior-inferior planes lead to hot and cold spots, giving complex dosimetric situations. Beam modulation methods like IMRT either adds or blocks radiation intensity with increase in monitor units and also bringing in un-necessary beam orientations to obtain optimization. The presence of wax compensator in the



path of the beam corrects for absence of tissue, and brings in dose delivery to 'near perfect' situation reducing additional uncertainties. 2-D compensators fabricated by milling machines use computerized tomography CT images through DICOM transfer depends on electronic technology adding to cost of treatment, in addition making introduction of metal filters which may give rise to stray radiations, thereby increasing the risks of second malignancies in peripheral zones. In Figure 8 it appears that it is difficult to say that semi-spherical wax impressions give the required shapes. This is because, though the semi spherical wax impression did not give the required shape as clearly as that for the wedge phantom, this is due to the fact that the profile was taken along a small area on the top of the semi-sphere around the central axis of the phantom. Figure 8 exhibited more of a method to check a fabricated compensator with an external dosimetry system if required. Regarding phantom selection we have resorted to closely mimic the clinical situations in the head and neck regions. Neck is usually semi cylinder in shape with variations along the medial to lateral borders. A semi spherical hollow object (a plastic ball of diameter 16 cm cut in half and closed along the base of the hemi sphere by Perspex sheet) filled with water is selected for dosimetry. A perspex sheet is used in order to verify the fluence pattern under 'IMatrix' with and without the compensator. A semi cylindrical shape of the neck has only 2 dimensional contour variation. However a semi spherical water phantom will have much higher degree of contour variation (3 dimensional). Hence a semi spherical water phantom was selected for dosimetric purposes to validate the uniformity of the fluence with the compensator. It is clarified that this wax compensator can address irregular shapes of outer contour but will not account for inhomogeneities inside the neck in terms of air space and cartilage.

Employing this cost effective type of tissue compensators, the dose inhomogeneity can be reduced to within 5% which has significant applications in the developing world. Good homogeneous agreement is observed with film dosimetry thus instilling confidence in more optimal treatment delivery. The dosimetric custom compensation method is highly accurate, and reproducible. In a simple mould room setup, the custom made divergent wax based tissue compensator could be fabricated with insignificant cost, without much of sophisticated inputs. Our study with cobalt beams could also be extended in linacs because the divergence of the beam is less with more SSD with respect to tray level. Also tissue equivalence could be confirmed with the beam quality before implementation. Beam hardening effects also will be minimal with wax material. This technique will allow the radiation oncologists to treat patients with head and neck radiation fields in a most efficient manner. This concept could be generalized for tissue obliquities in the scalp and breast regions and suitable compensation could be achieved with careful prostheses.

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