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The use of EBT3 film and Delta4 for the dosimetric verification of Eclipse™ treatment planning system in a heterogeneous chest phantom: an IMRT technique

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► ***Short Report***

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ABSTRACT

Background: This study aimed to evaluate the dose calculation accuracy of Eclipse™ treatment planning system (TPS) in a heterogeneous chest phantom with the intensity modulated radiotherapy (IMRT) technique using EBT3 film and Delta4. ***Materials and Methods***: Two IMRT plans (A and B) were prepared for radiotherapy of the heterogeneous chest phantom. Plan A was between the left lung and the surrounding soft tissue and plan B was carried out on the soft tissue. EBT3 film and Delta4 were used for dose measurement in the phantom. Eclipse™ TPS was also used for dose calculation. Finally, the gamma index values of the TPS with film and TPS with Delta4 were obtained. A 95% passing rate of gamma index with the passing criterion of 3mm/3% and a dose threshold of 20% as the standard criterion was considered in this study. Furthermore, the passing rates of gamma indices of the film and Delta4 were compared with each other via Bland-Altman analysis. ***Results:*** The mean passing rate of gamma index with standard passing criterion between the TPS calculations and film measurements was 96.95±0.22%, while it was equal to 97.7±0.56% and 98.45±0.21% between the TPS calculations and 2D and 3D Delta4 measurements, respectively. Additionally, the differences between the passing rates of gamma indices of the film and Delta4 were less than 5%. ***Conclusion:*** The findings demonstrate that the accuracy of dose calculations of Eclipse™ TPS in a heterogeneous chest phantom with the IMRT technique is within the standard passing criterion. Furthermore, it can be concluded that there is a good agreement between the film and Delta4, as IMRT QA devices.

Keywords: *Delta4, EBT3 film, Heterogeneous phantom, IMRT*

INTRODUCTION

In radiation therapy, the precision and accuracy of treatment planning process and dose delivery are significant in tumor control and spare normal tissue from inessential radiation dose [1, 2]. To achieve this aim, dose calculation by treatment planning systems (TPSs) was performed precisely; hence, quality assurance (QA) in the radiotherapy treatment planning process is essential [3]. On the other hand, due to the complexity of the IMRT technique and the difficulty of treatment dose verification using manual calculations, it is usually suggested that in addition to performing the periodic tests of the system, plan verification and pretreatment checks are carried out [4, 5]. The most common method used in IMRT QA is to deliver the IMRT plan to a phantom and then compare the dose distribution measured by a detector with values calculated by TPS [6].

Film dosimetry has been extensively adapted for use in IMRT QA because of its better spatial resolution, energy and dose rate independence, effective atomic number, a density close to tissue and water, etc. [7]. However, film dosimetry is a time-consuming method, if an acceptable level of accuracy is needed in absolute dose determination [8]. The arrays of detectors are used as a replacement for films for the purpose of assessing IMRT pretreatment QA, requiring an easy setup and verification methods [8]. Delta4 phantoms are diode-based detectors which have an acceptable linear response, reproducibility, and energy independence; however, they exhibit a lower spatial resolution than film due to the existing spaces between two perpendicular planes of diodes [9, 10].

There are several studies which have compared the dosimetric performance of QA devices in IMRT with a homogeneous phantom [10, 11]. In a study, Chandraraj *et al.* [10] compared the dosimetric performance of EDR2 film and three other commercial QA devices (MatriXX array, Delta4, and PTW seven29 array). Their findings revealed that the four QA systems investigated in patient-specific IMRT QA analysis were equivalent. Furthermore, they suggested that these systems could be applied interchangeably for routine patient specific QA. In another study, Hayashi *et al.* [11] investigated the dosimetric verification of IMAT treatment plans using a 2D diode array detector, polymer gel dosimeter and radiochromic film. They reported that the dose distribution measurements with 2D diode array and Gafchromic EBT2 films show very good agreement with other calculated distributions. However, gamma passing rates obtained by the BANG3 gel measurements were lower than those obtained using the other measurement devices.

In this research, the dose calculation accuracy of Eclipse™ TPS was quantified in a heterogeneous chest phantom with the IMRT technique using EBT3 film and Delta4. Furthermore, the gamma index values of the EBT3 film were compared with gamma index values of Delta4.

MATERIALS AND METHODS

Gafchromic™EBT3 film calibration, scanning and analysis

In this study, Gafchromic™ EBT3 film (ISP, Wayne, NJ, USA) of 8 × 10 inch was used. All measurements were conducted according to AAPM TG-55 reports [12].

Dose levels of 10, 20, 40, 80, 120, 160, 200, 240, and 300 cGy were used to plot the calibration curve. All films were scanned with the Microtek 9800XL scanner (Microtek Inc. Santa Fe Spring, CA) after 48-h of irradiation in order to stabilize the active layer color. The films were scanned with a 150-dpi (0.17mm) spatial resolution at the transmission scan mode in three colors (48 bit RGB) and images were stored in tagged image file format (TIFF). Image analysis was performed using ImageJ software (National Institutes of Health, Bethesda, Maryland) and the calibration curve was obtained based on the proposed method by Devic *et al.* [13].

ScandiDos Delta4 phantom detector array

The Delta4 phantom (ScandiDos, Uppsala, Sweden) consists of 1069 cylindrical diodes (1 mm diameter, 0.05 mm height, and 0.04 mm^3 volume) made of p-type silicon placed on two perpendicular arrays in a cylindrical polymethyl methacrylate (PMMA) phantom. Other features of Delta4 were reported previously [14, 15].

In this study, the Delta4 diode arrays were utilized to measure the 2D and 3D dose distributions and compared using gamma index to those calculated by Eclipse™ TPS.

Treatment planning and irradiation

Two different IMRT plans were designed for the heterogeneous chest phantom. The target tissue for the first plan (A) was between the left lung and the surrounding soft tissue and for the second plan (B), the target tissue was inside the soft tissue. For the treatment planning, a computed tomography (CT) scan was taken of the heterogeneous phantom and then was entered to Eclipse™ TPS version 13.0.20 (Varian Medical Systems, Palo Alto, CA) to produce treatment plans of A and B as well as make dose calculations at various points using Anisotropic Analytical Algorithm (AAA) with a grid size of 2.5 mm. The CT system (Siemens Somatom Emotion 16, Siemens, Germany) was 16-slice and slice thickness was chosen at 1 mm. For dose calculation, accuracy of Eclipse™ TPS, two IMRT plans with 7 fields were used and dynamic multi leaf collimator modulated to deliver 2Gy dose to the selected PTV in one session. The collimator angles were zero in all gantry angles.

The treatment plan was transferred to the TPS with the films placed inside the heterogeneous chest phantom for dose distribution measurement. Positioning the phantom was done based on the plan conditions and the phantom was exposed with 6 MV X-rays emitted from a Varian clinic 600 linac (Varian Medical Systems, Palo Alto, CA). All conditions including the maintenance and film scan procedure were followed according to the film calibration instructions. In the next step, the Delta4 phantom was irradiated based on the same treatment planning and dose distribution was obtained using diode arrays.

Statistical analysis

In the current study, a global gamma index with standard criterion (distance-to -agreement (DTA) = 3 mm and dose difference (DD) = 3%) was chosen to compare the measured (D_m) and calculated (D_c) dose distributions [16]. In addition, the 20% dose threshold was considered for all dose distribution points. The 95% point agreement between TPS calculations and measurements was considered as a passing value for QA of TPS. Also, the gamma indices with 2 mm/2%, 4 mm/4%, and 5 mm/5% criteria were obtained at a dose threshold of 5, 10, and 20% for further comparisons as well as evaluation of the film and Delta4.

The differences between the gamma index values obtained from the film measurements with TPS calculations (2D) as well as Delta4 measurements with TPS calculations (2D and 3D) were specified by using Bland-Altman analysis [17]. In this method, the x and y coordinates are the mean and difference the between gamma value and the two involved detectors, respectively. The horizontal lines are the mean value of this difference and the mean value ±1.96 standard deviation (that is, 95% level agreement).

RESULTS

EBT3 film calibration curve

The calibration curves of the film were obtained in three channels (RGB), as shown in figure 1 with corresponding colors. The formula of each curve was calculated in 10-300 cGy doses using Microsoft Excel software, based on the OD-dose curve and the method proposed by Devic *et al.* [13]. Goodness of the fit parameters implied an exact three-polynomial fitting in 10-300 cGy dose range for all three calibration curves. It was found that the red channel curve was more sensitive than the green and blue channels.

Dosimetric verification of Eclipse™ TPS

Figure 2 presents the isodose lines as well as dose normalized to the maximum dose, resulting from the film and Delta 4 in comparison with the TPS dose calculations.

Table 1 summarizes the passing rates of global gamma index of the EBT3 film (2D) and Delta4 (2D and 3D). The passing criteria were chosen as 2 mm/2%, 3mm/3%, 4 mm/4%, and 5 mm/5% as well as a dose threshold of 5, 10, and 20% for both A and B planes.

The points accepted by the gamma index for both the film and Delta4 were higher than 95% with 3mm/3% criteria and 20% dose threshold (standard criteria in this study) for both A and B plans. Table 1 shows that the mean passing rates of gamma index (for both plans) with standard passing criteria were equal to 96.95±0.22%, 97.70±0.56% and 98.45±0.21% for EBT3 film, 2D Delta4, and 3D Delta4, respectively. Additionally, the findings demonstrated that the mean passing rate of gamma value increased when higher DTA and DD criteria were used.

The mean passing rates of gamma index of the 3D Delta4 with standard criteria were 0.75 and 1.5% higher than the 2D Delta4 and film, respectively. Also, the mean passing rates of gamma index of the film (2D) and Delta4 (2D and 3D) in plan B with standard criteria was 0.24% higher than plan A (97.70% vs. 97.46%).

Comparison between the EBT3 film and Delta4 phantom gamma index

Findings showing the comparison between the passing rates of gamma index of the film and Delta4 are represented in figure 3. Parts of a and b are related to the comparison of film against 2D-Delta4 and film against 3D-Delta4 measurements for both plans, respectively. The results showed that the mean differences between the passing rate of gamma index of the film and 2D-Delta4, SD of bias, and 95% limits of agreement (mean value ±1.96 SD) were 1.24, 1.83 and -2.35-4.83%, respectively, while the values for film and 3D-Delta4 were equal to 3.65, 4.77, and -5.7-13.01%, respectively.

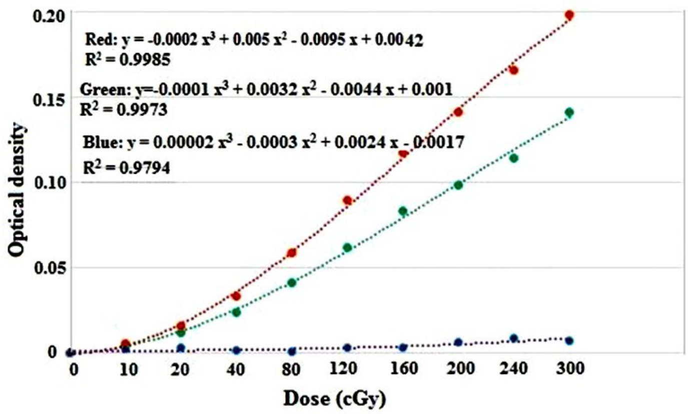

Figure 1. The film calibration curve, showing a greater sensitivity to the red channel.

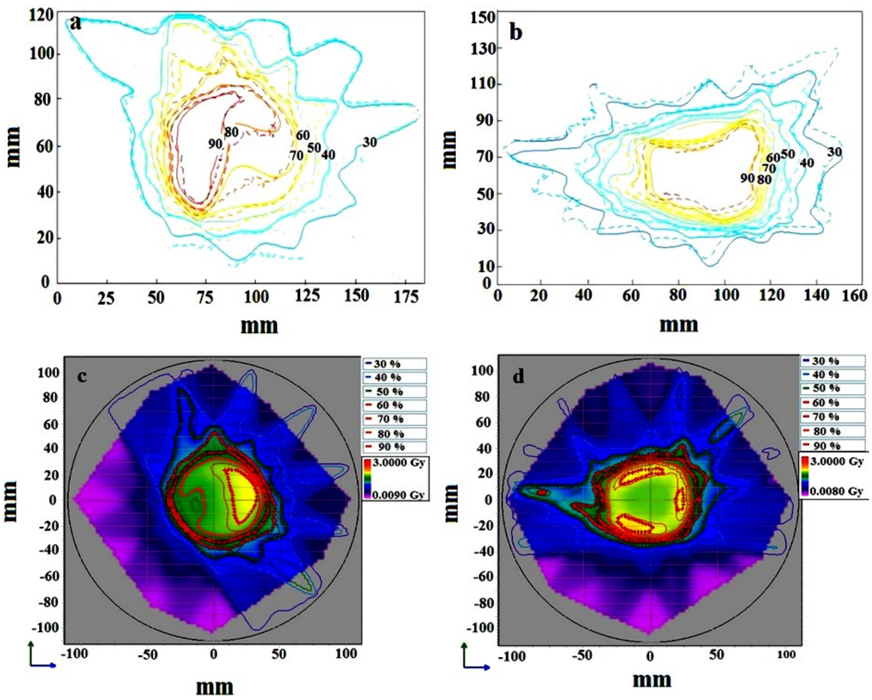

Figure 2. Comparisons of isodose distributions of measurements (dotted lines) and TPS calculations (solid lines) for plan A (a and c) and plan B (b and d) of IMRT using film (top) and Delta4 system (down). Plan A and plan B were designed between the left lung and the surrounding soft tissue and on the soft tissue, respectively.

Table 1. Comparison of passing rates of gamma index with different passing criteria for Plan A and plan B between TPS dose distribution calculation with film (2D) and Delta4 (2D and 3D) measurements in different criteria and dose thresholds. Plan A and Plan B were designed between the left lung and the surrounding soft tissue and on the soft tissue, respectively.

	Gamma Value for Plan A			Gamma Value for Plan B		
	Film & TPS	Delta4 & TPS (2D)	Delta4 & TPS (3D)	Film & TPS	Delta4 & TPS (2D)	Delta4 & TPS (3D)
Points with Γ ≤1 (%) 2 mm/2%- Threshold (5%)	75	81.5	82.7	79.1	84.8	87.5
Points with Γ ≤1 (%) 2 mm/2%- Threshold (10%)	74.1	79	79.7	80.3	82	85.9
Points with Γ ≤1 (%) 2 mm/2%- Threshold (20%)	89.5	77.3	78.3	81.9	80.5	84.8
Points with Γ ≤1 (%) 3 mm/3%- Threshold (5%)	86.7	97.9	98.6	94.9	98.2	98.8
Points with Γ ≤1 (%) 3 mm/3%- Threshold (10%)	86.1	97.5	98.4	96	97.9	98.7
Points with Γ ≤1 (%) 3 mm/3%- Threshold (20%)	96.8	97.3	98.3	97.1	97.6	98.6
Points with Γ ≤1 (%) 4 mm/4%- Threshold (5%)	91.9	100	100	98	100	100
Points with Γ ≤1 (%) 4 mm/4%- Threshold (10%)	91.4	100	100	98.6	100	100
Points with Γ ≤1 (%) 4mm/4%- Threshold (20%)	98.3	100	100	99.4	100	100
Points with Γ ≤1 (%) 5mm/5%- Threshold (5%)	95.3	100	100	99.1	100	100
Points with Γ ≤1 (%) 5mm/5%- Threshold (10%)	95	100	100	99.4	100	100
Points with Γ ≤1 (%) 5mm/5%- Threshold (20%)	98.9	100	100	99.8	100	100

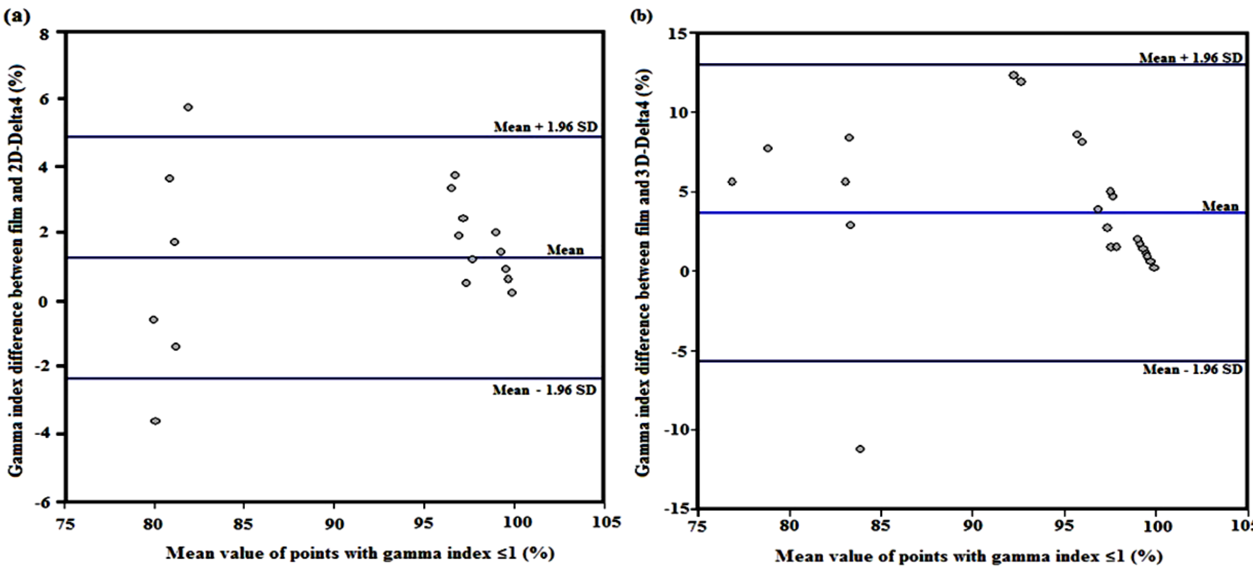

Figure 3. Bland–Altman agreement plots for film against 2D-Delta4 measurements **(a)** and film against 3D-Delta4 measurements **(b)**. The upper and lower lines represent the 95% standard deviation and the middle lines show the mean value.

DISCUSSION

As indicated in table 1, the accuracy of dose calculations of Eclipse™ TPS in a heterogeneous chest phantom with the IMRT technique is within standard passing criterion (3%/3mm). The findings show that the TPS has a good agreement with these two systems. The mean passing rates of gamma index between the film and Delta4 with TPS were not 100% equal. The decreased passing rate of gamma index between the film and TPS may be due to the lack of insufficient precision of the treatment setup and calibration curve. The inaccurate registration of the TPS plan and uncertainty of the scanner reproducibility could be considered as other factors. Also, the decreased passing rate of gamma index between Delta4 and TPS may have resulted from the different computational algorithms in the TPS and Delta4 phantom; as Eclipse™ TPS and Delta 4 phantom employ AAA and Pencil Beam algorithm, respectively. Another reason may be that the diode grid resolution was very low to accurately obtain the energy fluence applied to dose calculations [18]. In a study by Kan *et al.* [19], the accuracy of doses calculated by AAA and Acuros XB algorithm was evaluated by EBT3 film within and adjacent to heterogeneous medium using IMRT plan for nasopharygeal carcinoma. Their findings showed that both algorithms exhibited acceptable accuracy in comparison with the measured data. In another study, Sini *et al.* [20] investigated the dosimetric accuracy of AAA, pencil beam Algorithm, and collapsed cone convolution superposition Algorithm in thoracic tumors for different IMRT techniques. Their results generally demonstrated a satisfactory agreement (<2%) between calculated and measured doses for AAA and collapsed cone convolution superposition Algorithm.

With regard to the results presented in table 1, the mean passing rates of gamma index varied with changing DTA and DD criteria. For example, the obtained passing rate of gamma index with 2mm/2% criteria were less than 95% for both plans, due to a higher accuracy of the measurements and increased computational error record. Chandraraj *et al.* [10] reported similar results for four commercial systems. They showed when stricter gamma index criteria were applied, some of the treatment plans failed to pass the tolerance.

Table 1 indicates that the passing rates of gamma index between TPS and Delta4 are better in 3D distribution than in 2D. The reason for this could be that in the 3D situation, more comparison points contribute to the agreement, therefore it would have a higher passing rate. Raiasekaran *et al.* [21], reported the same results but using Octavius phantom. Based on their findings, 3D planar gamma analysis showed better results than the 2D one because of applying extra search dimension for evaluating the gamma, which leads to passing the pixel in the planar dose distribution using the 3D gamma analysis.

The differences between passing rates of gamma index of the film (2D) and Delta4 (2D and 3D) were less than 5% and this discrepancy was higher for the 3D-Delta4 gamma index with the film compared to the 2D-Delta4 gamma index with the film. Based on the Bland-Altman analysis, three points lay outside the two surrounding lines (±1.96 SD). These points were associated with the passing criterion of gamma index of 2mm/2% which could be due to the highest difference between film and Delta4 gamma index in this criterion. Banci *et al.* [22] provided a comparison between the MapCHECK™ diode array and the film. They reported that the differences in all of the outer points depend on the particular spatial distribution of the dose.

CONCLUSION

The results of this study indicate that the accuracy of dose calculations of Eclipse™ TPS in a heterogeneous chest phantom with the IMRT technique is satisfactory. In other words, the passing rate of gamma index of the film and Delta4 phantom with a standard passing criterion (3mm/3%) and a dose threshold of 20% was higher than 95%. Furthermore, the differences between the passing rates of the gamma index of the film and Delta4 were less than 5% and it can be concluded that there is a good agreement between the film and Delta4, as IMRT QA devices.

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Conflicts of interest: *Declared none.*

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