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Original Research Article

Characteristic of Gafchromic Film for Small Photon Field

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Abstract: Small photon field used in the intensity modulated radiotherapy (IMRT) and stereotactic radio surgery (SRS). It is difficult to measure beam profile and output factor because of electron disequilibrium, partial shutting of source because of this challenges, we need the good detector. This article is collection of 5 or more article and summary of the results of EBT3 that compared with EBT2 film and also they were compared with conventional dosimeter, ionization chamber and also examine the diametric accuracy of Gafchromic EBT3 for use in quality assurance. The results of these articles showed that the EBT3 films were excellent uniformity and similar darkening time amelioration as EBT2 films that a high uncertainty in readout of the film response was observed for samples irradiated with doses lower than 1 Gy. The side orientation sensitivity of former EBT2 films has been completely removed for EBT3 films because of the balance of configuration, though scanning orientation still has to be retained. It is possible to suggest the use of EBT3 film in conventional quality assurance testing for radiotherapy.
Keywords: small field, film dosimetry, EBT2, EBT3, quality assurance

INTRODUCTION

There are many techniques for delivering radiation therapy and intensity modulated of radiotherapy (IMRT) is one of them. Small photon field used in the IMRT and stereotactic radiosurgery (SRS).it is difficult to measure beam profile and output factor because of electron disequliberum, partial blocking of source. Because of these challenges, we need the good detector.

Today the tools for dosimetry and treatment are improved. Verification of treatment can be fulfilled by some of dosimeters tools. The dosimeters had some advantage and disadvantage. for example, ionization chambers, they have too large for measurement of small field ,TLD (thermo luminescent dosimeters), diodes although they have very small active but they have energy dependence and also dose rate and temperature dependence and also film EDR2 are limited for low energy dependency and dimensiolly[1].but this problem solved and replaced it by the EBT and Gafchromic film EBT2.they have high resolution, water equivalent, decreased post exposure[2] and after replaced by EBT3 that energy independent and for positioning at the scan time.

The aim of this study to investigate the capability of Gafchromic film for dosimetry of small field.in this paper we described the different type of Gafchromic film and their advantages and compared them with pinpoint and use of those in small photon field.

METHOD& MATERIAL

We searched in PubMed web site, Google scholar, searching some key words such as film dosimetry and Gafchromic film after read them and decided to collection them and written the Review article for those interested to know Dosimetry.

Body

Radio chromic film

EBT or external beam therapy Gafchromic film is a good detector for using in small radiation fields due to low energy dependence and high spatial resolution. Since introduction of them in 2004, Gafchromic's EBT radio chromic film (International Specialty Products, Wayne, USA) has been adopted for use in quality assurance testing of clinical radiation therapy such as 3D conformal, intensity modulated

(IMRT) and stereotactic treatments (SRS). EBT has found to be capable of producing reliable and reproducible dose measurements, with a high degree of spatial accuracy [1] but EBT has required the adherence to specific handling, irradiating and scanning procedure [1]. In February 2009 production of Gafchromic film EBT have stopped and replaced it by Gafchromic EBT2 film.at 2010, by Andres *et al.;* and by Lindsay *et al.;* this reported that the film EBT2 have decreased post exposure, development time, sensitivity to UV light [3]. EBT2 films were scanned in the 48-bit it have 3 channels such as red-green-blue (RGB) ode (16bitspercolor) and resolution 75dpi. The red channel has a greater response up to 10 Gy [3, 4] at 2006 Cheung T *et al.;* have been reported it and also at 2008 by Martisikova M that EBT film has been shown to display good uniformity of response, minimum dependent on energy, a dose response that is constant with depth and field size and is weakly dependent on dose rate. The major advantage of film dosimetry is the excellent spatial resolution (they limited by scanning resolution that comes with the use of a continuous medium) [5, 6]. At 2007 by Fuss M *et al.;* and also at 2008 by Battum LJ have reported that EBT2 film has been shown to display minimal dependent on energy.it has been reported by Richley *et al.;* at 2010 have been reported that EBT2 film has minimal intra and inter sheet non-uniformity(at 200 cGy ,2.4%dose uncertainty), is not effected by repeated scanning, suffers similar post irradiation development to that of EBT film, and is not affected if handled correctly by development from natural light [6-8]. The Gafchromic EBT2 film can be used with an acceptable degree of uncertainty [9, 10]). That has been reported at 2011 by Aland T *et al.;* that compared with EBT film; EBT2 film has a structure nonsymmetrical and only it has one active layer this active layer uses a yellow-dyed synthetic polymer as a binding agent.

Also Aland T *et al.;* calculation and reported The dose values measured in pieces of film placed at different depth in solid water and irradiated to 200 cGy using fields of different sizes have shown in Fig. 1a and b. the Results of Aland T *et al.;* in both figure suggested that the dose measured using the 20 * 20 cm2 field is consistently lower (by up to 1%) than the dose measured using the 10 9 10 cm2 field [1]. however, the results of Aland *et al.;* at 2011 shown in Fig.1b suggested that there was no relation with trend of increasing measured dose with decreasing field size. The standard deviations from the mean measured dose, across the different depths at 200 cGy, for the 10 * 10 and 20 * 20 cm2 fields were found to be 0.3 and 0.5%, respectively [2].

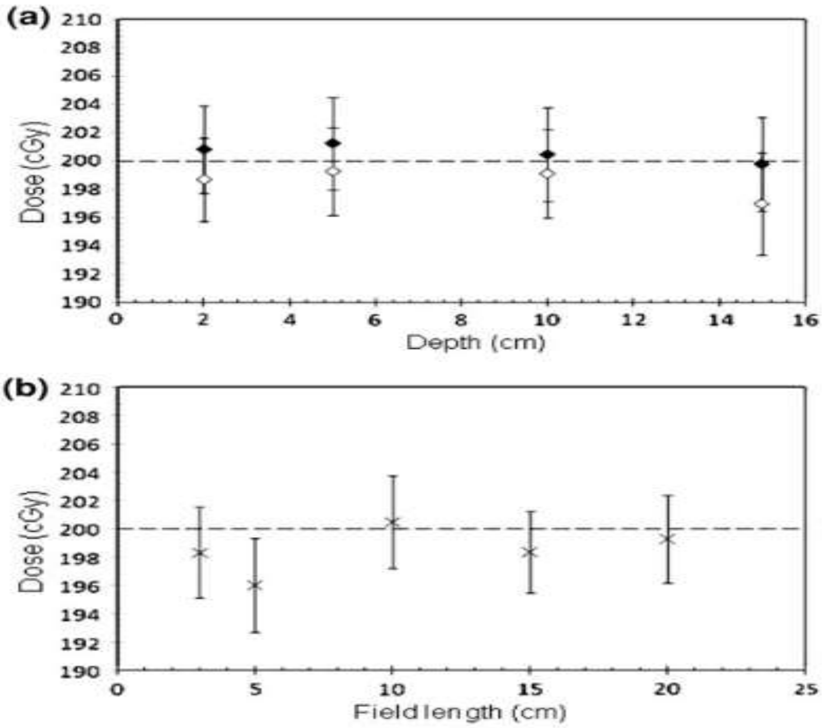

Fig. 1 a Dose measured in film at various depths irradiated to200 cGy using 10* 10 cm2 fields (filled data points) and 20* 20 cm2 fields (open data points). B Dose measured in film a 5cm depth irradiated to 200 cGy using square fields of various sizes [1]

EBT film, the predecessor of EBT2 film, has been shown to produce best results when stored at or below room temperature in light-tight packaging, [1] touched just at the edges and scanned at least 1 day or

24 hours after irradiation and for the sensitivity of measured dose to properties of the film scanner is correct, it has been suggested that EBT films be scanned in the center of the scanner, with a consistent orientation, and with a minimal number of consecutive scans [1]. The Scanner should be monitored and verified. The piece of EBT2 film was cut into 5*5cm2 and the film orientation was recorded by marking each piece of film. All of the pieces were scanned separately, in the Centre of the scan bed and with the same orientation on the scanner [11]. Each piece of film was scanned at least twice, once before and once after irradiation [1]. Aland *et al.;* used the Epson V700 scanner.

Development of the film (post irradiation)

The results of Krzysztof Ch *et al.;* at 2010 that reported for the post irradiation development of the film at doses of 100, 200, and 300 cGy was shown in Fig. 2 for development times, the vary range from 15 mins to 46 h after irradiation. The results of Krzysztof Ch *et al.;* clearly showed a primery increase in dose within the first 5 h after exposure, followed by a leveling out of the dose after that period. During the primery period, the increase in dose was found to range from 8% for 300 cGy to 12% for 100 cGy. After the 5 hours' period however, the dose still shown a trend to increase with time [7]. If films were scanned 2 hours then the dose uncertainty will be within ±0.5%.as a worst case scenario, if the calibration films are scanned 24 h after irradiation and the clinical films are scanned only 2 h after irradiation, then there will be a 4.0% uncertainty in dose [7].

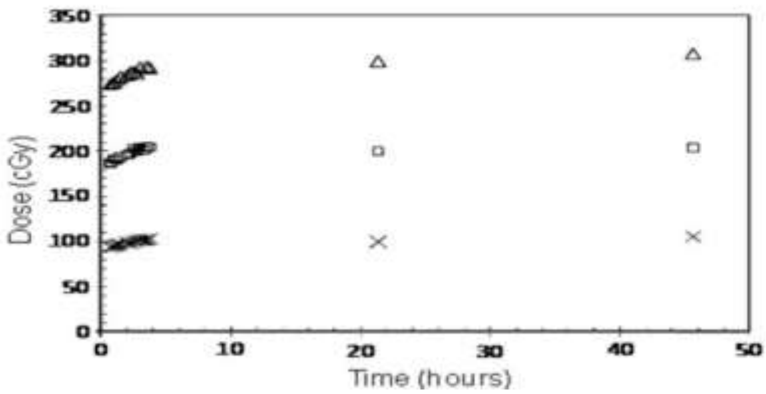

Fig 2: Post irradiation film development periods for film irradiated to [3] 100, 200, and 300 cGy as indicated by crosses, squares, and triangles, respectively

RESULTS

Results of Krzysztof Ch *et al.;*

The Results of Krzysztof Ch *et al.;* recommended that, an uncertainty in the measured dose equating to 2.8% was acceptable, EBT2 film can be used in conventional radiation therapy quality assurance testing. Their results were just applicable when the scanner was being operated in transmission mode. The blue-channel correction method of pixel-to-dose on version was recommended for EBT2film as a means to ‘‘compensate for small non-uniformities in the film’’ by deleting the Measured dependent dose on active layer thickness.

Independence on energy of EBT2

At 2010, Krzysztof Ch *et al.;* reported that The high uncertainty in readout of PV for doses below 1 Gy seen in Figs. 3 and 4 is because of the low signal to noise ratio of the scanner for materials with low optical densities. The imperfect contact between the film surface and the scanner glass may affect the readout on the result soft Krzysztof Ch *et al.;* [7]. The mentioned effects were less pronounced for films irradiated with higher doses [1].

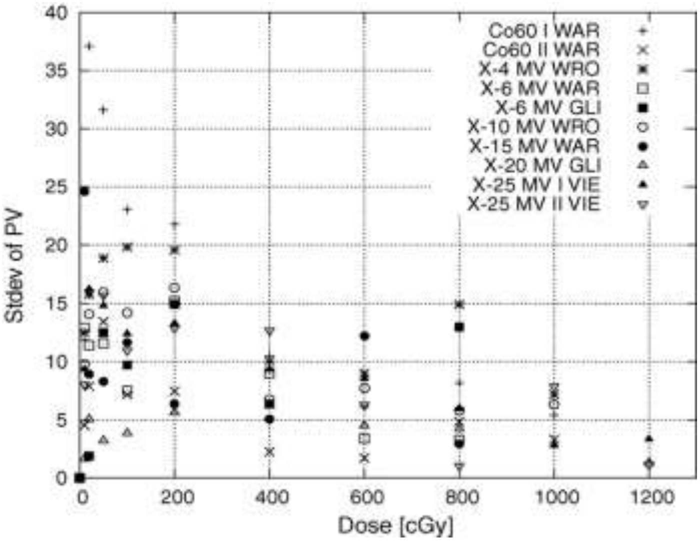

Fig. 3: Standard deviation of measured PV against the delivered dose for different energy beams. The scans were made with an EPSON V750 scanner [7].

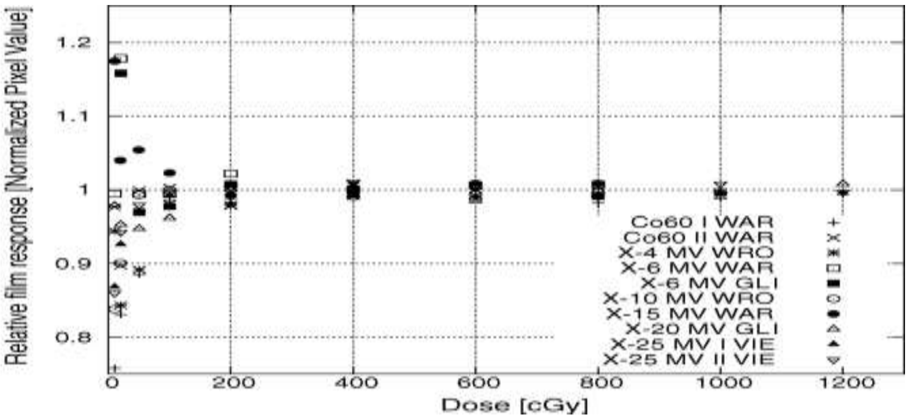

Fig 4: The relative response of the film samples. The normalized PV for each dose was obtained by dividing the film response by the mean PV for all beam energies [7].

Comparison of EBT and EBT2 and EBT3

At 2012, Thomas A. D. Brown, *et al.;* examined the film Gafchromic and they used the Epson 1680 Professional flatbed scanner and they analyzed the film by the net optical density (NOD) derived from the red channel 12 and Thomas A. D. Brown *et al.;* used the equation1 for calibration for every beam energy that the figure6-8 shown the results of them (Brown *et al.;*). equ1

$$NOD = -\ln\left(\frac{a + b.D}{a + b}\right)$$

They have achieved this results: The sensitivity (NOD per unit dose) of EBT film at 35 Kev relative to that for 4-MV x-rays was 0.73 and 0.76 for doses 50 and 100 cGy and also at25, 30, 35 Kev, the sensitivity of EBT2 film relative to that for 4-MV x-rays varied from 1.09 – 1.07, 1.23 – 1.17, and 1.27 – 1.19 for doses 50 – 200 cGy [12]. Also Brown et al achieved the relative sensitivity for EBT3 film that equal 3% of unity for all three monochromatic x-ray beams [12].

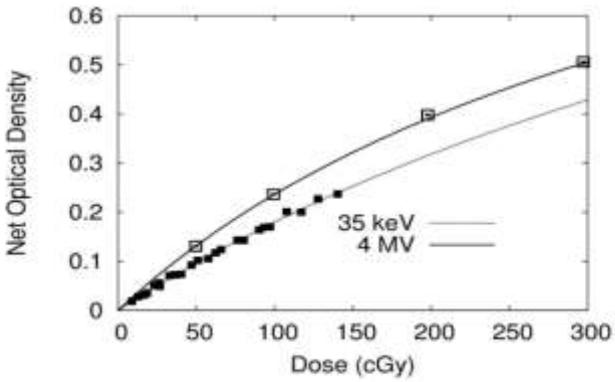

Fig 5: Net optical density versus dose for EBT film. The film was calibrated at 35 keV (filled squares) and 4 MV (hollow squares). Both sets of data were fitted with the function shown in Eq. (2) [12].

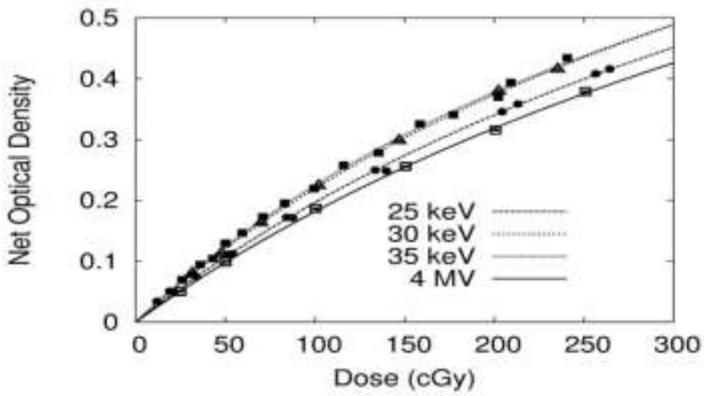

Fig 6: Net optical density versus dose for EBT2 film. The film was calibrated at 25 keV (circles), 30 keV (triangles), 35 keV (filled squares) and 4 MV (hollow squares). Each set of data were fitted with the function shown in Eq. (2). [12]

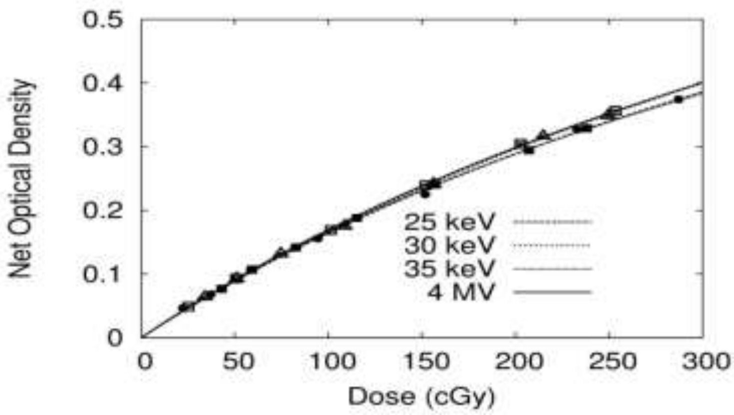

Fig 7: Net optical density versus dose for EBT3 film. The film was calibrated at 25 keV (circles), 30keV (triangles), 35 keV (filled squares) and 4 MV (hollow squares). Each set of data were fitted with the function shown in Eq. (2). [12]

Brown *et al.;* reported that the EBT and EBT2 film sensitivity showed strong dependent on energy at range of 25 keV- 4 MV, and for EBT2 have showed dependence from 25 – 35 keV and also they said the energy dependence of both films becomes weaker for higher doses [12]. The sensitivity of EBT3 showed a weak dependent on energy at range of 25 keV – 4 MV. Brown *et al.;* suggested that EBT3 film because this film was a better dosimeter for kV x-ray beams due to hard beam effects can result in large changes in the effective energy, although researchers should always check out the response of energy characteristics of their type of film [12].

Measurement of PDD and BP

Percentage depth dose for film EBT2

At 2013, Allahverdi M *et al.;* measured percentage depth doses for the 5, 10, 20 and 30 mm collimator at depths different at SSD=100, the measurement was less than 1% for pinpoint and EBT2[2]. The differences between EBT2 film measurements and MC calculation were less than 3% [2]. These differences were less than 2% for field sizes 20 mm and 30mm [13].

Beam profile

At 2013, Alaverdi M *et al.;* measured and reported also the Figure 8 that showed ratio of Pinpoint measurements and MC calculations over EBT2 film measurements versus distance for BP and for various field sizes [2]. The measurements with Pinpoint ionization chamber have showed the biggest penumbra for all cones. The reasons were the effect of volume averaging and it was big sensitive region of Pinpoint and over-response to low-energy Compton scatter due to interaction of photoelectric in the steel central electrode [2]. Allah Verdi *et al.;* recommended that the volume effecting is important in beam penumbra. The MC calculated results have seemed to be bigger than real penumbra due to big voxel dimension size (0.5 mm) [2] but these results for EBT2 were close to real penumbra due to their high resolution [5].

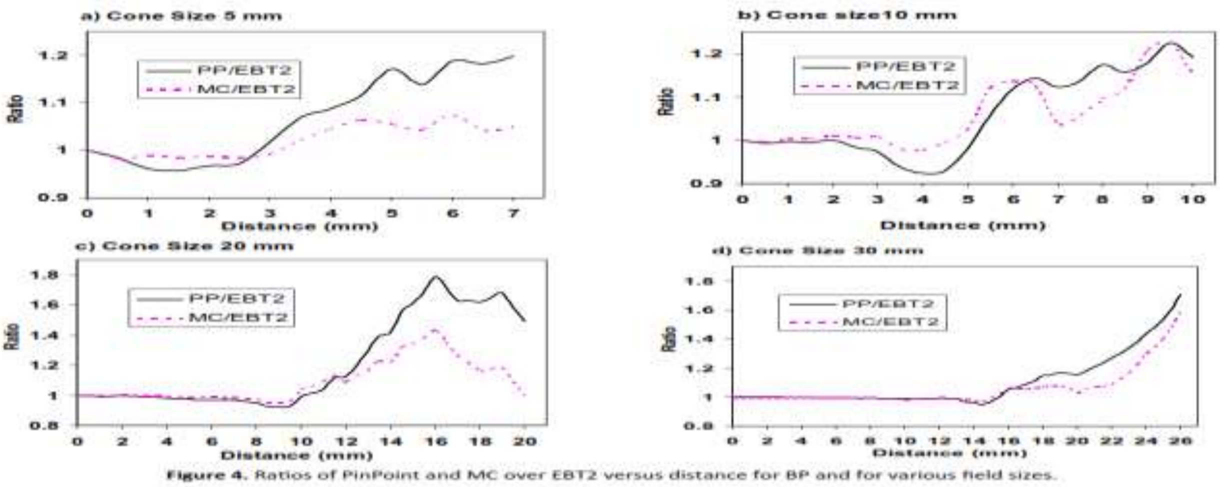

Fig 8: ratio of pinpoint and MC over EBT2 versus distance for BP and for various field sizes Output factor in EBT2 and compared with pinpoint chamber

Also Alaverdi *et al.;* measured and presented the measured output factors of Pinpoint, EBT2 and also calculated Monte Carlo for various circular cone sizes, Although ionization chambers were the reference dosimeter in routine radiotherapy but they need some correction for radiosurgery according the results of Alaverdi *et al.;* [2].They suggested that the reason was the plateau region of the dose profile that was small or did not exist in small fields and the sensitive volume of ion chamber was very widest than the plateau region. Corrected and uncorrected output factors measured by Pinpoint for various circular cone sizes and 10 ×10 cm2 square field were compared with EBT2 results and MC calculation Monte Carlo [14,15].

Compared of EBT2 and EBT3

Also at 2012, S. Reinhardt *et al.;* used the film EBT2 and EBT3 and compared with them and the film have verified in proton beams and compared to conventional EBT2 films. The film EBT3 has been compared with film EBT2.

Their result showed in Fig 9, where dose D is plotted against net OD. The uncertainty in net OD corresponds to the standard deviation of the mean net OD value in the analyzed ROI, which has been found to be on average 3.5% for all dose response curves. Response curves have been fit according Ref.16 to by the following equation2:

$$D=A_0 .\ net\ OD+ A_1 .\ net\ OD^{A2} \qquad \text{Equation2}$$

Uncertainty of dose related to appropriate parameters are 3% for the used calibration appropriate, although fit uncertainties of up to 6% have been perceived for calibration of EBT2 film with protons. These elevated appropriate uncertainties are determinate to fewer modeling points of the calibration curves. Also an overall accuracy in dose determination better than 4% could be achieved for all films and radiation types except for the proton calibration of EBT2 films because of the smaller modeling rate in this specific experiment [12].

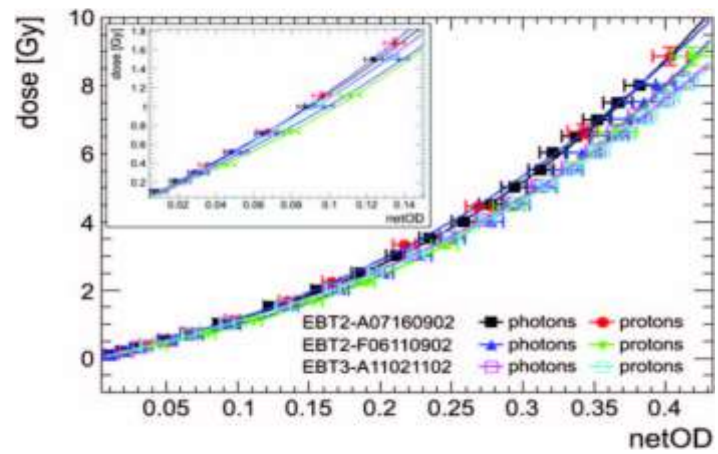

Fig 9: NetOD response to clinical proton and photon beams for different batches of EBT2 and EBT3 films. Response deviations from batch-to-batch exceed deviations related to different radiation types. Lines correspond to fits. The inset shows zoomed image for dose range 0–2Gy [12].

Proton depth dose measurements

Reinhardt.S *et al.;* measured the Depth dose curves by EBT2 and EBT3 films have shown in Fig.10&11 together with the depth dose curve provided by the clinical treatment planning system used as reference.

Reinhardt.S *et al.;* reported that There was a great agreement of EBT2 and EBT3 depth dose curves beyond the whole proton range. Reference and film curves comply with each other in the plateau region, while both films demonstrated a depreciation of dose in the Bragg peak, as already reported for the elder EBT films [16-18]. Reinhardt's *et al.;* could be seen better by plotting the relative deviation _D film-TPS of film measurement (DFilm) and reference curve (D) against remnant proton energy. (Fig. 4 is the results of Reinhardt. S *et al.;*)

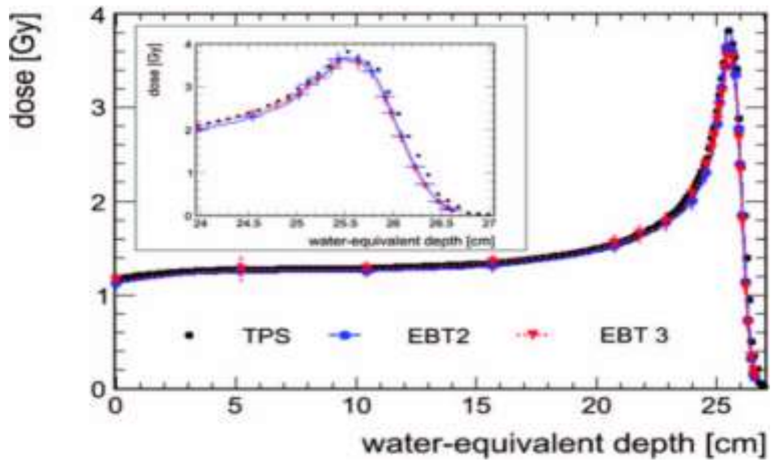

Fig 10: Comparison of proton depth dose measurements (initial energy= 200 MeV) using EBT2 and EBT3 films with reference data of the planning system (TPS). Lines are applied as guide to the eye. There is no significant difference between EBT2 and EBT3 films, both showing an average under response of up to 5% for energies below 40 MeV and up to 20% in the vicinity of the Bragg peak, corresponding to the lowest residual energy of 4 MeV [12].

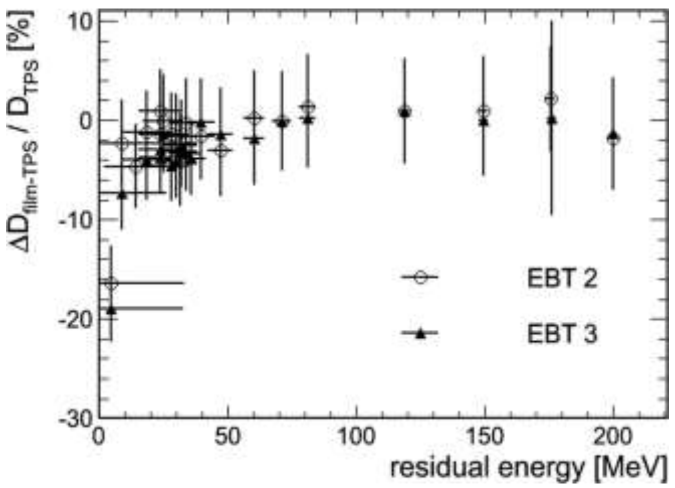

Fig 11: Relative deviation of film dose and reference dose are within measurement uncertainties for all residual energies exceeding 20 MeV. LET dependence becomes visible for residual proton energies below 15 MeV [12].

EBT3 compared of EBT3 film with Markus ion chamber

Also at 2013, Simian Gill and Robin Hill study about the film EBT3, they have evaluated the ability of this film for evaluated of output factor. This factor has been evaluated by EBT3 film at 50, 75,100,125 kVp and. The film read out was executed with a flatbed EPSON Expression 10000XL scanner [9]. The evaluation of data was compared with benchmark data by using the type of ion chamber called Markus ionization chamber. The output factors evaluated using EBT3 film, the Advanced Markus ionization chamber and those assessed by the AAPM TG-61 [9]. The consent in the relative output factors evaluated with the Gafchromic EBT3 film and the Advanced Markus ionization chamber was found to be within 2 % and with a maximal local difference of 3.3 % perceived for the smallest applicator size. These differences could be related to the detector resolution, slight increases in uncertainty for the smaller radiation field sizes and the inherent uncertainty with the EBT3 film dosimetry, but these differences were found to be consistent with the estimated total uncertainty in the revolted as calculated by the ISO GUM besides for the smallest applicator size [9].

SUMMARY AND CONCLUSION

Overall this paper is summary of some article and about the EBT3 films that they were excellent uniformity and similar dark-ending time improvement as EBT2 films. The side orientation sensitivity of previous EBT2 films has been completely eliminated for EBT3 films because of the balance of configuration, though scanning orientation still has to be retained. We can have used this film for quality assurance, also in this paper, the administration and characteristics of the newly released EBT2 Gafchromic film were considered in conjunction with an Epson Perfection V700 Photo flatbed scanner used in transmission mode. This film was also demonstrated to be water equivalent within the measurement uncertainty of the film. The examination of Gafchromic EBT films does not show dependent on energy for the evaluation of beam energy range and for the achieved 5% accuracy of the measuring procedure. Based on the results of this paper and older article that were achieved, it is possible to suggest the use of EBT2 Gafchromic film in conjunction with an Epson Perfection V700 flatbed scanner in transmission mode using only the red channel data for routine quality assurance testing for radiotherapy, but the EBT3 is better than EBT2. And we could have suggested the use of EBT3film for radiotherapy. Ionization chambers used calibration and beam measurements in conventional radiotherapy

Dimensions such as but due to the absence of lateral electron equilibrium, steep dose gradients and the lack of plateau region in beam profile [3].They need some factor for correction and check out of this chamber, therefore that has recommended the EBT2 that suitable dosimeter chiefly for small field for measure some factor such as penumbra and OF(output factor) But used the which type of film that they have some advantages and disadvantages and Selecting the suitable measurement method is a key part of excellent Dosimetry[19].

CONFLICT OF INTEREST

The author declares no conflict of interest

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