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Comparison between radiochromic film and Sun nuclear edge diode detector during the commissioning of small field size radiosurgery cones

Fontana T.S.[b*], Bueno, K.P.[a,b], Albino, L.D.[a,b], Roesler, E.H.[a], Santos, M.F.[a,b,] Asfora, V.K [b], Khoury, H.J.[b]

[a] Real Instituto de Radioterapia, Real Hospital Português (RHP), 52010-075, Recife, PE, Brazil
[b] Departamento de Energia Nuclear, Universidade Federal de Pernambuco, 50740-540 Recife, PE, Brazil

*Corresponding author: MSc. Thiago S. Fontana. Email: Thiagoschmeling@gmail.com

ABSTRACT

Stereotactic Radiosurgery (SRS) is a procedure that uses ionizing radiation in a single fraction or few fractions to treat intracranial lesions. Usually, for these treatments, small photon fields, formed by circular collimators or micro multileaf collimators are used. The objective of the present work is to compare the measurements of the dose in depth (PDD), the off-axis ratio (OAR), and the output factor (OF) using Edge diode and radiochromic films and analyzing the agreement between the two detectors during these measurements. In the gamma index analysis of the profiles, the minimum percentage reached was 98.3% of the points in the criterion 1% and 0.5 mm. The maximum percentage difference in the output factor was 2.79% for a cone 4 mm and 10FFF. In the gamma index analysis of the PDDs, the minimum percentage reached was 97% of the points in the criterion 1% and 1mm. The results show a good agreement between the edge detector and the film in small field measurements for radiosurgery.

Keywords: **Radiosurgery, commissioning, circular collimators, radiochromic film, diode**

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1. INTRODUCTION

Stereotactic Radiosurgery (SRS) is a procedure that uses ionizing radiation in a single fraction or few fractions to treat intracranial lesions. Usually, for these treatments small photon fields, formed by circular collimators or multileaf collimators, are used [1]. Micro Multi-leaf collimators have thicknesses less than 3 mm and have the advantage over the stereotactic cone of shaping the tumor more precisely [2]. On the other hand, the stereotactic cone allows a greater dose reduction (falloff) at the edges of the radiation field compared to the MLC, in addition to a smaller penumbra, which makes them advantageous in some circumstances [3]. The radiation fields used in these treatments are extremely small, with a diameter varying between 4 mm and 17.5 mm. So, detectors with good resolution and low directional and energy dependence are required. The experimental dosimetry of the small radiation fields remains one of the most challenging tasks to perform due to the steep dose gradients and loss of lateral electronic equilibrium. The ideal dosimeter needs to have small sensitive volume to minimize volume-averaging effects, to be water-equivalent at MV energies, and with negligible energy and instantaneous dose rate dependence [4]. The radiochromic films (RC) are used because they are near present tissue equivalence, have weak energy and dose-rate response dependence, and offer a 2D high spatial resolution [5]. Recently, an edge detector was developed to be used for dosimetry of small fields. It is a semiconductor designed for measurements in high gradient regions. Therefore, the objective of the present work is to use Edge diode and radiochromic films to compare the measurements of the dose in depth (PDD), the off-axis ratio (OAR) and the output factor (OF) and analyzing the agreement between the two detectors during these measurements.

2. MATERIALS AND METHODS

This study was performed using the Edge diode detector manufactured by Sun Nuclear Corporation. It is an *n*-type silicon diode detector with an active detection area and sensitivity of 0.8 mm^2 and 32 nC/Gy, respectively. The diode is encapsulated in a brass material with a wall thickness of 0.13mm and located 0.3mm from the top, 4.3 mm from the bottom, and 2.7 mm from the side, with the cross marked on the top surface. The top surface thickness is water equivalent depth to 0.5mm. A zero-voltage bias was applied to the electrometer.

The radiochromic film used in this study is the EBT3 from Ashland Company. It has a dynamic dose range from 0.1 to 20Gy and density close to human tissue (Zeff = 6.84). It has a double layer of protection that eliminates the dependence on the orientation of the film compared to the EBT2 model and has an excellent spatial resolution.

All measures taken in this work were performed on TrueBeam STX linear accelerator at the energies of 6FFF and 10FFF for seven cone sizes (4; 5; 7.5; 10; 12.5; 15 and 17.5 mm), shown in Figure 1a. The data collected with the film was carried out in a solid water plate (Figure 1b). The measurements using the edge detector were performed with an automatic water scanning phantom (Blue phantom, Scanditronix-Wellhofer, IBA, Germany) with a scanning volume of 48×48×41 cm^3, shown in Figure 1c.

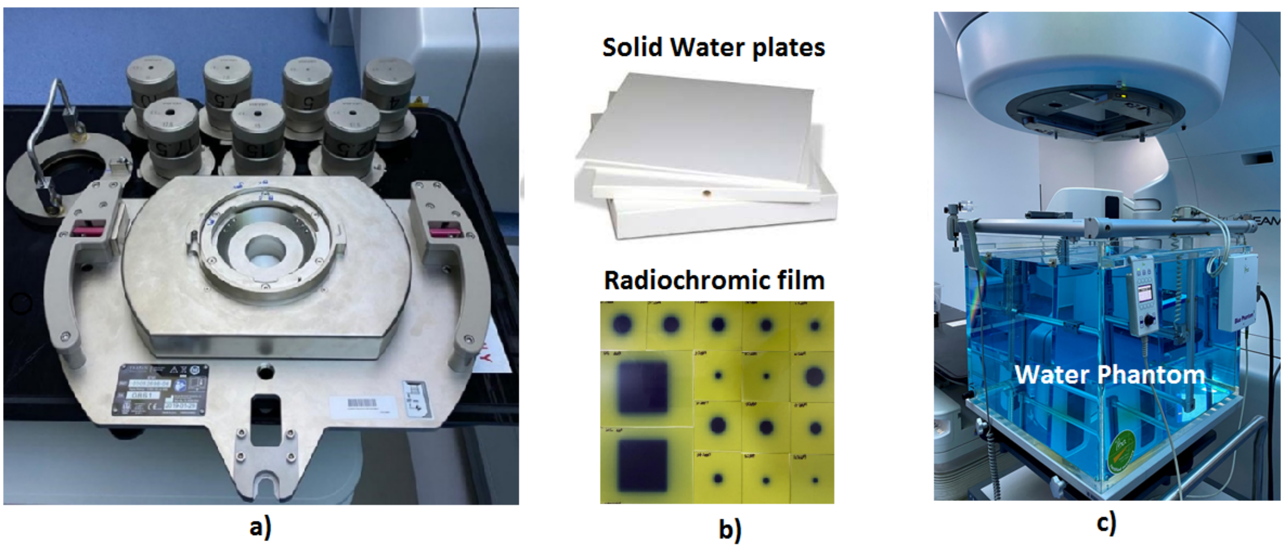

Figure 1: *a) The indexing tray and the cones that were used; b) solid water and irradiated radiochromic film and c) 3D automated phantom.*

2.1- Percentage Depth Dose (PDD)

The percentage depth dose was measured using the Edge detector positioned with its axis parallel to the central radius of the radiation field and varying its vertical position in steps of 0.5 mm. Measurements were made keeping the source surface distance (SSD) at 100cm and moving the detector from the deepest position (30 cm) to the surface. The measurements were performed with the seven cone sizes, and with the gantry angle of 0°. The results obtained were compared with the manufacturer's Golden data (TPS).

2.2- Off-Axis Ratio (OAR)

The profiles were measured in three distances (80, 90, and 100 cm) keeping the depth fixed at 5 cm, under the same scanning conditions as the PDD. The same distances and depths were maintained when irradiating the film in solid water.

2.3- Output Factor (OF)

Output factors were measured with the detector positioned at 5cm depth and at the source surface distance (SSD) of 95 cm. The output factor was obtained by the ratio of the detector response of a generic cone size divided by the reference field that was 10cm x 10xcm.

Correction factors tabulated in the IAEA TRS-483 were used to correct the ratio of readings measured at the reference depth: depth of maximum dose measured at 5 cm depth. Indeed, as explained in the IAEA TRS 483, correction factors can be considered valid at 5 cm depth for detectors not showing a substantial field size dependence [6].

The measurements with the film were carried out on a sheet of film cut into segments of 2 x 2 cm. The film segment was irradiated separately and 16 hours after the irradiation [7] the films are arranged in the same way before being cut and scanned on the Epson 11000XL Scanner and analysed on the Omnipro Accept IMRT.

3. RESULTS AND DISCUSSION

3.1- Percentage Depth Dose (PDD)

Figure 2 shows the results obtained for the PDD measured with the Edge detector compared to the manufacturer's reference data.

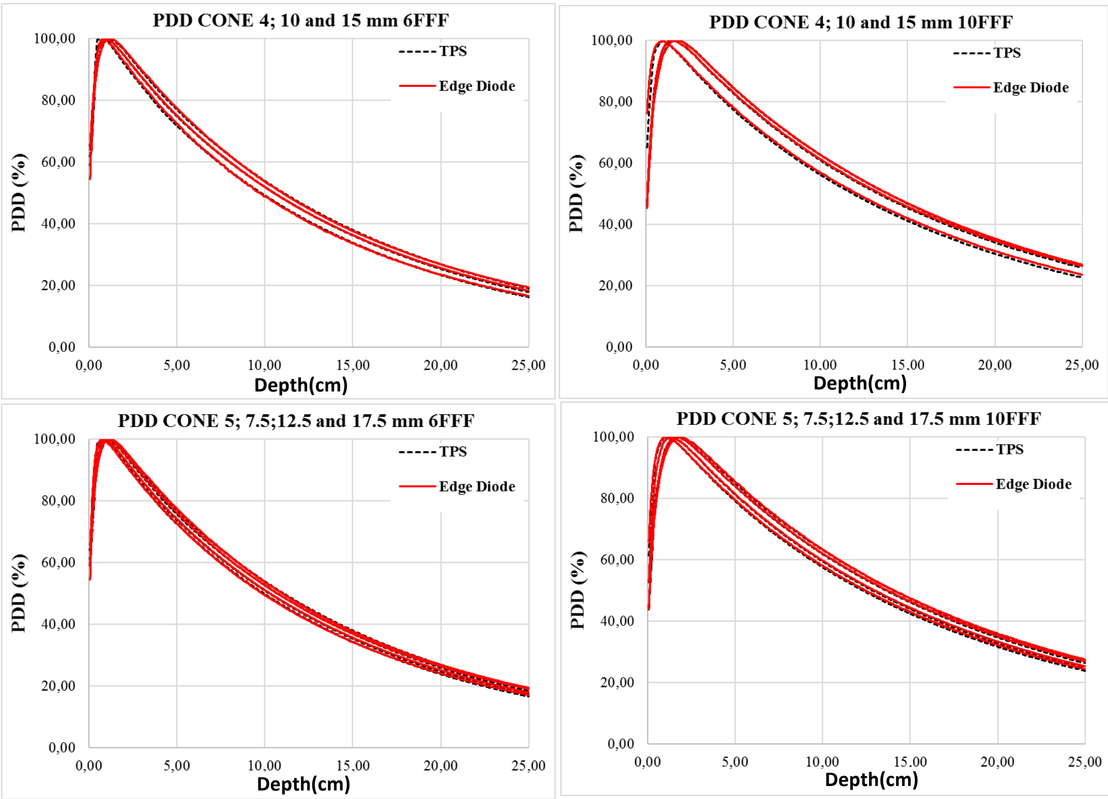

Figure 2: *PDD measures for all cone sizes and energies in comparison to the reference data (TPS).*

The metric used to evaluate the agreement of the PDD and OAR with the manufacturer's reference data was the Gamma analysis, a method already used in the clinical practice of the services that offer intensity-modulated radiotherapy (IMRT) treatment to guarantee the quality of the treatments offered in addition to bringing safety. to the patient and staff. Such metric generally uses two evaluation criteria, the dose percentage, and the distance variation. Points that meet the dose and distance criteria established by the user are called approved points. The reference value used in the institution is that more than 95% of the points must be approved using a criterion of 3% and 2 mm. Figure 3 shows the gamma analysis of all PDDs with the criterion of 1%/1mm, 2%/1mm, and 3%/2mm for 6FFF and 10FFF:

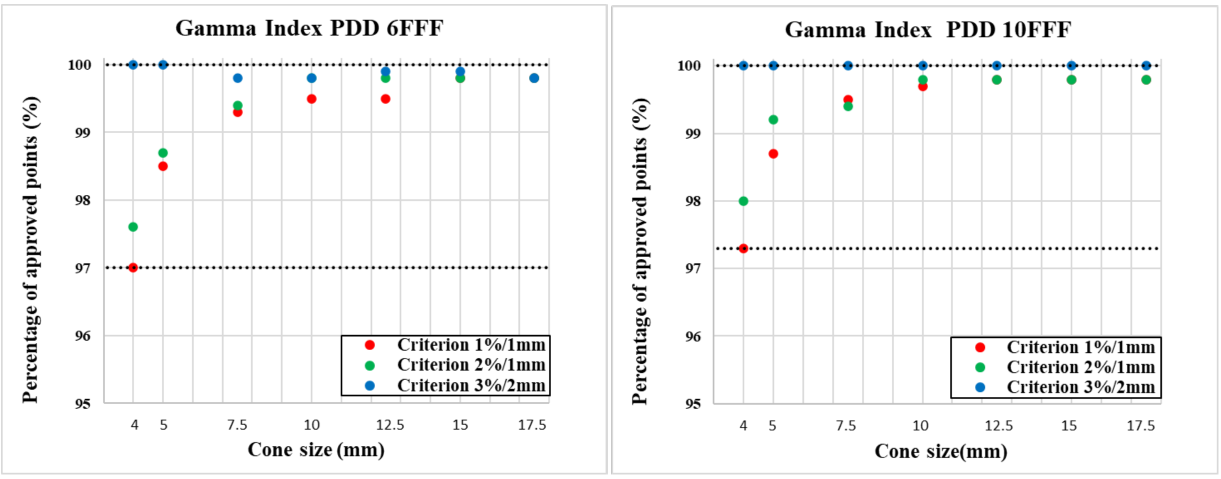

Figure 3: *Percentage of approved points in relation of cone size using three criteria for PDD.*

3.2- **Off-Axis Ratio (OAR)**

Figure 4 shows the results obtained for the OAR measured with the Edge detector compared to the radiochromic film

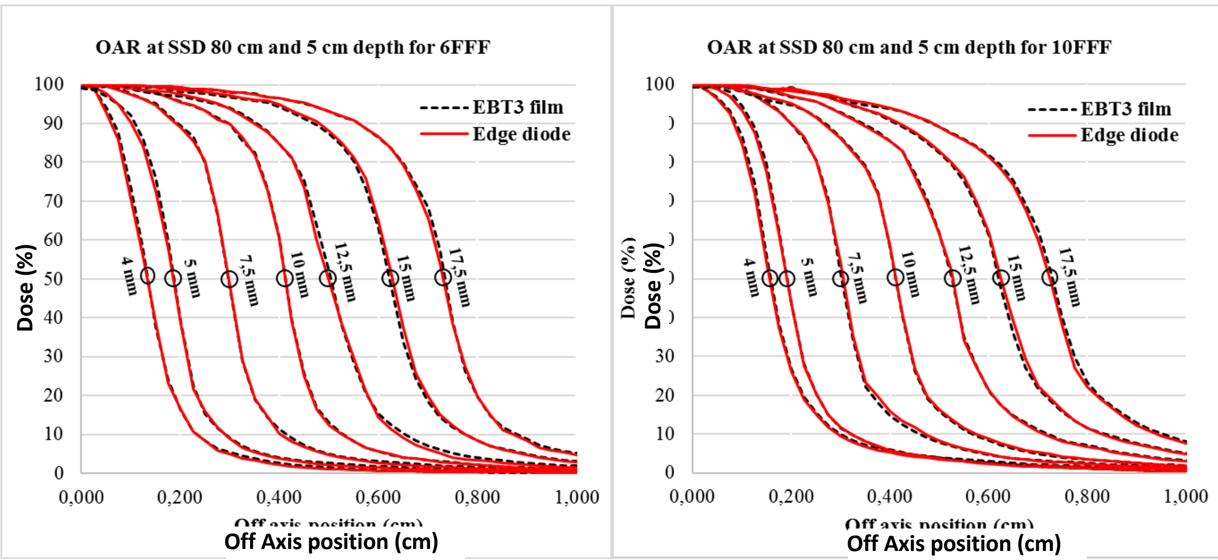

Figure 4: *OAR measured for all cone sizes at SSD 80cm.*

In the same way, as in the PDD, the gamma analysis of the OAR data was also carried out using the radiochromic film as a reference (Figure 5)

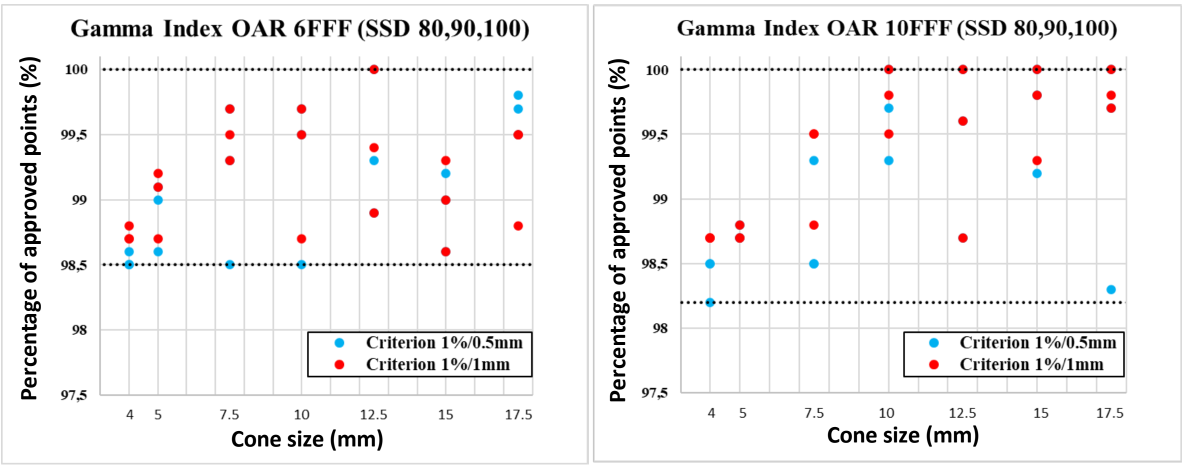

Figure 5: *Percentage of approved points in relation of cone size using three criteria for OAR measures.*

3.3- **Output Factor (OF)**

Figure 6 shows the comparison between radiochromic film and Edge diode for Output factor:

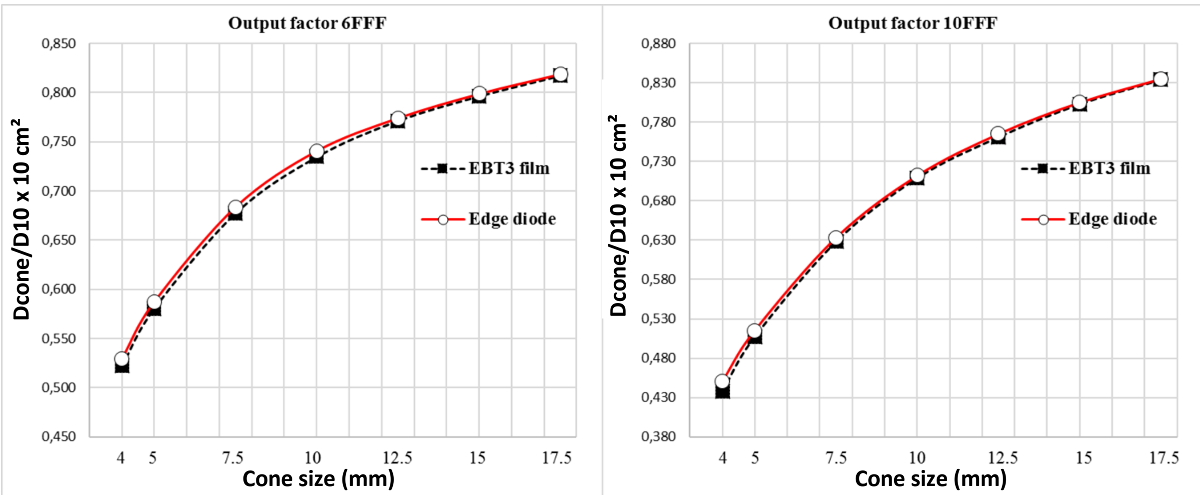

Figure 6: *Output factor using radiochromic film as a reference.*

In the case of the OF, the percentage differences of the values in relation to the film were analyzed (Figure 7):

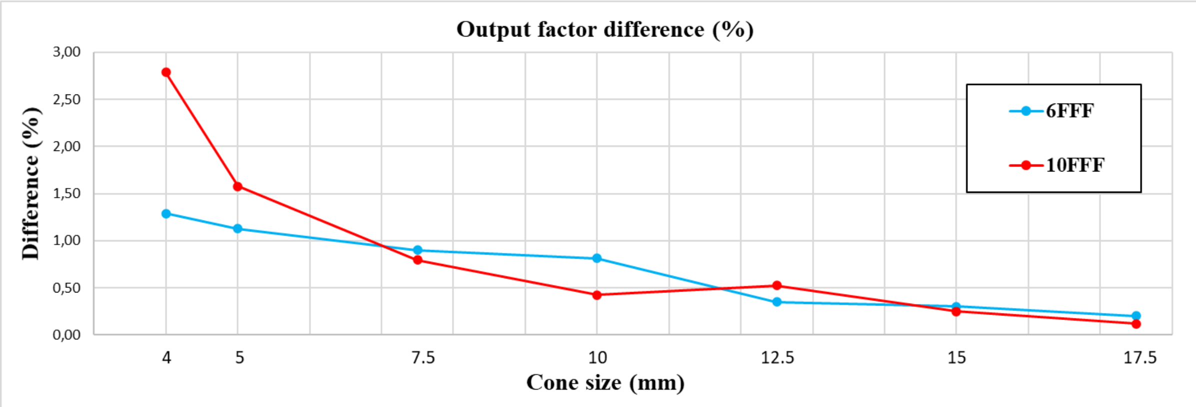

Figure 7: *Differences found in the output factor for 6FFF and 10FFF compared to EBT3 film.*

In the gamma index analysis of the profiles, the minimum percentage reached was 98.3% of the points in the criterion 1% and 0.5 mm. The maximum percentage difference in the output factor was 2.79% for a cone 4 mm and 10FFF. In the gamma index analysis of the PDDs, the minimum percentage reached was 97% of the points in the criterion 1% and 1mm. The results obtained for both film and diode measurements are consistent with those of authors who used the same devices (cones and accelerators) [8],[9].

The metric chosen for comparison between the different detectors was the gamma analysis proposed by low [10] and recommended as a way of analyzing the patient-specific quality assurance of radiotherapy according to the AAPM TG 218 [11]. The results obtained are consistent with AAPM TG218, showing tolerances and number of approved points that are consistent with the practices adopted in radiotherapy.

Regarding the output factors, we can consider the percentage difference between reference and measurement, which in this case shows values consistent with the literature [8,9]. The analysis of PDD and profiles was also performed using gamma analysis and showed similarities with the literature [12,13]. According to Venselaar [14] we can assume the field geometry as being complex because it deals with small fields, this author suggests three tolerance levels for analyzing the profiles, 3% inside the radiation field, 15% in the penumbra region and 4 % outside the radiation field. The percentage component of the gamma analysis shows that the results are consistent with the limits of variation proposed by this author.

4. CONCLUSIONS

There are already some published works comparing the edge diode with film and scintillators in the use of proton therapy [15] and in terms of its spatial resolution [16]. This diode is also used in high technology radiotherapy involving high dose rates (flash radiotherapy) as shown in the manuscript [17]. Its use in radiotherapy is also reported when using cones for radiosurgery [18] but not at high dose rates as evaluated in this work.

The results allow us to conclude that the edge diode detector can replace the film for the commissioning of radiosurgery cones with a high level of agreement.

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