Optimisation of output factor measurements using the Magic Plate 512 silicon dosimeter array in small megavoltage photon fields

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Abstract. We evaluate the impact of an air gap and optimization of this air gap for the MP512 silicon detector array when operated in dosimetry mode for small photon field measurements in solid water. We present output factor measurements for 6MV and 10 MV photon beams with the square field sizes ranging from 0.5 to 10 cm^2. The size of the air gap above the MP512 detector was changed from 0.5, 1.0, 1.2, 2.0 and 2.6 mm. We compare the output factors measurements of the MP512 with EBT3 film and the MO*Skin* dosimeter. For the two photon energies investigated, we find that the output factor measured by the MP512 reduce with increasing air gap and reducing of field size. The reduction in output factor is most pronounced for the 0.5 and 1 cm^2 field sizes. The air gap of 0.5 mm and 1.2 mm showed good agreement with the EBT3 film and MO*Skin* output factor for 6 and 10 MV photon fields, respectively. The negligible effect on dosimetry for the field sizes larger than 4x4 cm^2 demonstrates that the electronic disequilibrium caused by small air gap only influences the dosimetry measurements for small fields. The study shows that the output factor reduction is enhanced by increasing of air gap and demonstrates that the optimal air gap for the MP512 at 6 and 10 MV photon fields is 0.5mm.

1. Introduction

Modern radiation treatment techniques such as Stereotactic Radiosurgery (SRS) and Stereotactic Body Radiation Therapy (SBRT) are increasingly being used in cancer treatment. Large doses per fraction of SRS/SBRT are delivered in small photon radiation fields leading to steep dose gradients, Quality assurance (QA) is needed to ensure that the delivered dose matches the plan dose distribution [1]. Current commercial dosimetric QA tools for SRS/SBRT include ionization chambers, used for point dose measurements, as well as two-dimensional diode arrays and pixelated ionization chamber arrays. One limitation of the ionization chamber is that the dosimetry in small field can be perturbed by the chamber volume averaging effect [2]. Film has good spatial resolution but their processing is time consuming. ArcCHECK (Sun Nuclear, Melbourne, FL) contain an array of 1386 diodes distributed in a cylindrical acrylic phantom. To perform the patient QA, the treatment plan needs to be transferred to the QA system. The Delta4 (ScandiDos, Uppsala, Sweden), which consist of 1069 silicon diodes in a crossed array inside a cylindrical polymethylmethacrylate (PMMA) phantom, requires the recalculation of the dose on a CT scan phantom for the verification procedure. The operation system of both ArcCHECK and Delta4 is performed on the treatment couch [3] and is not designed to operate in transmission mode. In small irradiation field dose delivery via SRS and SBRT, the QA procedure needs to have a detector with high spatial resolution. The Magic Plate 512 (MP512) a two dimensional monolithic silicon detectors array has a spatial resolution of 2 mm (pitch of array elements), which is suitable for such small field dosimetry. The patient treatment verification can be performed without the need to transfer the treatment plan to the detector and real time dose measurement can be made [4]. The purpose of this study is to examine the effect a small air gap immediately above surface of the MP512 has on the measured output factors for 6 and 10 MV photon fields as part of QA in SBRT and SRS.

2. Methodology

MP512 is a silicon monolithic detector manufactured on a p-type substrate. The MP512 array consists of 512 pixels with size 0.5 x 0.5 mm^2 and pitch 2 mm with an overall dimension of 52 x 52 mm^2. The MP512 monolithic detector is wire bonded on a printed circuit board 0.5 mm thick and covered by a thin layer of raisin to protect the bonding wires as well as the silicon detector surface from moisture [4]. The output factor measured with MP512 is compared with similar measurement using EBT3 films as well as MO*Skin* dosimeters. The MP512 was placed on a solid water phantom at the depth of 10 cm with 10 cm additional back scatter material and was aligned at the centre of the beam. The measurements were carried out with size of the air gap above the detector set at 0.5, 1.0, 1.2, 2.0 and 2.6 mm. The field size was varied from 0.5 x 0.5 cm^2 to 10 x10 cm^2 while SSD was 90 cm. The measurements were performed on a Varian 21XI linear accelerator with 6 MV and 10 MV photon beams and dose rate 600 MU/min. In each case 100 MU was delivered with open field.

3. Results

Figure 1 shows the output factor for 6 MV measured by MP512 at 10 cm depth in a PMMA phantom for different air gaps above detector. Also shown air data from equivalent measurements performed using EBT3 film and MO*Skin*, with no air gap above them however. All measurements air normalized to the response in a 10 x 10 cm^2 field size. For small field sizes (0.5 and 1 cm^2) at 6 MV, the MP512 measured output factor reduces with increasing air gap above the detector. This reduction is significant when the air gap increases beyond 2mm. For larger field sizes ($\geq$2x2 cm^2) at 6 MV, we observe a small but increasing effect on the measured output factor with increasing air gap. The optimum MP512 air gap is 0.5 mm as it shows good agreement with the EBT3 film and MO*Skin* output factor. Figure 2 shows the output factor for 10 MV photons measured by MP512 with different air gaps above detector compared to the EBT3 film and MO*Skin* (with no air gap), normalised to the MP512 response at 10 x10 cm^2 field size. For all field sizes at 10 MV, the MP512 measured output factor reduces with increasing air gap above the detector. The output factor measured by MP512 with air gap size of 1.2 mm seems to matches best to the output factors measured with the EBT3 and MO*Skin*.

4. Conclusion

The output factors measured by the 2D detector array MP512 with different air gaps immediately above the detector placed at a depth of 10 cm in solid water phantom have been measured in both 6 and 10 MV photon fields. The properties of the array confirmed suitability for use as a phantom dosimeter for QA in SRS and SBRT. The output factor measured by MP512 with an air gap of 0.5 mm and 1.2 mm matches to within 2% that measured by GAF^{TM} film and MO*Skin*^{TM} for field sizes down to 0.5x0.5 cm^2, for 6 and 10 MV, photon field respectively.

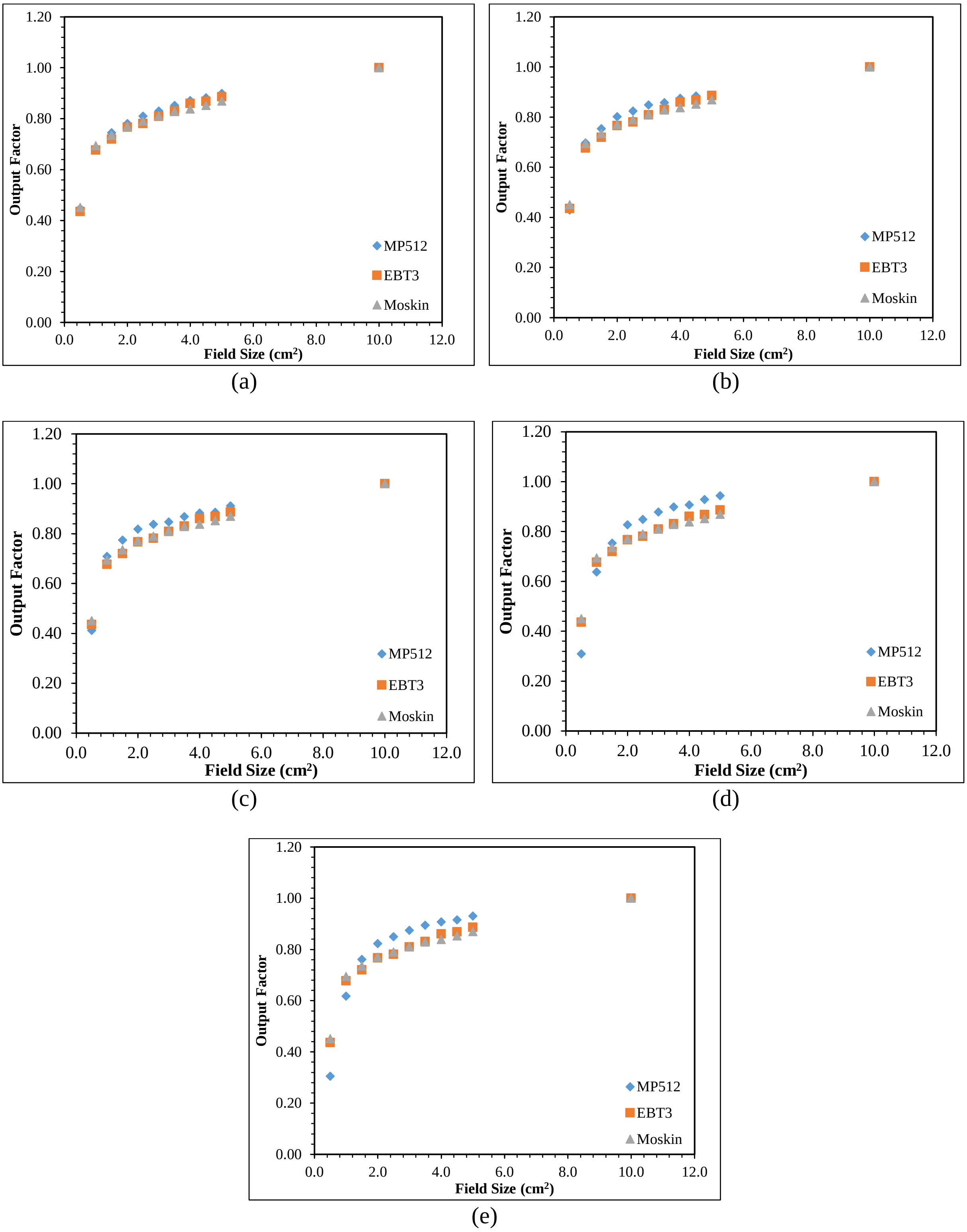
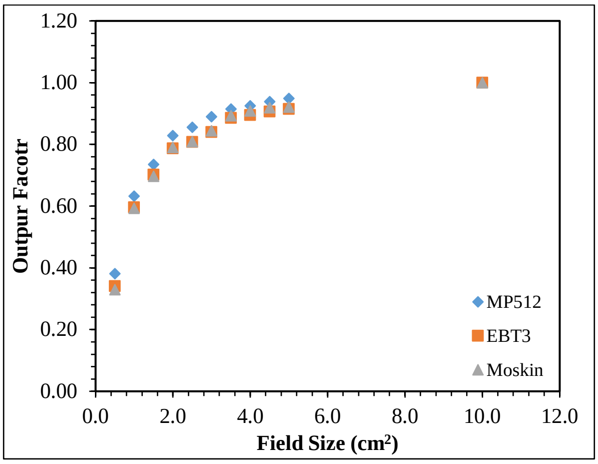
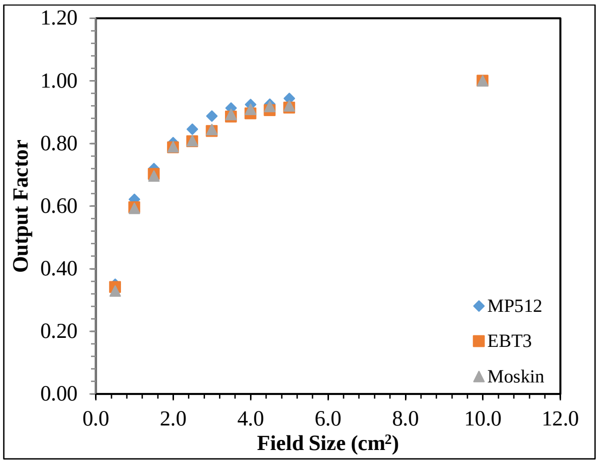


Figure 1. Field size response of MP512, EBT3 film and MO*Skin* for 6 MV photon beam normalized to the response at 10 x 10 cm^2 field size at depth 10cm in a PMMA phantom for different airgaps. (a) 0.5 mm, (b) 1.0 mm, (c) 1.2 mm, (d) 2.0 mm and (e) 2.6 mm



(a)



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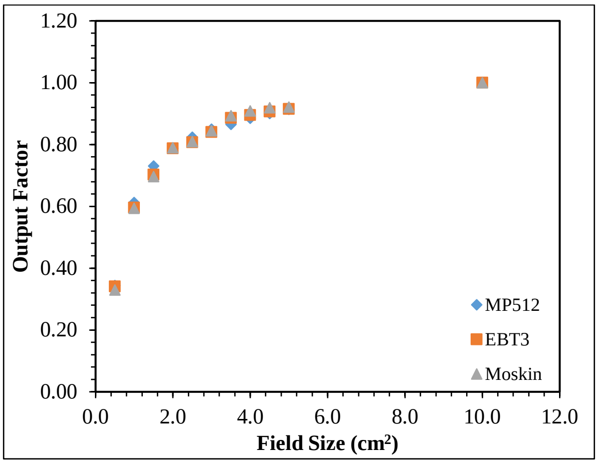

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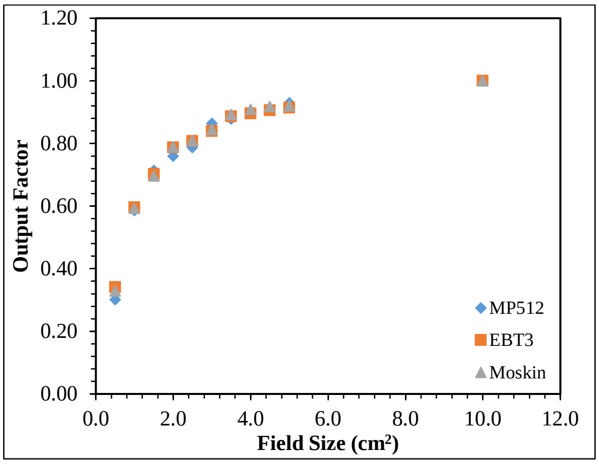

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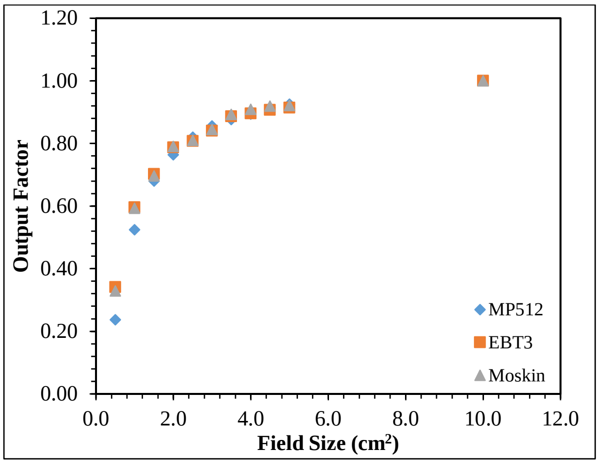

(d)

Figure 2. Field size of MP512, EBT3 film and MO*Skin* for 10 MV photon beam normalized to the response at 10 x 10 cm^2 field size at 10 cm depth in PMMA phantom. (a) 0.5 mm, (b) 1.0 mm, (c) 1.2 mm, (d) 2.0 mm and (e) 2.6 mm

5. Reference

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