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Measurements of $\Omega^{f\,clin,\,fmsr}_{Qclin,\,Qmse}$ by Using Different Detectors in Radiation Therapy Systems

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Abstract

Background: It worth to be mentioned that the use of small size photon beam is frequently used in modern radiotherapy to treat brain tumors and functional disorders.

Aim of Study: To measure output factors (OFs) and calculate the field factor ($\Omega^{fclin,\,fmsr}_{clin,\,Qmse}$) of small fields and study its suitability for small field relative dosimetry.

Material and Methods : Numerous detectors were used for measuring the output factors for 6 MV photon beams by a CyberKnife®. To normalize different detector responses for the same field configuration, a correction factor was calculated for each detector by simulating the radiation delivery using Monte Carlo (MC) methods. Detectors used in the study were PTW60019 MicroDiaond, PTW 60018 Silicon diode, PTW31018 MicroLion, and Exradin W1 Scintillator. Field factors were calculated using Alfonso formula. Output factors for a CyberKnife were measured in circular fields with the diameters range from 5mm to 60mm. Measurements were made in a water tank at a 1.5cm in term of depth and at 80 cm for source-to-axis distance.

Results: The results of the current study show that the output measured by the detectors Micro Diamond and Exradin W1 Scintillator (PSD) were within the uncertainties of the Monte Carlo simulations for all the beam cones. The silicon diode detector was over-responding, while the MicroLion was under-responding. We found that an accurate dosimeter could be the MicroDiamond and Exradin W1 Scintillators in small field dosimetry.

Conclusion: We found that at small collimator settings only the synthetic microdiamond (PTW60019) and Exradin W1 scintillation detectors can be used as relative dosimeters without applying any correction factor.

Key Words: *Synthetic diamond – Exradin W1 Scintillator (PSD) – Small field dosimetry.*

Introduction

THE CyberKnife system is based on 4 main subsystems: A 6 degrees of freedom robot, a compact linear accelerator that can deliver small fields using 12 circular cones that made up tungsten corresponding with diameter range start from 5mm up to 60mm (i.e., 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50, and 60mm), an x-rays system and a dedicated treatment planning system. The linac source is at 80cm from the virtual isocenter (which is better said the origin of the coordinate system, since there's no real isocenter). 100 positions can be assumed by the source on a sphere centered on this point, and from each position 12 directions can be assumed, leading to 1200 different beams. Not all the directions will really be used, but by different weighting of these beams highly conformal shapes can be achieved. Compared to conventional stereotactic radiosurgery systems, the CyberKnife allows to use noncoplanar and non-isocentric geometries enhancing the ability to avoid critical structures. However, single isocenter and multi-center strategies can be used. Definitely, many papers have been recently published pointing at characterizing commercial dosimeters in these challenging conditions. Their response was examined under irradiation in field sizes down to 5mm and Monte Carlo (MC) simulations were accomplished in order to calculate the correction factors to be applied to the yielded investigational data.

In small fields, detector readings are affected both by volume-averaging and by the densities of the detector sensitive volume and surrounding components. To a slighter extent, atomic number also affects detector readings, via differences between photon spectra in broad and narrow fields. When evaluating the accuracy of dosimetric measurements it should be established whether any part of the detector sensitive volume lies within a distance lower than the radius where the lateral electronic equilibrium breaks down; and if so, whether the electron fluence will be greatly perturbed by a detector of the size, density and com-

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position used, and whether accurate correction factors are available to account for the resulting perturbation and volume-averaging. An optimal detector would provide the dose at a point would be energy independent and would require only a single calibration valid for all possible energies and irradiation scenarios.

Air-filled ionization chambers posses lower limited in term of size by the signal to noise ratio, which 0.01cm^3 volume requires for therapeutic dose levels to achieve a signal noise ratio of around 1000. For such small chambers, radiation-induced stem currents and cable currents become very large in term of comparison to the signal. The OF values associated with diodes are significantly greater than SZ for fields lower than 10mm in diameter and correction factors must be applied.

New category of a detector which offer advantages for small field dosimetry over diodes in terms of water equivalence, and air-filled microchambers in terms of volume averaging and density variation, are commercially available. A good example for this sort of detectors is scintillation detector, which combines good water equivalence and a small sensitive volume [1]. The correction factors for OF measurement associated with this detector is evaluated by Francescon et al as $\leq$0.3% for all VSI system circular collimators, although this wasn't verified by measurement [2]. OF measurements are compared via subsequent multi-center study to corrected diode measurements that demonstrated an average agreement of ≤ 1.0% for all CyberKnife circular fields and a study using another 6MV treatment beam with similar field sizes reported corrections of $\leq$0.6% [3].

Another promising technology commercialized by PTW is the microDiamond (MD) [4,5]. Although MD is inferior to a point scintillator in both aspects, it provides superior water equivalence to diode detectors and smaller sensitive volume than air-filled microchambers. The first evaluation of microdiamond measured OF values using CyberKnife VSI circular fields are compared with respect to the mean of corrected diode and microchamber measurements. Consequently, the maximum difference (microdiamond over-response) of 1.9% at the 7.5mm field size is registered [6]. A subsequent measurement comparison using CyberKnife, in which a corrected diode measurement was used as a reference, inferred a maximum over-response of 0.6% at the 7.5mm field size (Russo et al., 2016) [7], and an expanded version of that study has reported this to be increased to 1.3% (Masi et al., 2016) [8].

At the smallest field size (5mm) these studies report an over-response of 1.0% [6], 0.2% (Masi et al., 2016) [8] and under response of 0.2% (Russo et al., 2016) [7]. This detector has been considered in several previous studies to use other treatment devices [3,9-14] and have recorded an inconsistent behavior at small field sizes, from over-response of 5.0%) [11] to under-response of 2.7% [12]. The complexity of these results applicability to CyberKnife relies on the differences in collimator design, beam quality, measurement depth and distance, definition of machine specific reference field, and presence or absence of a flattening filter, and also by the variety of empirical and numerical methods employed.

In this paper we have tested the response in small fields of these new type of dosimeters (microdiamond and scintillating detector) and of two consolidated technologies (microLion, and diode), by measuring the output factor. The yielded results present an assessment of the MD dosimetric properties in view of its application in small field reference dosimetry. Also, due to most of the published article lack a proper estimation of the uncertainty in the various steps involved in the determination of output factor and the correction factors we will study the uncertainty of our detectors.

Patients and Methods

It worth to be mentioned that all detractors used in this study are at Medical Physics Department, ULSS, Vicenza, Italy as a part of STEP programme scholarship that funded by the ICTP/IAEA (2017-2018).

Detectors:

PTW 60019 MicroDiamond:

Micro Diamond detectors are considered as a solid state type characterized of small size and high response. In addition, their response is almost independent upon energy. They also feature a very good directional response. The outer dimension of the device cap as well as of the diamond plate position was marked by using a white dashed line. Technically, the 7mm overall diameter of the MD, together with the lateral size of the 3x3x0.3mm^3 diamond plate and the 2.2mm diameter of the top contact [5]. The active volume implanted in the diamond crystal has a cylindrical shape of 1.1mm radius and length of 1mm, the reference point is on the detector axis. The literature reviews and manufacturers recommended for all measurements, the Micro Diamond dosimeters were oriented with their axis parallel to the beam direction with the detector facing up with the gantry at zero degrees [4,12,13,15,16].

PTW31018 MicroLion chamber:

The microLion (Physikalisch-Technische Werkstätten) was developed specifically for small-field dosimetry. The sensitive volume in this chamber is composed of isooctane (C_8H_{18}) rather than air, enabling the sensitive volume to be reduced to $1.7mm^3$, and a high electrical signal response is conserved for a given dose. The design is a parallel plate chamber with a diameter of 2.5mm and electrode spacing of 0.35mm. The entrance window is composed of polystyrene, graphite, and varnish. The central electrode is made of graphite only. The ionization chamber type 31018 is designed for use in connection with the PTW dosemeters UNIDOSwebline or TANDEM PTW dosemeters and the external high voltage source HV-Supply. Due to problems with signal stability, this dosimeter is no longer produced by PTW, which proposes the micro-diamond instead.

PTW 60018 Diode:

Silicon diode detectors associated with the highest response per volume for all common detector types. Thus, their sensitive volume is usually small enough to avoid dose-volume effects down to very small fields. However, the density perturbation effect is still present. It is a matter of fact, the directional response corresponding to silicon diodes is not ideal, as well as the response to low-energy scattered photons. To achieve the reduction the latter effect, diodes exist in a shielded design where the shield reduces the signal from these photons. In small fields, the low-energy scatter contribution is low, hence diode shielding is not needed and unshielded diodes are recommended for small fields [17].

Exradin W1 Scintillator (PSD):

The plastic scintillator of Standard Imaging includes a light guide and an optical detector. The W 1 is nearly water equivalent and suppresses the Čerenkov light with the Supermax two channel electrometer. PSD was composed of a cylindrical scintillating fiber (multicladding SCSF-78M, Kuraray Co., Ltd., Tokyo, Japan) with a diameter of 0.5mm and a length of 1.0mm coupled with a PMMAoptical fiber (Super Eska SH-2001, Mitsubishi, Rayon Co., Ltd., Tokyo, Japan) with a diameter of 0.5mm and a length of 5m to guide the scintillation produced to a polychromatic charge-coupled device (CCD) (U2000c, Apogee Imaging System, Roseville, CA, USA). A light collection system was developed to maximize the signal-to-noise ratio (SNR) using an optical lens (Minolta MC Rokkor-X PG, f/# =1.4, focal length =50mm). Pair the W1 Scintillator with the SuperMAX Electrometer to effectively eliminate Cherenkov effect without the need for extraneous hand calculations. The dosimetric data was evaluated via Standard Imaging's two channel SuperMax electrometer.

Experimental setups:

Measurements were performed with:

(i) A CyberKnife® Robotic Radiosurgery System (Accuray Incorporated, Sunnyvale, CA, USA), at Medical Physics Department, ULSS, Vicenza, Italy; (ii) The performance of measurements is occurred in a PTW MP3 water tank with a spatial position accuracy of ±0.1mm was used for scanning all detectors, by positioning the MD, diode, ML and Plastic Scintillator Detector (PSD) detectors were used with their stems parallel to the beam axis (parallel orientation). No bias voltage was applied to MD and 800V was applied to Ml, according to the manufacturer's instructions. The PTW TRUFIXR detector positioning system was used for MD and ML, so to improve the depth positioning accuracy in the water phantom.

CK measurements were performed in a 6 MV flattening-filter-free beam (TPR20/10=0.640 at a field size of 60mm in diameter), delivered at 800 MU min^{-1} and collimated by using circular fixed tungsten cones. SSD 80cm has been used for the under investigation field sizes, which associated with nominal diameters of 60mm, 50mm, 40mm, 35mm, 30mm, 25mm, 20mm, 15mm, 12.5 mm, 10mm, 7.5mm and 5mm. Actually, the definition of the machine-specific reference field fmsr was the 60mm collimator. A complete description of this treatment system is given in Kilby et al., [18]. Additionally, SDD of 80cm is also used for OF measurements performance, with the detectors positioned at a depth of 1.5cm in the water phantom.

Measuring protocols and data analysis:

OF measurements were accomplished for all the field sizes previously discussed. Measured OF values were defined as [3,14]:

$$O^{f_{clin}, f_{msr}}_{Q_{clin}, Q_{mse}} = \frac{M^{f_{clin}}_{Q_{clin}}}{M^{f_{clin}}_{Q_{clin}}}$$

Where $M^{f_{clin}}_{Q_{clin}}$ and $M^{f_{clin}}_{Q_{clin}}$ are the detector readings for the f_{clin} and the f_{msr} fields respectively and f & Q are the collimator size in millimeters and the beam quality. The suffixes clin and msr represent the field of interest (clinical field) and the machine-specific reference (60mm for a CyberKnife system), respectively [19]. The approach taken consisted of performing a measurement with the reference cone (60mm) before and after the measurements with the cones of interest (5-50mm).

Each detector reading shows the average of five consecutive measurements, which obtained after 100 MU irradiation steps. Consequently, all the measured OFs corrected in order to take into account the dose per pulse dependence of the device response, as reported by the manufacturer (PTW 2017). In this respect, the observed applied correction factors for all measured OFs were below one percent.

The field factors were obtained according to the following formula:

$$\perp^{f_{clin},\ f_{msr}}_{Q_{clin},\ Q_{mse}} = OF^{f_{clin},\ f_{msr}}_{Q_{clin},\ Q_{mse}}\ K^{f_{clin},\ f_{msr}}_{Q_{clin},\ Q_{mse}}$$

According to the formalism proposed by [19], by using the previously mentioned definition of OFs in equation (1) and the $K^{\wedge lin\ f_{msr}}_{clin,\ Q_{mse}}$ correction factors, which is produced by MC calculation.

The W 1 was obeyed to Cerenkov background correction using the two-channel method recommended by the vendor (Guillot et al 2011), whereby the corrected reading is derived from the charge measurements in colour channels 1 (C1) and 2 (C2) as Gain * (C1-C2 * CLR). CLR refers to the Cerenkov light ratio and it is obtained using measurements made with two different irradiated optical fiber lengths. According to Morin et al., description (2013) [20] the orientation of the water phantom geometry was vertically with the detector as for OF measurement was used to determine CLR, which it meets the recommendation of the vendor (Standard Imaging 2014). The vendor supplied dual-channel SuperMAX electrometer (Standard Imaging) is using for the performance of W 1 measurements. Indeed, calibration of CLR and OF measurements was repeated over a period of 2.5 months to assess the reproducibility.

Uncertainty evaluation:

Actually, uncertainty of the output factor measurements was evaluated, according to the IAEA CoP-483 dosimetry protocol relies on two different contributions: The first is the establishment of the measurement conditions (0.4%, 1 standard deviation, SD) and the second one is the dosimeter reading relative to beam monitor (0.6%, 1 SD). Thus, these values are quoted in the same IAEA protocol as well. Consequently, a global uncertainty in the OF ratio of 1% (1 SD) is estimated. Possible effects, which coming from the unsuitable spatial resolution of the detector and from the difficulty of a correct detector positioning in narrow fields were not taken into the account of the evaluation process.

Results

Measurements with PTW 60019 MicroDiamond (MD):

Figs. (1,2) indicate a comparison between output factor (OF) measurements of PTW 60019 MicroDiamond detector and $ɥɪ^{cl.n'\ fm_{sr}}_{clin,\ Q_{mse}}$ factor after applying the Monte Carlo (MC) correction factor $K^{f_{clin},\ f_{msr}}_{Q_{clin},\ Q_{mse}}$ that reported in [21,22] respectively. The figures display the slightly difference of the output factor using MicroDiamond before and after applying the Monte Carlo correction factor. For instance, the output factor with collimator diameter 5mm is 0.668 & its corresponding $f^{f\ cl.n'\ f_{msr}}_{cl\ \wedge n,\ Q_{mse}}$ using the correction factor published by De Coste et al., [21] is 0.673, while using (IAEA CoP – 483) [22] is 0.651; with collimator diameter 7.5mm the output factor is 0.837 and the corresponding $Ъ^{f_{clin},\ f_{msr}}_{clin,\ Q_{mse}}$ according to the data of De Coste et al., is 0.825. The slightly difference is obvious by using the data of (IAEA TRS 483) in $Q^{f\ _{un'}\ fm_{sr}}_{clin'\ Q_{mse}}$ by which it is 0.822. The uncertainty have been calculated for correction factors of both De Coste et al., [21] and IAEA CoP-483 [22], see Table (1). The MicroDiamond is a good candidate for dosimeter of small field.

Table (1): Comparison between OF and the Monte Carlo correction factor made by De Coste et al., [21], and the correction factors reported in a new protocol TRS483 [22] with Standard Deviation for PTW60019 MicroDiamond.

Collimator	5	7.5	10.5	12.5	15.0	20.0	25.0	30.0	35.0	40.0	50.0	60.0
OF	0.668	0.837	0.885	0.917	0.940	0.964	0.974	0.980	0.984	0.987	0.991	1
Correction 483	0.975	0.9825	0.988	0.991	0.995	0.998	0.999	0.999	1	1	1	1
Correction Francescon	1.007	0.986	0.99	0.991	0.993	0.998	0.998	0.997	1	1	1	1
SD	0.023	0.002	0.001	0	0.001	0	0.001	0.001	0	0	0	0

Measurements with Liquid filled microchamber (PTW 31018 microLion):

Fig. (3) Represents a comparison between output factor measurements of MicroLion detector and $\Omega^{fclin,\ fmsr}_{Qclin,\ Qmse}$ value after applying the correction factors, which are reported in Francescon et al., [23]. The microLion measured values agreed with Monte Carlo results for all the cones except the cone that have 5mm. The results refer to the under-responses of microLion. This aspect is caused by the volume averaging effect due to the high-density of the surrounding material.

Measurements with PTW 60018 Diode:

Fig. (4) illustrates a comparison between output factor measurements of the PTW 60018 Diode detector and $\Omega^{fclin,\ fmsr}_{Qclin,\ Qmse}$ after applying the correction factors reported in [24]. The silicon diodes agreed with of the calculated output factors for cones with a diameter of 20mm or greater without any correction factor. Silicon diodes are widely used for radiosurgery system commissioning and QA measurements, thereby resulting in a slightly lower actual dose delivered to the patient for the smallest cones than that predicted by the planning system when no correction factor is applied to the measurements. The PTW 60018 silicon diode associated with the worst results with noticeable over-response for cones smaller than 20mm in diameter. The silicon diodes' over-responded agreed with Araki's calculated values in small fields [25].

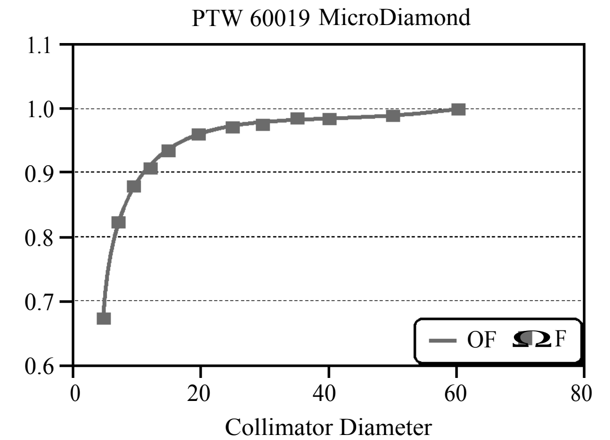

Fig. (1): Comparison between OF (Output Factor) and Ω F in PTW 60019 MicroDiamond (MD) detector by using the correction factor De Coste et al., [21], $\Omega^{fclin,\ fmsr}_{Qclin,\ Q_{mse}}$ simplified Ω_F figure.

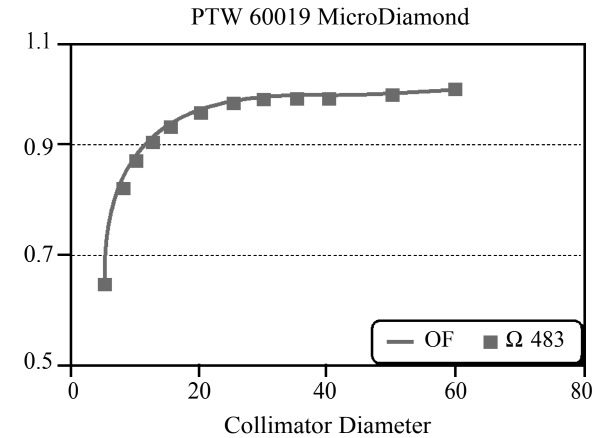

Fig. (2): Comparison between OF (Output Factor) and Ω_{483} in PTW 60019 MicroDiamond (MD) detector by using the correction factor by TRS [22], $_{Qclin,\ Qmse}$ simplified Ω_{483} figure.

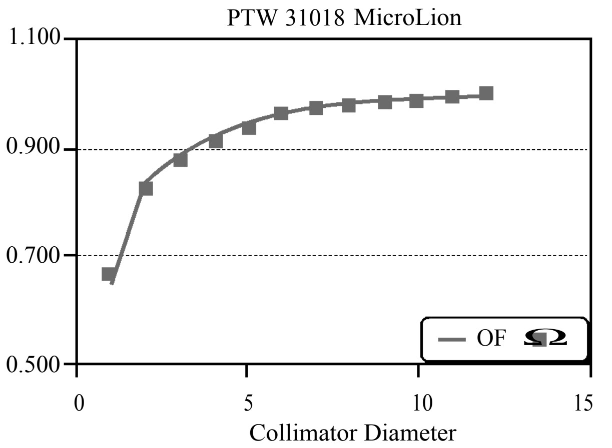

Fig. (3): Comparison between OF (Output Factor) and Ω in PTW 31018 MicroLion (ML) detector by Francescon et al., correction factor [23], $\Omega^{f\,clin,\ fmsr}_{Qclin,\ Qmse}$ simplified Ω figure.

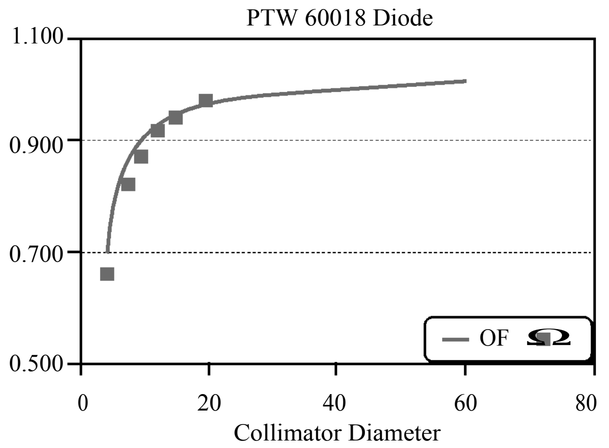

Fig. (4): Comparison between OF (Output Factor) and Ω in PTW 60018 Diode detector using Francescon et al., correction factor [24] $\Omega_{Qclin,\ Qmse}$ simplified Ω figure.

Measurements with Exradin W1 Scintillator:

Fig. (5) Demonstrates a Comparison between OF and $\Omega^{fclin,\ fmsr}_{Qclin,\ Qmse}$ for Exradin W1 Scintillator detector using Francescon et al., correction factor [24]. The measured output factors using the Exradin W 1 Scintillator provide very good agreement, with those calculated in two different Monte Carlo studies mentioned before [2,24]. Then, Exradin W 1 Scintillator needthe smallest correction factor for small field size that leads to consider the Exradin W 1 Scintillator one of our choices in small field dosimeters. The scintillation detector combines good water equivalence and a small sensitive volume.

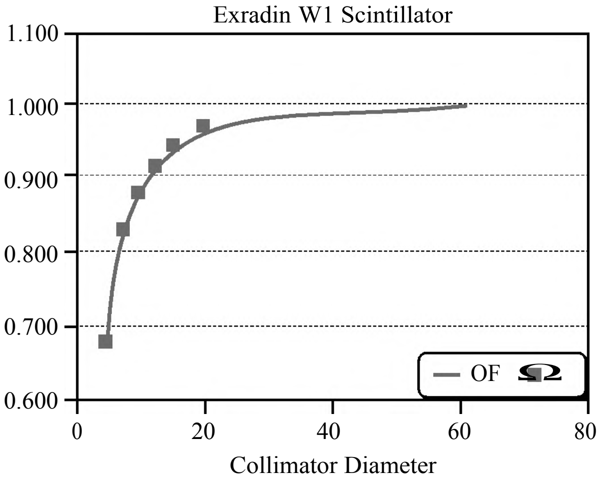

Fig. (5): Comparison between OF (Output Factor) and Ω in Exradin W 1 Scintillator detector using Francescon et al correction factor [24] ($\Omega_{Qclin,\ Qmse}$) simplified Ω figure.

Discussion

We compared several radiation detectors by measuring their output factors and their field factors, i.e., $\Omega^{fclin,\ fmsr}_{Qclin,\ Qmse}$. The field factor converts the absorbed dose in water for a machine-specific reference field f_{msr} to the absorbed dose in water for the clinical field f_{clin} [19]. Current detectors have limitations to perform accurate small field dosimetry (fields ≤20mm), which was verified during the completion of this study. As broadly known, the silicon diodes are water nonequivalent which is responsible for the over-response in the tails of the larger fields of CyberKnife systems as well as the small fields <10mm.

The MicroLion detector under-responded at the 5mm cone due to the compensation of a volume averaging effect, which caused by the surrounding high-density material. Our observations emphasize that small field factors, i.e., $\Omega^{fclin,\ fmsr}_{Qclin,\ Qmse}$, can be accurately measured using water equivalent dosimeters such as PSDs, which provided results similar to those predicted by our independent MC calculations. On the other hand, Exradin W 1 Scintillator radiation detectors might be considered as good candidates for the reference dosimeters for water-based measurements such as total scatter factor, tissue phantom ratio, treatment delivery verification, and percent depth dose.

With the MicroDiamond, overall diameter sizes have the most uniform response with corrections ≤1%. Our results endorse a good agreement between MicroDiamond measurements and those made with other detectors. It worth to be mentioned that corrected using simulations based on the dimensions mentioned in [5]. The MicroDiamond is the optimal detector in term of commissioning and routine use of CyberKnife. It is a matter of fact, measurements of this detector exhibit a good agreement of both DORs and profiles in the three directions that confirm the suitability of MicroDiamond detectors for clinical dosimetry.

Searching for the optimal or ideal detectors to be used for measuring the output factors for a small field with CyberKnife® is the crucial question that needs to be answered. Related to the output factor measurements, one suggested criterion is that the correction $K^{f\,clin,\ f\,msr}_{Qclin,\ Qmse}$ should remain <5% for all field sizes [26]. Our results displayed that all used detectors meet this criterion for field size diameters ≥20mm. while for the smallest fixed collimators, only the PTW60019 MD and W1 Exradin scintillation detector are suitable. Our data completely agree with published result of Francescon et al., [24]. Referring to the Table (2), the percentage of standard deviation (σ_Ω) %) is calculate for the field factor. The results illustrate that, (σ_Ω)% range from (0.16%-1.07%) and from (0.62%-0.93%) by using both IAEA CoP-483 [22] andFrancescon et al., [21], (Francescon et al., 2012), [24]. Monte Carlo correction of Francescon et al is favorable for all detectors under investigation according to the obtained standard deviation. Also the mean values of the field output correction factors and the uncertainty have been estimated. The uncertainty of type A for both MicroLion and Diode are <0.3%, while the uncertainty of type B is <0.65% as closely as the published data of Francescon et al., [23].

On the other hand, we should take into considerations to study both side properties for each detector under investigation. However both W 1 Exradin scintillator and PTW60019 microdiamond are associated with the smallest corrections for all measurement types, both of these detectors have disadvantages. A major current practical limitation of the W 1 detector is that it doesn't interface with any commercially available plotting tank system. This means that it can only be used for manual scanning which makes it impractical for anything except output factors measurement. In addition, this detector has exhibited relatively large measurement non-reproducibility after repeat set-ups, which it might be related to uncertainties in the Cerenkov correction obtained using the method of **[20]**. Similar CLR variability and output factor variations have been observed in a larger measurement series using CyberKnife **[8]**. CLR inconsistencies have been also noted elsewhere and a dependency of CLR on the exact fiber orientation within the beam has been suggested **[13]**.

Until the practical limitations of the W 1 Exradin scintillator are overcame, the synthetic microdiamond is probably the closest to be an optimal detector for small field dosimetry in a routine setting that is commercially available today.

Conclusion:

Concluding our discussion, we have realized that the synthetic microdiamond detector (PTW 60019 MicroDiamond) this considered as a promising technology for related study. This affords superior water equivalence to diode detectors and smaller sensitive volume than air-filled micro chambers, although MicroDiamond detector is inferior to an Exradin W 1 scintillator in both respects. By using PTW60019 MicroDiamond that no essential corrections have to be applied to the detector response for collimator diameter larger than about 10mm, since $K_{Qclin,\ Qmse}^{f\ °tZn.\ f\ msr}$ is less than 0.1 in that range. That means for the smallest fixed collimators only the synthetic microdiamond (PTW60019) and Exradin W1 scintillation detector are suitable. Although both of these detectors associated with limitations that give the microdiamond a more alternative applicability, the correction factors for scintillation and MicroDiamond synthetic detectors are much smaller. Ultimately, accurate relative dosimetry is applicable by using the microDiamond and Exradin W 1 scintillation dosimeter for field sizes below 10mm.

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قياسات معامل المجال للحقول الصغيرة $\Omega^{fclin, fmsr}_{Qclin, Qmse}$ المستخدم فى كواشف أنظمة العلاج الأشعاعى المختلفة

فى الآونة الأخيرة تصاعدت موجات إستخدام أنظمة جديدة مستحدثة للعلاج الأشاعى للأورام السرطانية مثل IMRT وSRS مما يطلب إستخدام حقول علاجية إشعاعية صغيرة مما جعل الكواشف الإشعاعية المستخدمة فى السابق فى أنظمة العلاج الإشعاعى غير مناسبة للإستخدام مع هذه التقنيات فى مدى الحقول الصغيرة. ذلك أدى إلى تصاعد الأهتمام بدراسة كواشف إشعاعية تم تطويرها للعمل فى ذلك المدى من الحقول الصغيرة وترتب على ذلك أهمية دراسة قياسات معامل الخرج لأجهزة العلاج الأشعاعى لتلك الكواشف فى مدى الحقول الصغيرة بالأخص دونما ٢٠مللى متر. وبناء على توجيهات الوكالة الدولية للطاقة الذرية ودعم مركز ICTP فى إيطاليا. قد قمنا خلال هذا البحث بقياس معامل الخرج لجهاز CyberKnife بإستخدام أنواع مختلفة وحديثة من الكواشف المتخصصة فى قياسات معامل الخرج للحقول الصغيرة فى أنظمة العلاج الأشعاعى للأورام السرطانية. من ثم تم تطبيق معامل تصحيح المدرج من قبل الوكالة الدولية فى البرتوكول الحديث للعلاج الإشعاعى TRS483 على معامل الخرج الناتج من الكواشف التالى ذكرها:

١- PTW 60019 MicroDiamond (MD).

٢- Liquid filled microchamber (PTW 31018 microLion).

٣- PTW 60018 Diode.

٤- Exradin W1 Scintillator.

ومن ثم تطبيق النتائج المعطاة على معادلة العالم ألفونسو ٢٠٠٨ للخصول على معامل المجال لتلك الكواشف الإشعاعية وأتضح من خلال هذه الدراسة أن كاشف PTW 60018 Diode هو الأكثر أستجابة over-responding فى الحقول الصغيرة فى مدى أقل من ٢٠مللى متر وأن كاشف Liquid filled microchamber (PTW 31018 microLion) هو الأقل أستجابة under-responding فى مدى الحقول الصغيرة أقل من ٢٠مللى متر. فى حين أن كواشف Exradin W1 Scintillator و(MD) PTW 60019 MicroDiamond فى غنى عن أحتياج لتطبيق معامل تصحيح على معاملات الخرج الخاصة بها فى مدى الحقول الصغيرة إلا أن الكاشف الوميضى Scintillator قد يحتاج إلى تصحيح معامل شرينكوف لتفادى تأثير شرينكوف المصاحب للكواشف الوميضية كما أنه يحتاج إلى إستخدام شبيه مائى للوسيط الحيوى water phantom مخصص مما يجعله صعب التطبيق أو غير محبذ فى تطبيقات العلاج الإشعاعى فى مدى الحقول الصغيرة. على الجانب الآخر فإن كاشف microdiamond بجانب أنه لا يحتاج إلى تطبيق معامل تصحيح على معامل الخرج الخاص به قد وجد أنه المفضل فى تطبيقات العلاج الإشعاعى فى مدى الحقول الصغيرة حيث أنخ صغير الحجم مقارنة بكوتشف معتاد إستخدامها فى مثل تلك الأنظمة للعلاج الإشعاعى على سبيل المثال لا الحصر ion chamber كما أنه water equivalent بالنسبة للتطبيقات الطبية مما يعطيه ميزة فى العلاج الإشعاعى للسرطان كما يتميز بأنه reproducile دونما تغير فى كل من signals وcounting of output مما يعطية مزايا عالية عن كل من الكاشف الوميضى Scintillator Exradin W1 وكذلك كاشف PTW 31018 microLion وPTW 60018 Diode فى التطبيقات العلاجية للسرطان فى مدى الحقول الصغيرة. لذلك ومن خلال تلك الدراسة ننصح بإستخدام كاشف PTW 60019 MicroDiamond (MD) فى أنظمة العلاج الأشعاعى فى مدى الحقول الصغيرة دونما ٢٠ مللى متر.