Comparison of Enhanced Dynamic Wedge with Physical Metal Wedge based on the Basic Dosimetric Parameters

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For clinical implementation of Enhanced Dynamic Wedge (EDW), it is necessary to adequately analyze and commission its dosimetric properties in comparison to common physical metal wedge (MTW). This study was implemented with the essential measurements of parameters for clinical application, such as percentage depth dose, peripheral dose, surface dose, effective wedge factor, and wedge profile. In addition, through the comparison study of EDW with open and MTW, the analysis was performed to characterize the EDW. We also compared EDW dose profiles of measured values using chamber array 24 (CA24) with calculated values using radiation treatment planning system. PDDs of EDW showed good agreements between 0.2~0.5% of open beam, but 2% differences with MTW. In the result of the measurements of peripheral dose, it was shown that MTW was about 1% higher than open field and EDW. The surface doses of 60° MTW showed 10% lower than the others. We found that effective wedge factor of EDW had linear relationships according to Y jaw sizes and was independent of X jaw sizes and was independent of X jaw sizes and asymmetric Y jaw opening. In comparison with measured values and calculate values from Golden-STT based radiation treatment planning system (RTP system), it showed very good agreement within difference of 1%. It could be concluded that EDW is a very reliable and useful tool as a beam modification substitute for conventional MTW.

Key Words: Enhanced Dynamic Wedge, Dose profiles, Golden STT, Effective wedge factor

INTRODUCTION

An Enhanced Dynamic Wedge (EDW) is one of the ways of making wedged beam distributions. It is quitely different from a physical wedge in aspect of dosimetric characteristics. For the purpose of tissue deficit compensation or making homogeneous dose distribution, wedged beams are frequently used in radiation therapy planning. Conventionally, physical metal wedge (MTW) is widely used for that purpose. But it has some risks of collision with patients, undesired effects such as output loss due to dark area of universal wedge system and unnecessary physical loading of therapist.[1-4] Enhanced dynamic wedge (EDW) system has a potential to reduce such kinds of demerits of MTW system. Moreover EDW system has various wedge angles, 10°, 15°, 20°, 25°, 30°, 45° and 60°, so it could give chances to choose various wedged beams. EDW is also fundamentally an intensity modulated radiation therapy technique in which one collimating jaw sweeps across the field to define a desired wedged dose distribution while dose rate is modified according to jaw position. It can make discrete or continuous wedge angles from 0° to 60° for field widths from 4 to 30 cm in the direction of the wedge, and up to 40 cm perpendicular to the wedge direction. Varian dynamic wedge was introduced by Leavitt et al.[3-5] in 1990, and EDW, which enhances some technical problems of initial dynamic wedge system was developed continuously in 1997. Because EDW virtually makes wedged beam shapes using dynamic colli-

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mator jaws, it is necessary to be very cautious to use at clinic when it is commissioned and applied. If we commission it carefully before using at clinic, it would be a very useful tool for radiation therapy. The purpose of this paper is to compare the EDW system with the conventional MTW system in aspect of several dosimetric parameters such as PDD, peripheral dose, surface dose and also to analyze the effective wedge factors according to the various X, Y Jaw settings. In addition, this study includes the comparison with both dose profiles obtained by the measurements and calculated by commercial RTP system implemented golden-STT (Segmented Treatment Table).[3-4]

MATERIALS AND METHODS

1. Percentage depth dose measurement

For the analysis of characteristics of depth dose distribution, we measured PDDs of open beam, 60° MTW and 60° EDW for 6 MV and 15 MV beams (Varian Clinac 2100 C/D, Varian Oncology Systems, USA) using field size of 10×10 cm^2 with source-skin distance (SSD) 100 cm. In this paper, the authors selected 60° wedge angle for comparison because more steeper wedge tends to make change the beam quality. The PDDs were scanned in the water phantom (Blue phantom, Wellhofer, IBA co., Belgium) from d_{max} to 30 cm depth (1.5 cm, 2.8 cm for 6 MV, 15 MV respectively) with a cylindrical ionization chamber (IC10, Wellhofer, IBA co., Belgium) for 6 MV and 15 MV photon beams.

2. Surface dose and peripheral dose

The measurements for peripheral dose and surface dose were also performed for comparison with open beam, 60° MTW and 60° EDW for 6 MV. For the purpose of measurements of surface dose, the parallel plate chamber (Markus, 34059, PTW, Germany) with sensitive volume of 0.22 cm^3 and solid phantom (Wellhofer, IBA, White Solid phantom, Belgium) were used. The measurements were performed in the area of build-up range (1.5 cm) of 6 MV under source to surface distance 100 cm^2 for three items above. In case of peripheral dose measurements, they were measured at the point of up to 7.5 cm offset outside from the field with size of 15 ×15 cm^2 for 6 MV. The measurements were accomplished by a water phantom and IC10 chamber. These data were normalized at the values of centers of fields.

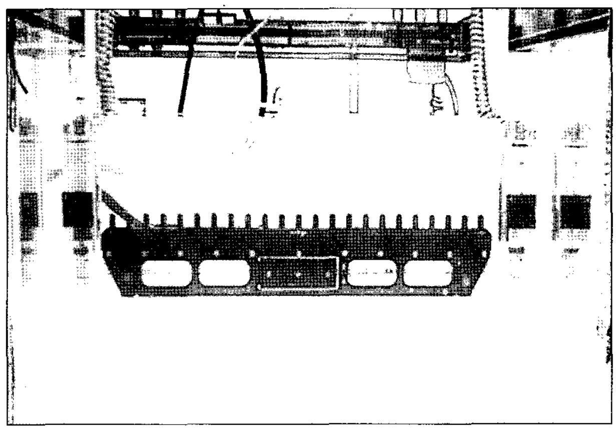

Fig. 1. EDW beam profile measurement set-up for 10 cm depth in the water phantom. All 23 chambers are apart from 2 cm spacing each other, and to get the resolution of 0.5 cm, four irradiations are needed and summed up cumulative doses on each points.

3. Beam profiles measurements and comparisons

The measured beam profiles of 60° EDW for 6 MV using multi-chamber array (CA 24, Wellhofer, IBA co., Belgium) were scanned at the depth of d_{max} (1.5 cm) and 10 cm. The CA24 chamber array has 23 ion chambers spaced by 2.0 cm apart in a linear fashion. The 23 channels for the chamber array were connected with Wellhofer MD240 electrometer, which was interfaced with the PC-CAN board in a control PC. The chamber array was mounted on a regular guide rail in a Wellhofer water phantom. To acquire one EDW wedged profile, minimum four sessions, which were to obtain 0.5 cm resolution in the 2 cm chamber's separations, were needed (Fig. 1).[6,7] In addition, the beam profiles calculated using RTP system (CadPlan ver. 2.7, Varian Oncology Systems, USA) were performed with same geometric conditions as the CA24 measurements. The EDW of Cadplan system was configured by Golden-STT. It was compared with each data to find the discrepancies between the measured and calculated values, and to evaluate the validation of Golden-STT calculation algorithm.

4. EDW effective wedge factors

EDW wedge factor is defined as the ratio of the EDW field output to open field output for the same geometric condition at the center of the field aperture. The depths for measurement were all maximum depths for the specific photon energy (1.5 cm for 6 MV, 2.8 cm for 15 MV). The measurements of wedge factors were implemented with an ionization chamber (IC10, Wellhofer, IBA co., Belgium with Keithley 35040, Keithley Instruments, Inc., Cleveland, OH, USA). The measurements of effective wedge factor of EDWwere performed under conditions of symmetric and asymmetric collimations, and analyzed the effects. The set-up geometries for asymmetric Y-jaw dependency on effective wedge factors of EDW were presented at Fig. 2.[8-11]

RESULTS

1. Percentage depth doses (PDDs)

For 6 MV photon beam, PDDs of 60°EDW showed 0.4% and 2% higher than that of open field and 60° MTW respectively (Fig. 3a). On the other hand, PDDs of open field, MTW and EDW for 15 MV showed a relatively good agreement with the measurement uncertainty within 0.5% (Fig. 3b).

2. Surface dose and Peripheral dose

Surface doses of open beam and EDW were in a goodagreement within 1% of difference between 0 cm to d_{max} (1.5 cm). On the contrary, the surface doses of 60° MTW were shown some differences in comparison to the others (Table 1). It was presumed that this result was mainly due to beam hardening effect of physical metal wedge.

In the result of the measurements of peripheral dose, it was shown that the dose outside the field was higher when MTW was applied, than when open field and EDW were applied. It was

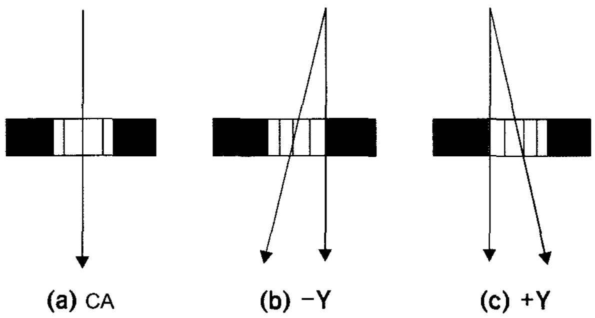

Fig. 2. Set-up scheme for asymmetric Y-jaw dependency on EDW effective wedge factors. (a) CA, central axis of symmetric opening, (b, c) Divergent axis of asymmetric Y-jaw opening. Y-jaw openings were all the same and measured points were considered by beam's divergencies for asymmetric set-up.

Table 1. Surface doses in the build-up region of 60° EDW, Open field and 60° MTW for Varian CL 2100 C/D 6MV photon beam. The data of 60° EDW, Open field were very similar each other, but the data of 60° MTW showed maximum 9.2% difference from that of open beam.

Depth (cm)	60° EDW (%)	Open (%)	60° MTW (%)
0	53.6	52.6	43.4
0.3	92.6	92.2	89.2
0.6	97.9	97.4	96.1
0.9	99.2	99.2	99.2
1.2	99.7	99.8	99.8
1.5	100	100	100

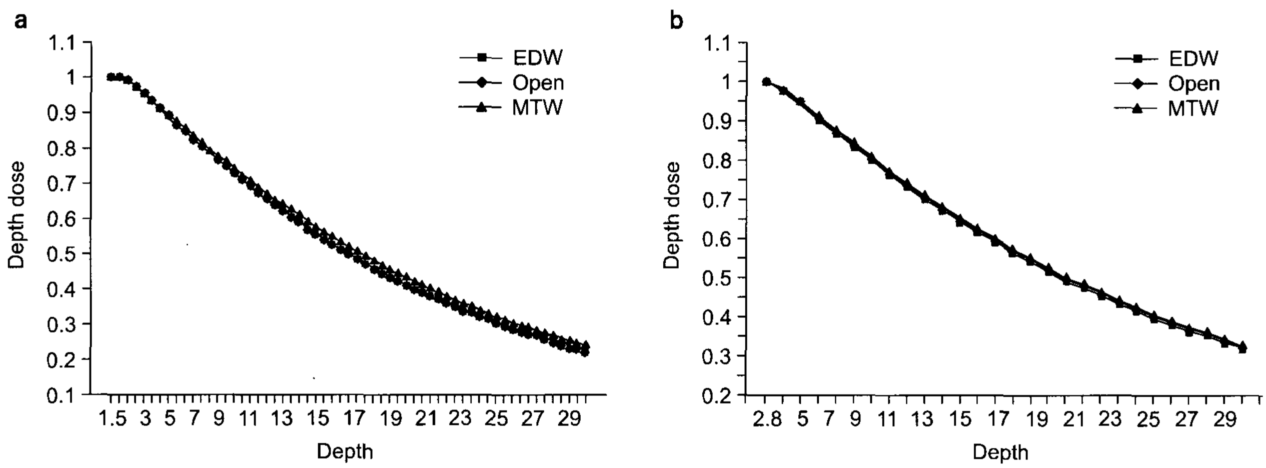

Fig. 3. Comparison of percentage depth dose of 60° EDW, (a) open field, 60° MTW for 6 MV photon beam. The PDD of 60° MTW was slightly higher than others, (b) open field, 60° MTW for 15 MV photon beam. All the PDDs were nearly same.

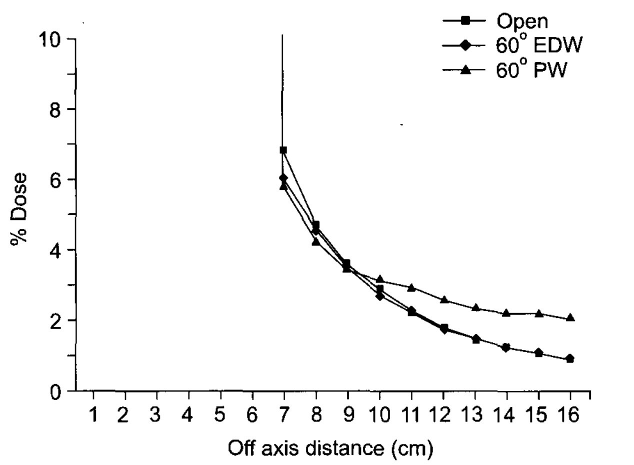

Fig. 4. Peripheral dose comparison for open field, 60° EDW, 60° PW (MTW). In the outside of field, the peripheral dose of 60° MTW was about 1% higher than others.

considered that MTW in the beam pathway generated much more scatter rays compared with EDW and open beam (Fig. 4).

3. Beam profiles

Beam profiles of EDW were acquired by using chamber array 24 (CA 24). One profile was composed of all of four sessions, which have spots spacing with 2 cm apart. Therefore, in order to achieve a EDW dose profile with 0.5 cm resolution, four sessions of cumulative measurements were needed (Fig. 5).

The measured beam profiles at d_{max} and 10 cm depth were compared with the calculated profiles by CadPlan system. Because EDW configuration method of CadPlan is based on the combination of open field beam data and Golden-Seg-

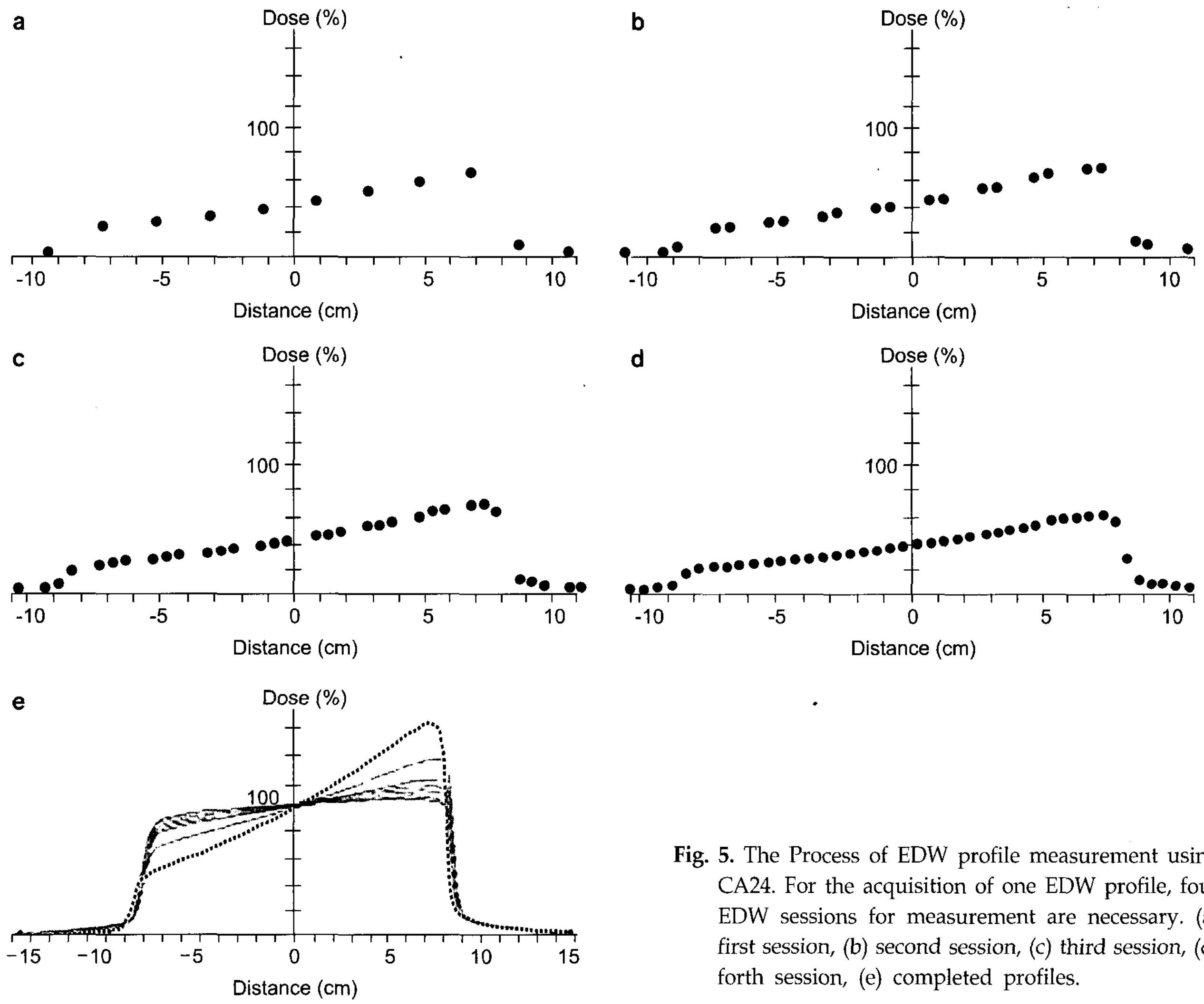

Fig. 5. The Process of EDW profile measurement using CA24. For the acquisition of one EDW profile, four EDW sessions for measurement are necessary. (a) first session, (b) second session, (c) third session, (d) forth session, (e) completed profiles.

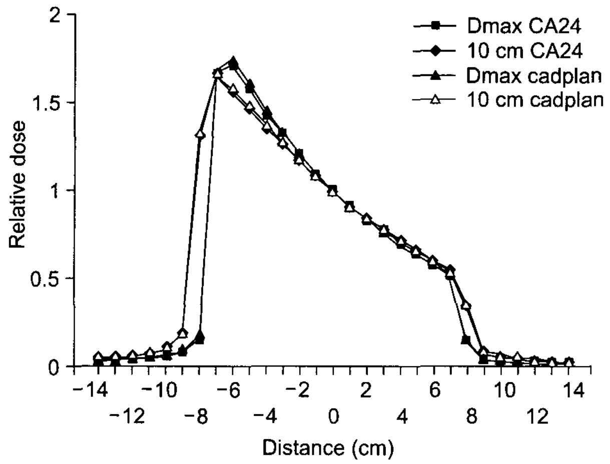

Fig. 6. The comparisons with measured and calculated EDW dose profiles with CA24 and Cadplan system respectively. Good agreements were shown within 1% difference.

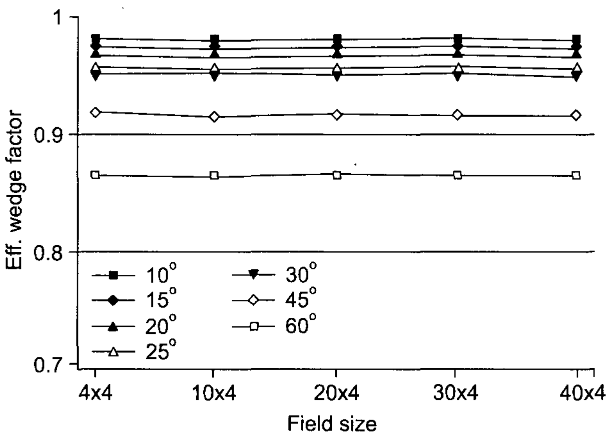

Fig. 7. EDW wedge factors according to the different X-jaw sizes during Y-jaw is constant as 4 cm. There were shown quite Independency on EDW wedge factors by Y-jaw sizes.

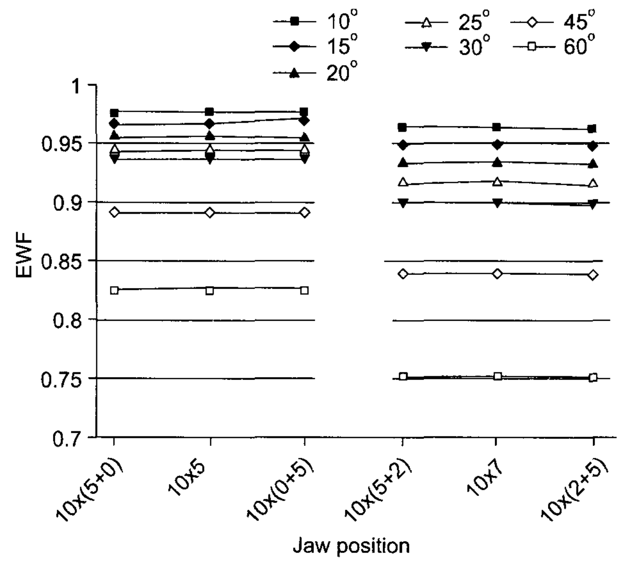

Fig. 8. Comparison of EDW wedge factors according to the asymmetric and symmetric Y-jaw setting. It showed that if Y-jaw opening sizes were same, the factors would be so close.

mented Treatment Tables (Golden-STT), no other beam data for EDW are needed. It is necessary for comparing with measured values. The agreements between the measured and the calculated values were good within 1% of difference. The comparison graphs were shown in Fig. 6.

4. Effective wedge factor

Wedge factor measurements were accomplished by several different geometrical conditions i.e. various combinations of collimator jaws for dependency of XY-jaws. Through our work, we have known that EDW wedge factor is mainly dependent on Y-jaw sizes and independent on X-jaw setting. Moreover, in spite of asymmetric Y-jaw setting, wedge factors were solely affected by Y-jaw size, namely if Y-jaw setting would be same, wedge factors would be same whether they were symmetric or asymmetric Y fields (Fig. 7, 8).

As a result, the wedge factors are so straight forward with respect to Y-jaw (Fig. 9), and quite independent of X-jaw sizes and asymmetric Y-jaw as well.

DISCUSSION AND CONCLUSION

For the reliable clinical application of EDW, it is mandatory that dosimetric parameters should be well commissioned. Admittedly, it is necessary to compare EDW system with a conventional wedge system and analyse RTP calculation method. The characteristics of EDW beam were so similar to those of open beam in aspect of basic beam data such as depth dose, surface dose, and peripheral dose. Basically EDW beam shaping is generated by open collimated beam and Golden-STT, therefore there might not be time-consuming process to obtain EDW profiles using CA24. In addition, EDW system showed significantly different results from MTW system in wedge factors, especially in the special properties such as Y-jaw

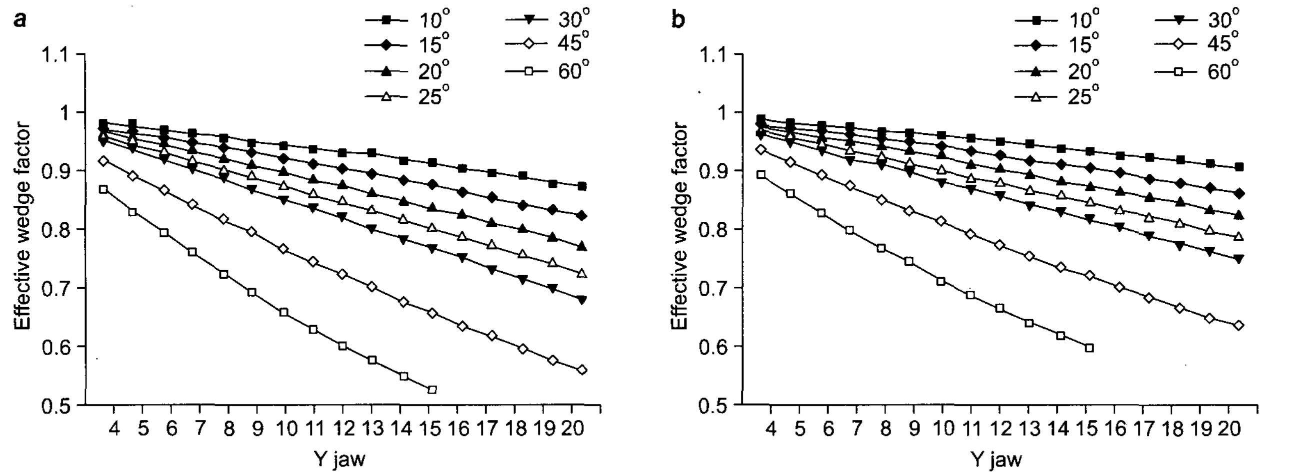

Fig. 9. Results of EDW factors. (a) EDW wedge factors of 7 different angles (10°, 15°, 20°, 25°, 30°, 45° and 60°) for 6 MV photon beam. They decreased so linearly, (b) EDW wedge factors of 7 different angles (10°, 15°, 20°, 25°, 30°, 45° and 60°) for 15 MV photon beam. They also decreased so linearly same as 6 MV.

dependency, only on Y-jaw opening size, not on jaw position. This properties were investigated in this paper and need to study further more complex combinations of EDW beams. This paper are valuable for basically characterization of EDW. Therefore, careful apply of EDW system in a routine clinical practice should be needed and the responsible physicist should evaluate all of the characteristics of EDW beam in comparison with conventional metal wedge system. Moreover, an appropriate QA method should be designed with care according to their institution's situations.

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선량계측인자에 따른 기능강화동적쐐기와 금속쐐기의 비교

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기능강화동적쐐기는 쐐기 형태의 선량 분포를 만드는 방법과 선량 특성적인 면에서 금속쐐기와 상당한 차이를 가지고 있다. 기능강화동적쐐기의 임상적용을 위해서는 금속쐐기와 다른 선량특성을 분석하고 이에 따른 적절한 커미셔닝이 필수적이다. 본 연구의 목적은 기본 선량계측인자에 기초한 기능강화동적쐐기와 금속쐐기의 선량특성을 분석하는 데 있다. 선량 계측학적 특성을 나타내는 심부선량분포, 조사면 주변 선량, 표면선량, 실효 쐐기인자, 쐐기의 선량측면도를 측정, 분석하였다. 또한 열린 조사면과 금속쐐기와의 비교측정을 통해 기능강화동적쐐기가 가지고 있는 고유한 특성을 분석하였다. 기능강화동적쐐기의 선량측면도 측정은 Chamber Array 24 (CA24)를 이용하였으며, Golden Segmented Treatment Table (Golden-STT)로 구현한 치료 계획 장치의 계산값과 비교하였다. 또한 실효쐐기인자 측정은 각각의 X, Y 콜리메이터에 따른 특성을 분석하였다. 심부 선량 백분율측정에서 열린 조사면과 기능강화쐐기의 비교결과, 0.2~0.5% 이내로 일치하였고, 금속 쐐기인 경우 약 2%의 비교적 큰 차이를 보였다. 조사면 주변선량측정에서는 금속쐐기가 약 1% 높았다. 표면선량 측정 결과, 금속쐐기가 약 10% 낮게 평가되었다. 기능강화쐐기의 실효쐐기인자는 Y jaw가 커짐에 따라 연속적으로 감소됨을 알 수 있었다. X jaw에 따른 쐐기인자 의존도 측정에서는 X jaw에 따른 의존도는 거의 없는 것으로 평가되었다. 또한 비대칭 조사면의 쐐기 인자측정에서는 비대칭에 상관없이 Y jaw의 크기만 같으면 실효쐐기인자가 같았다. 선량측면도 측정에서는 CA24를 이용해 얻은 실측값과 Golden STT로 Cadplan에서 구현한 계산값이 1%이내로 일치하였다. 본 연구를 통해 기능강화동적쐐기가 가지고 있는 특성을 분석하였으며, 금속쐐기를 대체할 수 있는 유용한 도구임을 알 수 있었다.

중심단어: 기능강화동적쐐기, 선량측면도, Golden-STT, 실효쐐기인자