Original Article

Evaluation of Dose Calculation Algorithms Accuracy for ISOgray Treatment Planning System in Motorized Wedged Treatment Fields

Sajjad Raghavi[1], Hamid-Reza Sadoughi[2], Mohammad Ehsan Ravari[1,3], Marziyeh Behmadi[1,3]

[1]Department of Medical Physics, Faculty of Medicine, Semnan University of Medical Sciences, [3]Cancer Research Center, Semnan University of Medical Sciences, Semnan, [2]Department of Medical Physics and Radiology, Faculty of Paramedicine, North Khorasan University of Medical Sciences, Bojnurd, Iran

Abstract

Background: Different dose calculation methods vary in accuracy and speed. While most methods sacrifice precision for efficiency Monte Carlo (MC) simulation offers high accuracy but slower calculation. ISOgray treatment planning system (TPS) uses Clarkson, collapsed cone convolution (CCC), and fast Fourier transform (FFT) algorithms for dose distribution. This study's primary goal is to evaluate the dose calculation accuracy for ISOgray TPS algorithms in the presence of a wedge. **Methods:** This study evaluates the dose calculation algorithms using the ISOgray TPS in the context of radiation therapy. The authors compare ISOgray TPS algorithms on an Elekta Compact LINAC through MC simulations. The study compares MC simulations for open and wedge fields with ISOgray algorithms by using gamma index analysis for validation. **Results:** The percentage depth dose results for all open and wedge fields showed a more than 98% pass rate for points. However, there were differences in the dose profile gamma index results. Open fields passed the gamma index analysis in the in-plane direction, but not all points passed in the cross-plane direction. Wedge fields passed in the cross-plane direction, but not all in the in-plane direction, except for the Clarkson algorithms. **Conclusion:** In all investigated algorithms, error increases in the penumbra areas, outside the field, and at cross-plane of open fields and in-plane direction of wedged fields. By increasing the wedge angle, the discrepancy between the TPS algorithms and MC simulations becomes more pronounced. This discrepancy is attributed to the increased presence of scattered photons and the variation in the delivered dose within the wedge field, consequently impacts the beam quality. While the CCC and FFT algorithms had better accuracy, the Clarkson algorithm, particularly at larger effective wedge angles, exhibited greater effectiveness than the two mentioned algorithms.

Keywords: *Dose calculation algorithms, effective wedge angle, GATE, ISOgray, Monte Carlo simulation, treatment planning system*

Submitted: 05-May-2024 **Revised:** 17-Jul-2024 **Accepted:** 12-Aug-2024 **Published:** 05-Nov-2024

Introduction

The accurate and fast calculation of a three-dimensional (3D) dose distribution within the patient is a critical approach in modern radiation oncology. It provides a reliable and verifiable link between the selected clinical parameters and the observed clinical outcomes for a specific treatment approach.[1]

Dose calculation systems have rapidly improved over the last few decades due to the development of computer processing. The most recently developed dose calculation algorithm in the radiation therapy planning system was developed to accurately and rapidly calculate the irradiated dose and scattered irradiated volume.[2] One of the important challenges for development of modern dose calculation algorithms is the conflict between "high speed" and "high accuracy," in such a way that speed and accuracy limit each other.[1]

In general, dose calculation algorithms are divided into three categories: (a) Correction-based algorithms, (b) model-based algorithms, and (c) Monte Carlo (MC)-based algorithms. Each of these methods can be used in 3D treatment planning, although they differ in accuracy and speed. Correction-based algorithms are semi-experimental, relying on measured data from a water phantom. Model-based algorithms, such as convolution/superposition, calculate the dose distribution from a physical model.[3,4]

How to cite this article: Raghavi S, Sadoughi HR, Ravari ME, Behmadi M. Evaluation of dose calculation algorithms accuracy for ISOgray treatment planning system in motorized wedged treatment fields. J Med Signals Sens 2024;14:31.

Address for correspondence:
Dr. Marziyeh Behmadi, Cancer Research Center, Semnan University of Medical Sciences, Semnan, Iran. Department of Medical Physics, Faculty of Medicine, Semnan University of Medical Sciences, Semnan, Iran.
E-mail: behmadim881.mph@gmail.com

Access this article online

Website: www.jmssjournal.net

DOI: 10.4103/jmss.jmss_28_24

Quick Response Code:

Convolution/superposition dose calculation algorithms are computationally slow. Therefore, many different approximations have been introduced to speed up the calculations, for example, the polyenergetic and parallel kernel approximations. Calculation techniques such as fast Fourier transform (FFT) and collapsed cone are often used to speed up the convolution and superposition calculations. However, the use of the FFT technique results in fast and less accurate dose calculations for treatments with inhomogeneities while the collapsed cone technique allows more accurate but slower calculations compared to the FFT technique.[5]

MC method is considered to be the most accurate algorithm for dose calculation but it requires the longest processing time.[6] Apart from MC method, all other methods make different degrees of approximation and simplification which lead to much faster calculation speeds but also result in less accurate dose distributions compared to the MC simulation.[3,7,8]

ISOgray treatment planning system (TPS) employs three algorithms to calculate dose distribution in 3D space. These algorithms are Clarkson and two points kernel (Collapsed-cone and Convolution FFT) that categorize the model-based algorithm that widely used in commercial radiotherapy TPSs.[6,9]

Reduction of errors and uncertainties in the dose calculation plays an important role in the success of a treatment procedure.[10,11] International Commission on Radiation Units and Measurements (ICRU) has recommended an overall dose accuracy within 5%.[8] Considering the uncertainties resulting from patient setup, machine calibration and dose calculation from TPSs, it is necessary to have a dose calculation algorithm that can predict dose distribution within 3% accuracy.[12]

Several researchers have evaluated different single-dose calculation algorithms at different tissue conditions by comparing TPS results with experimental measurements and discussed the factors affecting the accuracy of calculation.[5,7,13] On the other hand, some studies have evaluated the accuracy of several dose calculation algorithms.[14-16] Farhood *et al.*[17] and Bahreyni Toossi *et al.*[14] in 2017 evaluated the accuracy of TiGRT TPS in breast and head-neck regions, they announce that the TPS overestimate the dose compare to measurements. Tan *et al.* in 2014,[18] Kim *et al.* in 2016,[2] and Kavousi *et al.* in 2018[3] evaluated the accuracy of several algorithms of different TPSs and showed that some simple algorithms have large deviation in some cases. Several studies have assessed the dose calculation accuracy of different algorithms TPSs in the wedged field technique. Venselaar and Welleweerd in 2001[19] evaluated the dose calculation accuracy of several TPSs and showed that for most systems, dose calculation accuracy in wedged fields was within the tolerance limit. Farhood *et al.* in 2016[15] evaluated the accuracy of TiGRT and ISOgray TPS for wedge fields by comparing to measurements. Furthermore, Golestani *et al.* in 2015[9] and Mohammadi *et al.* in 2017[6] considered the accuracy of ISOgray by comparing different ISOgray TPS algorithms to dosimetry and MC results in the presence of wedge filter. They declare that the error in dose calculation is significant in the presence of a wedge. Zabihzadeh *et al.* in 2020 investigated output factors and dose profiles for symmetric and asymmetric wedged fields of 6 MV beams by measurement and simulation. They reported lower output factor for asymmetric wedged fields than the corresponding symmetric open and wedged fields.[20] Recently, Zeinali *et al.* in 2023 reported the acceptable results of collapsed cone superposition algorithm for chest wall tangential fields using virtual wedge filters.[21]

To the best of our knowledge, no investigation has been carried out on the different dose calculation algorithm's accuracy of ISOgray TPS in wedged fields that investigate the accuracy of effective wedge angels by comparing TPS results to MC simulation. Therefore, this study aimed to assess the accuracy of different dose calculation algorithms of ISOgary TPS for open and wedge fields with different wedged angels.

Materials and Methods

The ISOgray (DosiSoft, France) TPS was used for this study. ISOgray is a widely used TPS known for its accuracy and reliability in dose calculation. It employs various algorithms for dose calculation. The evaluated algorithms in this study were divided into two categories:

A. Measurement-based algorithm that includes Clarkson
B. Model-based algorithms using point kernel convolution that includes FFT, superposition and collapsed cone convolution (CCC).

To perform the current study, the validated simulation of Elekta Compact (6 MV) Linear accelerator Raghavi *et al.*[22] and ISOgray TPS (DosiSoft, France) were used. In order to validate the simulation, we compared the percentage depth dose (PDD) and dose profile of the reference field size and depth (10 cm × 10 cm, 10 cm) with the relative dosimetry for open and wedge fields according to TG-106 protocol.

Simulations were done with Gate 7.2 (Ubuntu 16.04, Geant4 10.2) as an open source MC code. MC codes were run on a computer with the following performances: Intel Core i7 CPU with 3.2 GHz and 8GB RAM. To read and extract the data from MC output files, MATLAB R2015b (MathWorks Inc., MA) was used. The simulation was validated with gamma index code which was written in MATLAB m-file.

The study was done in two parts as below:

1. MC simulation

The geometrical details and the composition of each linac's components and a water phantom with

60 cm × 60 cm × 60 cm size were modeled and simulated at source-surface distance = 100 cm for open and wedge fields. In all setups, the gantry angle was 0° so that the beam was perpendicular to the surface of the phantom. Figure 1 illustrates a schematic view of the linac modelling. The simulation has been validated in previous study of authors.[22] The PDD and dose profile for open and wedge 5 cm × 5 cm, 10 cm × 10 cm and 20 cm × 20 cm field sizes were simulated.

To speed up the simulation, the phase space method, which was placed after the ionization chamber, was used. In the wedge field model, the phase space was located before the wedge to achieve the true dose profile. The first part of the phase space code was run for 2×10^9 particles. In the second part of the code, the phase space was considered as a source and 4×10^{10} and 6×10^{10} particles for open and wedge fields were tracked and the dose distribution and dosimetric parameters were calculated, respectively. The position of the phase space in the first and second codes was illustrated in Figure 1a and b, respectively.

2. ISOgray TPS Evaluation

The PDDs and dose profiles for the same three field sizes and depths for open and wedge (60°) fields of CCC, FFT, and Clarkson algorithms were compared with MC results in a water phantom. For the other wedge angles, effective doses were calculated with the combination of MC open and wedge fields using the Petti equation (1–1) for 2°, 5°, 7°, 10°, 15°, 20°, 30° and 45° wedge angles in 10 cm × 10 cm field size and 10 cm depth.[23]

$$B = \frac{f}{\frac{\tan\theta_W}{\tan\theta_E} + f - 1} \quad (1\text{-}1)$$

Which B is the wedge field weighting factor that has normalized to 1 by open field weighting factor (A), θ_W and θ_E are nominal and effective wedge angles, respectively, and the f factor is the ratio of the slopes of the PDD curves for the open and wedge fields.

Figure 2 illustrates how to combine the two isodoses curve to obtain the effective wedge angle.

In the last step, the effective isodose curves, that resulted from the equation, were compared with ISOgray results and the accuracy of ISOgray TPS algorithms including FFT, CCC, and Clarkson in the presence wedge filter was studied using gamma index tool with 3% - 3 mm criteria.

Results

To evaluate ISOgray TPS, the TPS's PDDs and the dose profiles were compared with MC dose calculation results for three field sizes (5 cm × 5 cm, 10 cm × 10 cm and 20 cm × 20 cm) and reference depth (10 cm) for open and wedge fields.

The gamma index results for all investigated algorithms, field sizes and depths at both in-plane and cross-plane directions with 3% - 3 mm criteria were illustrated in Tables 1-5 for open and wedge PDDs and dose profiles. Based on Tables 1 and 2, the PDD for all open and wedge fields for all algorithms passes more than 98% of points.

The gamma index results for open fields' dose profiles indicate that, for all investigated algorithms, the points at the in-plane direction meet the criteria. However, not all points at the cross-plane direction meet the criteria as reported in Table 3.

These results for wedge fields are different, based on Table 4. Even though the dose profile points for the in-plane direction could not pass the gamma index criteria, the cross-plane directions points could pass the 90% points except for Clarkson algorithms in 5 cm × 5 cm and 10 cm × 10 cm field sizes.

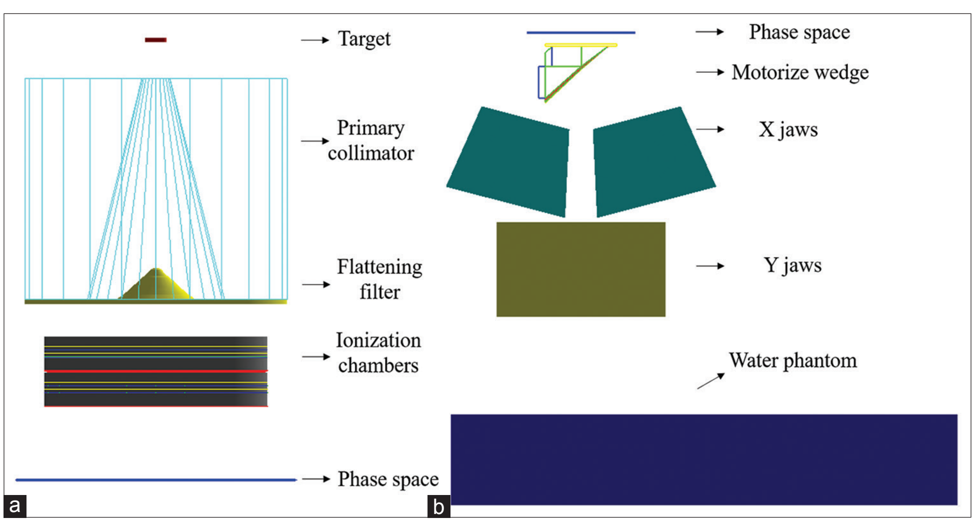

Figure 1: A schematic geometry of 6 MV Elekta Compact linac was used in the present study. (a) First phase, (b) Second phase

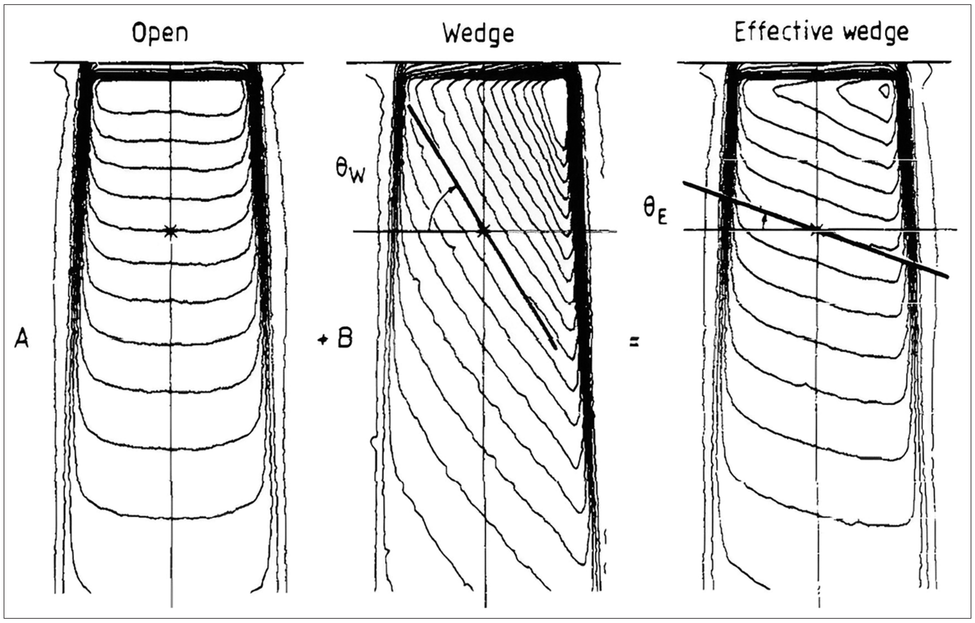

Figure 2: The effective wedge distribution D is given by the combination of the open D0 and wedge Dw fields in the proportions A and B, respectively; where A + B = 1 (33)

Table 1: Percentage depth dose comparison of Monte Carlo and treatment planning system algorithms in open fields by gamma index (3% - 3 mm)

	Field size (cm^2)		
	5×5	10×10	20×20
CCC (%)	98.68	98.68	100
Clarkson (%)	100	100	100
FFT (%)	100	98.68	98.68

CCC – Collapsed cone convolution; FFT – Fast fourier transform

Table 2: Percentage depth dose comparison of Monte Carlo and treatment planning system algorithms in wedge fields by gamma index (3% - 3 mm)

	Field size (cm^2)		
	5×5	10×10	20×20
CCC (%)	98.68	98.68	100
Clarkson (%)	100	100	98.68
FFT (%)	100	100	98.68

CCC – Collapsed cone convolution; FFT – Fast fourier transform

To clarify the result, Figures 3-5 are illustrated for three investigated algorithms and field sizes at reference depth, which demonstrate the PDDs and the dose profiles for open and wedge fields, respectively. In all three figures, the different TPS dose calculation algorithm results were demonstrated beside the MC results, which considered as reference.

In the last step, the investigated effective wedge angle dose profiles that have been calculated from the analytical equation (Petti and Siddon[23]) by MC results, were compared with the different ISOgray algorithm dose profiles using the gamma index.

Based on Table 5, more than 94% of dose profile points of all algorithms can pass the gamma index with 3%-3 mm criteria except for the 45° wedge angle which only Clarkson algorithm can pass more than 90% of points.

Figure 6 demonstrates the MC and different TPS algorithms dose profiles for effective wedge angles (5°, 10°, 15°, 20°, 30° and 45°) at reference field size and depth.

Table 6 illustrates the investigated nominal wedge angles and the effective wedge angles resulting from MC and TPS algorithms isodose curves. The effective wedge angles have been calculated by fitting a line to isodose curves based on the ICRU24[8] protocol.

Discussion

According to Tables 1 and 2, which compare the PDD results of the MC and ISOgray algorithms for three different open and wedge field sizes, it can be observed that all algorithms can achieve passing rates of over 90% for the points evaluated. This suggests that the PDD calculations produced by all algorithms are considered to be sufficiently accurate.

As demonstrated in Table 3 which reports the comparison of MC and ISOgray algorithms dose profile results for three open field sizes at both directions, the cross-direction results for all algorithms have less agreement relative to the in-plane direction. It is due to the TPS commissioning has been done by a dosimeter with 0.6 cm^3 sensitive volume (TM30013 Farmer type chamber) which has a larger sensitive volume in the cross-plane direction compared to the in-plane direction. Furthermore, the gamma index passing rate decreases as the field size decreases due to the increase of penumbra area in small

Table 3: Dose profile comparison of Monte Carlo and treatment planning system algorithms in open fields by gamma index (3% - 3mm)

Algorithm	Field size (cm^2)					
	5×5		10×10		20×20	
	Direction					
	In plane	Cross plane	In plane	Cross plane	In plane	Cross plane
CCC (%)	100	65.22	100	81.57	100	91.39
Clarkson (%)	91.49	59.57	94.80	92.21	96.69	95.36
FFT (%)	100	65.96	100	84.20	100	93.38

CCC – Collapsed cone convolution; FFT – Fast fourier transform

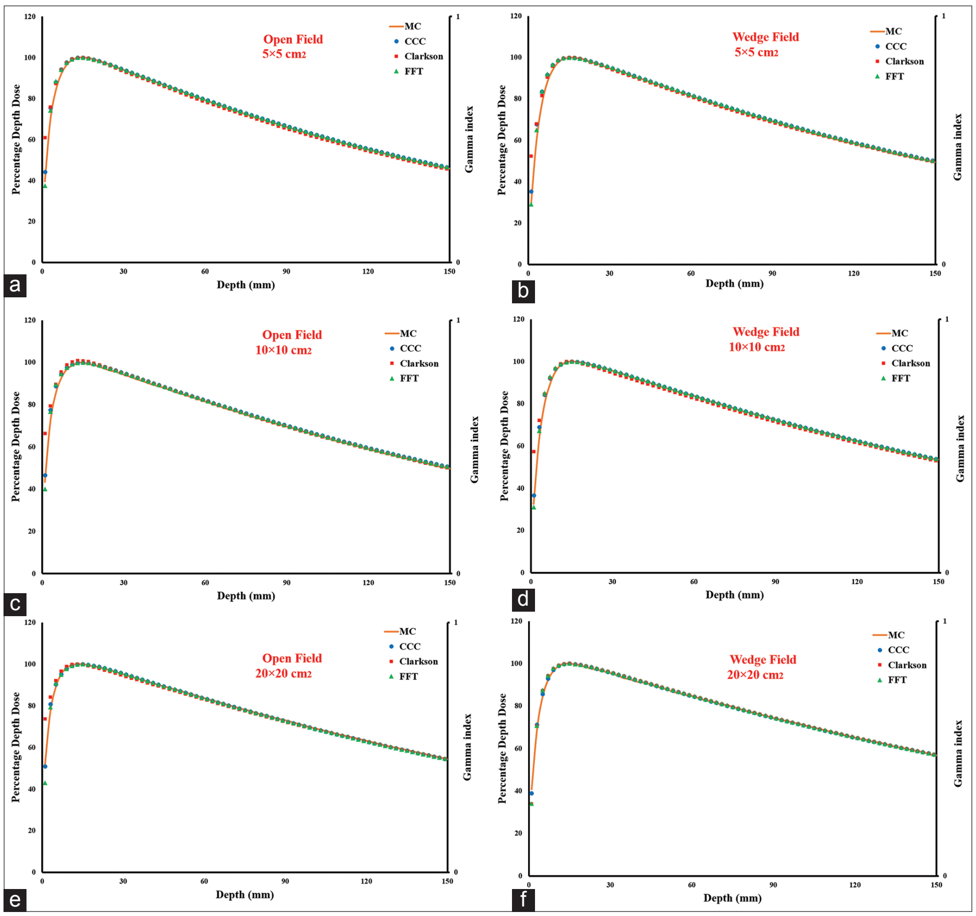

Figure 3: Treatment planning system algorithms and Monte Carlo's percentage depth doses comparison for three open and wedged fields (60°) for reference fields size. MC – Monte carlo; CCC – Collapsed cone convolution; FFT – Fast fourier transform. a) Open Field 5×5 cm2; b) Wedge Field 5×5 cm2 ; c) Open Field 10×10 cm2; d) Wedge Field 10×10 cm2; e) Open Field 20×20 cm2; f) Wedge Field 20×20 cm2

fields and electron disequilibrium in the penumbra area. The studies by Muhammad *et al.* (2010)[24] and Dawod[25] confirm the results obtained in this work. In general, TPS dose calculations may not be as accurate in out-of-treatment plan fields, which might be due to the inaccurate dose modeling in these regions.[10,26-28]

Figure 4 clearly shows a noticeable inaccuracy in the dose calculation algorithms in the penumbra area of the cross-plane direction, especially for small fields. The plot shows the results of both the TPS and MC simulation for open fields. According to the figure both CCC and FFT algorithms have similar results compared to the Clarkson algorithm. This similarity can be attributed to CCC and FFT being model-based algorithms, while Clarkson is a measurement-based algorithm. The discrepancy between the model-based algorithms and the measurement-based algorithm in the penumbra area suggests that the model-based algorithms may not accurately capture the dose distribution in this region. This could be due to limitations in the modeling assumptions or parameters used by these algorithms. However, as the 2013 study by Asnaashari *et al.*[29] showed, measurement-based algorithms like Clarkson have less compliance than model-based algorithms.

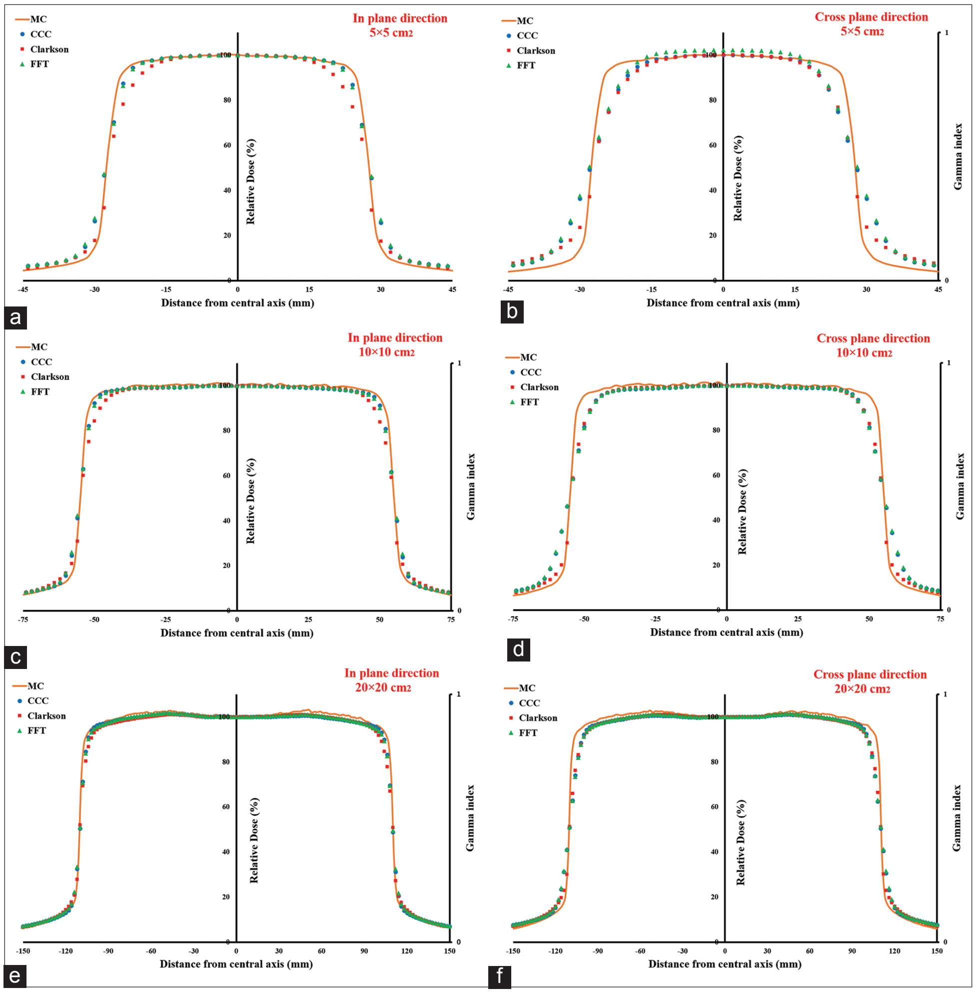

Figure 4: Treatment planning system algorithms and Monte Carlo's dose profile comparison for three (5 cm × 5 cm, 10 cm × 10 cm, 20 cm × 20 cm) open fields at 10 cm depth. MC – Monte Carlo; CCC – Collapsed cone convolution; FFT – Fast fourier transform. a) In plane direction 5×5 cm2; b) Cross plane direction 5×5 cm2; c) In plane direction 10×10 cm2; d) Cross plane direction 10×10 cm2; e) In plane direction 20×20 cm2; f) Cross plane direction 20×20 cm2

Table 4: Dose profile comparison of Monte Carlo and treatment planning system algorithms in wedge fields by gamma index (3% - 3 mm)

Algorithm	Field size (cm^2)					
	5×5		10×10		20×20	
	Direction					
	In plane	Cross plane	In plane	Cross plane	In plane	Cross plane
CCC (%)	100	100	84.21	100	61.11	94.44
Clarkson (%)	93.61	48.93	98.70	71.43	87.41	98.66
FFT (%)	100	100	87.01	100	61.59	98.66

CCC – Collapsed cone convolution; FFT – Fast fourier transform

Based on the information presented in Table 4, which compares the MC and TPS algorithm dose profile results for three wedge field sizes in both in-plane and cross-plane directions, there are some notable observations. There is less accommodation in the in-plane direction relative to the cross-plane direction for CCC and FFT algorithms opposite to Clarkson algorithm which there is better accommodation in the cross-plane direction respect to in-plane direction. For CCC and Clarkson algorithms, these results were achieved because there are different thicknesses of wedges along to in-plane direction, which causes nonuniformity in the production and absorption of scattered rays. With increasing the field size, more surface of the wedge is placed in the field and the nonuniformity increase; therefore, mismatching will increase as well. The results in Table 4 show that the CCC and FFT algorithms are unable to accurately calculate the dose profile in the direction of the wedge slope. As reported in Fraass *et al.* study in 1998.[30]

The effect of nonuniformity in scatter rays caused by the wedge slope in the in-plane direction is clearly evident

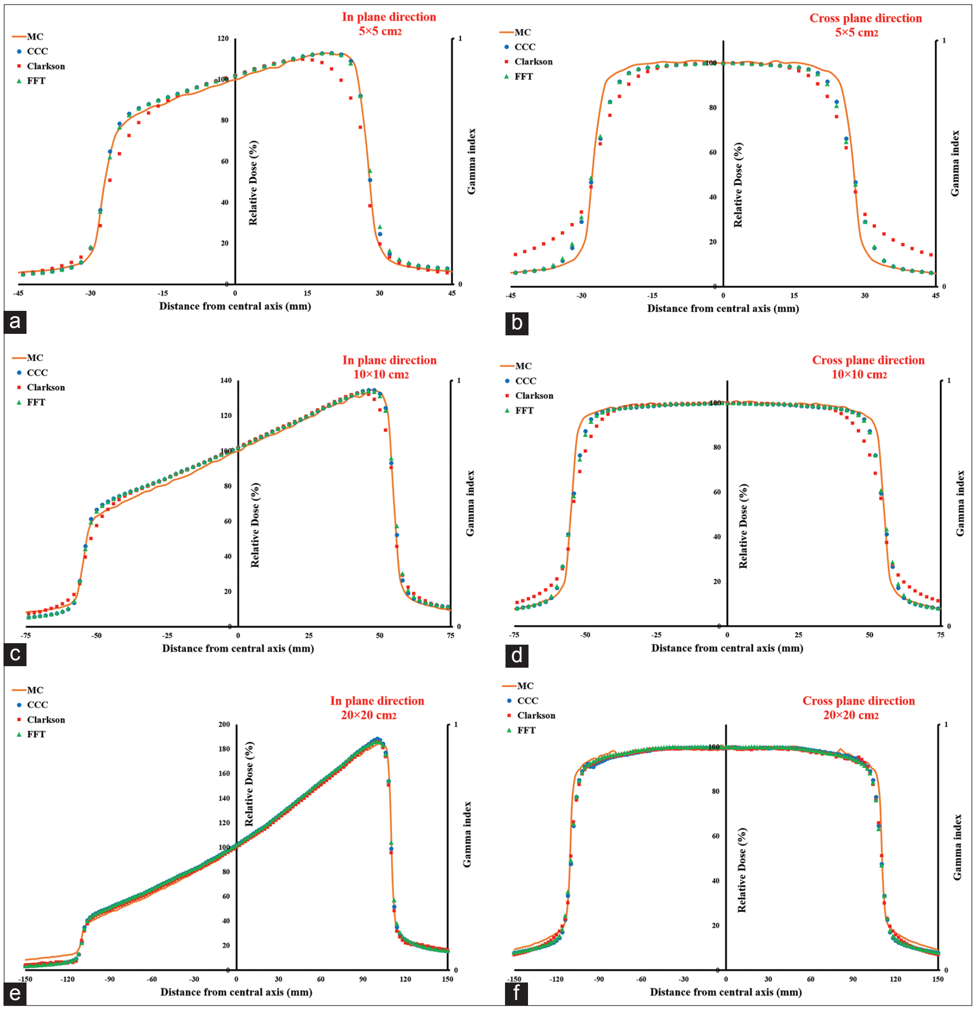

Figure 5: Treatment planning system algorithms and Monte Carlo's dose profile comparison for three (5 cm × 5 cm, 10 cm × 10 cm, 20 cm × 20 cm) Wedge fields (60°) at 10 cm depth. MC – Monte Carlo; CCC – Collapsed cone convolution; FFT – Fast fourier transform. a) In plane direction 5×5 cm2; b) Cross plane direction 5×5 cm2; c) In plane direction 10×10 cm2; d) Cross plane direction 10×10 cm2; e) In plane direction 20×20 cm2; f) Cross plane direction 20×20 cm2

Table 5: Effective wedge angles comparison of Monte Carlo and treatment planning system algorithms for 10 cm×10 cm field size by gamma index (3% - 3 mm)

Wedge angle (°)	Algorithm (%)		
	CCC	Clarkson	FFT
2	100	94.67	100
5	100	94.67	100
7	100	94.67	100
10	100	94.67	100
15	100	96	100
20	100	96	100
30	100	97.33	100
45	85.52	92	80

CCC – Collapsed cone convolution; FFT – Fast fourier transform

in Figure 5, which shows the mismatch increasing with increasing field size. In addition, in small fields, the penumbra area encompasses a greater portion of the radiation field, and as noted for open fields, the accuracy of the TPS algorithms decreases. But in the case of wedge fields, there is a trade-off between the TPS accuracy affected by the increasing nonuniformity of scattering with field size and the interpolation occurring in the high-gradient dose region of the field (penumbra area).

In addition, in small fields, the penumbra area encompasses a greater portion of the radiation field, and as noted for open fields, the accuracy of the TPS algorithms decreases.

Based on the information provided in Table 4 regarding the Clarkson algorithm, it is evident that the error increases with an increase in field size along the in-plane direction. This can be attributed to the limitations of the algorithm in accurately calculating the nonuniform scattering caused by wedge slope. While the error for the Clarkson algorithm along the in-plane direction is relatively lower compared to the other algorithms, as the field size increases, the error along the in-plane direction also increases, while it decreases along the cross-plane direction.

According to Table 5, the comparison of MC with TPS algorithms for dose profiles at various effective wedge angles show that the discrepancy between TPS algorithms

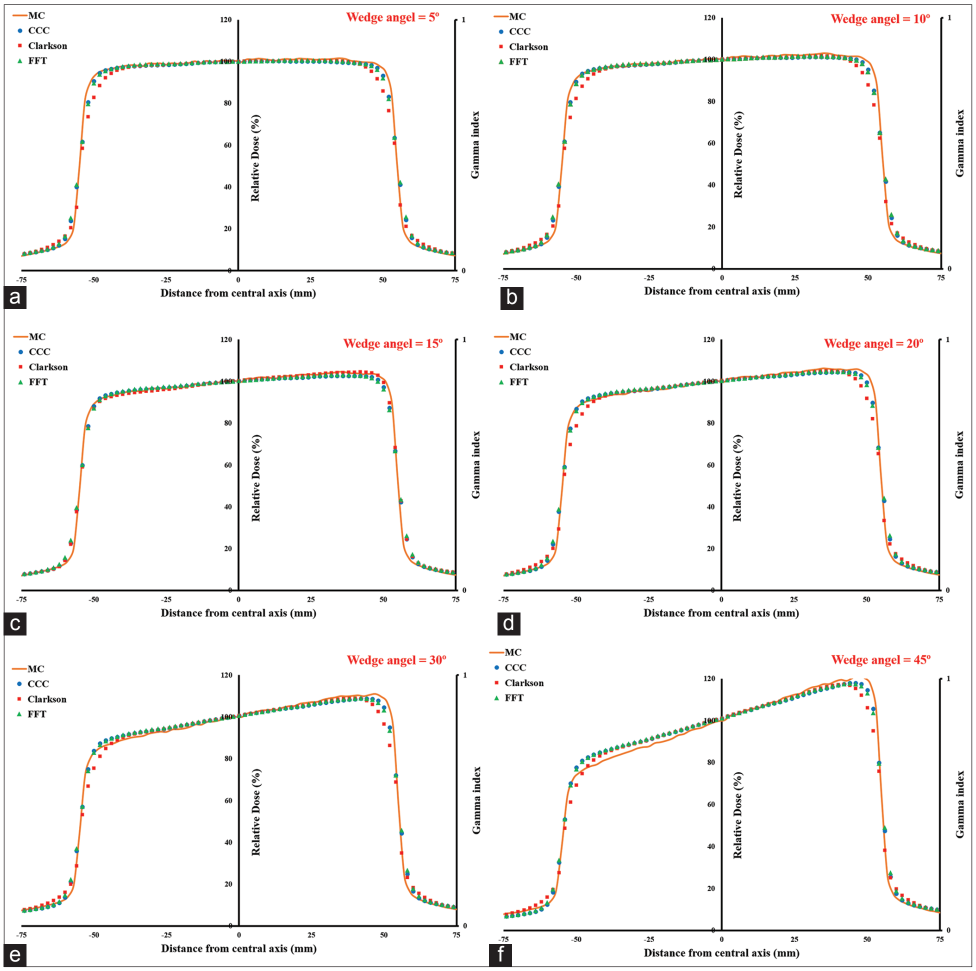

Figure 6: Treatment planning system algorithms and Monte Carlo's effective wedge dose profiles comparison for 10 cm × 10 cm at 10 cm depth, (a) 5°, (b) 10°, (c) 15°, (d) 20°, (e) 30°, (f) 45°. MC – Monte carlo; CCC – Collapsed cone convolution; FFT – Fast fourier transform

Table 6: Calculated effective wedge angles results from experimental measurements, Monte Carlo and treatment planning system algorithms isodose curves

Nominal wedge angle (°)	MC wedge angle (°)	CCC wedge angle (°)	Clarkson wedge angle (°)	FFT wedge angle (°)
2	2	2	8	3
5	4	5	10	6
7	6	6	11	7
10	9	8	14	9
15	14	12	17	13
20	18	16	21	17
30	28	24	29	24
45	43	37	41	38

CCC – Collapsed cone convolution; FFT – Fast fourier transform; MC – Monte Carlo

and MC simulations increased as the wedge angle increases. This discrepancy is attributed to the higher number of scattered photons and variable amount of transmitted rays in the wedge field, which influence beam quality. Studies by Nath *et al.* in 1994,[31] Pasquino *et al.* in 2009,[32] Momennezhad *et al.* in 2010,[33] and Dawod in 2015[25] validate these findings.

The difference between MC and TPS algorithms algorithm dose profiles for effective wedge angels is observed in Figure 6. As shown in Figure 6, the discrepancy increases with higher wedge angles, primarily in the penumbra area and the thin edge of the wedge.

Table 6 demonstrates the effective wedge angles associated to the isodose curves derived from the MC simulation and TPS algorithms. The findings suggest that in practice, effective wedge angles are typically lower than the nominal wedge angles, with the disparity increasing as the wedge angle increases. This discrepancy is attributed to the heightened contribution of scattered rays resulting from the presence of the wedge at larger effective wedge angles. TPS results show that at lower wedge angles, especially for the Clarkson algorithm, the effective wedge angles are overestimated. However, at larger angles, all algorithms tend to underestimate the effective wedge angles. Overall, CCC and FFT algorithms demonstrate higher accuracy at small wedge angels, while the Clarkson algorithm performs better at larger angles. While the discrepancies in effective wedge angles increase with larger wedge angles for CCC and FFT due to increased scattering, the Clarkson algorithm, although exhibiting narrower differences compared to CCC and FFT at larger angles, only shows acceptable differences in effective wedge angles for wedge angles between 15° and 30°.

The most significant variation occurs between the nominal and CCC algorithm effective wedge angles at 45°, which is lower than the disparities noted by Behjati *et al.* in 2018[34] and Gamit *et al.* in 2020.[35] Nevertheless, it exceeds the acceptable threshold recommended by ICRU24.[8]

Conclusion

In conclusion, the assessment of the ISOgray TPS through comparison with MC dose calculation offers valuable insights into the system's performance in determining PDDs, dose profiles, and effective wedge angles across various field sizes and configurations. This detailed analysis illuminates both the capabilities and constraints of ISOgray TPS algorithms, highlighting areas of accuracy, and potential enhancements needed for precise treatment planning in open and wedge fields. While the TPS dose calculation algorithms generally aligned with MC results, discrepancies were observed in certain scenarios, particularly for small open fields and large-wedged fields, with the Clarkson algorithm exhibiting more variability compared to model-based algorithms. On the other hand, the practical effective wedge angle consistently proved to be lower than the nominal wedge angles, with the disparity becoming more pronounced at larger wedge angles. TPS tends to overestimate effective wedge angles at smaller angles, notably with the Clarkson algorithm, whereas at larger angles, all algorithms tend to underestimate them. This emphasizes the importance of utilizing TPS with MC-based dose calculation algorithms to mitigate dose calculation errors effectively.

Acknowledgment

The authors would like to thank Semnan University of Medical Sciences for financial support of this study and also the radiotherapy department of Imam Ali hospital (Bojnurd, Iran) for providing experimental measurement conditions.

Financial support and sponsorship

This study is funded by Semnan University of Medical Sciences, Semnan, Iran.

Conflicts of interest

There are no conflicts of interest.

References

1. Oelkfe U, Scholz C. Dose calculation algorithms. In: New technologies in radiation oncology. Berlin, Heidelberg: Springer Berlin Heidelberg. 2006. p. 187-96.
2. Kim YL, Suh TS, Choe BY, Choi BO, Chung JB, Lee JW, *et al*. Dose distribution evaluation of various dose calculation algorithms in inhomogeneous media. Int J Radiat Res 2016;14:269-78.
3. Kavousi N, Nedaie HA, Gholami S, Esfahani M, Geraily G. Evaluation of dose calculation algorithms accuracy for eclipse, PCRT3D, and monaco treatment planning systems using IAEA TPS commissioning tests in a heterogeneous phantom. Iran J Med Phys 2019;16:285-93.
4. Khan FM, Gibbons JP. Khan's the physics of radiation therapy. Philadelphia, Pennsylvania, United States, Wolters Kluwer Health; 2014.
5. Miften M, Wiesmeyer M, Monthofer S, Krippner K. Implementation of FFT convolution and multigrid superposition models in the FOCUS RTP system. Phys Med Biol 2000;45:817-33.
6. Mohammadi K, Hassani M, Ghorbani M, Farhood B, Knaup C. Evaluation of the accuracy of various dose calculation algorithms of a commercial treatment planning system in the presence of hip prosthesis and comparison with Monte Carlo. J Cancer Res Ther 2017;13:501-9.
7. Anjum M, Qadir A, Afzal M. Dosimetric evaluation of a treatment planning system using pencil beam convolution algorithm for enhanced dynamic wedges with symmetric and asymmetric fields. Iran J Med Phys 2008;5:169-74.
8. ICRU (International Commission on Radiological Units) Report 24. Determination of absorbed dose in a patient irradiated by beams of X- or gamma-rays in radiotherapy procedures. Washington DC: ICRU; 1976.
9. Golestani A, Houshyari M, Mostaar A, Arfaie AJ. Evaluation of dose calculation algorithms of Isogray treatment planning system using measurement in heterogeneous phantom. Rep Radiother Oncol 2015;2:e5320.
10. Venselaar J, Welleweerd H, Mijnheer B. Tolerances for the accuracy of photon beam dose calculations of treatment planning systems. Radiother Oncol 2001;60:191-201.
11. Van Dyk J, Barnett RB, Cygler JE, Shragge PC. Commissioning and quality assurance of treatment planning computers. Int J Radiat Oncol Biol Phys 1993;26:261-73.
12. Chen WZ, Xiao Y, Li J. Impact of dose calculation algorithm on radiation therapy. World J Radiol 2014;6:874-80.
13. Zaghian R, Sedighi Pashaki A, Haghparast A, Gholami MH, Mohammadi M. Investigation of collapsed-cone algorithm accuracy in small fields and heterogeneous environments. J Biomed Phys Eng 2021;11:143-50.
14. Bahreyni Toossi MT, Farhood B, Soleymanifard S. Evaluation of dose calculations accuracy of a commercial treatment planning system for the head and neck region in radiotherapy. Rep Pract Oncol Radiother 2017;22:420-7.
15. Farhood B, Bahreyni Toossi MT, Soleymanifard S. Assessment of dose calculation accuracy of TiGRT treatment planning system for physical wedged fields in radiotherapy. Iran J Med Phys 2016;13:146-53.
16. Lu L, Yembi-Goma G, Wang JZ, Gupta N, Huang Z, Lo SS, *et al*. A practical method to evaluate and verify dose calculation algorithms in the treatment planning system of radiation therapy. Int J Med Phys Clin Eng Radiat Oncol 2013;2:76.
17. Farhood B, Bahreyni Toossi MT, Soleymanifard S, Mortezazadeh T. Assessment of the accuracy of dose calculation in the build-up region of the tangential field of the breast for a radiotherapy treatment planning system. Contemp Oncol (Pozn) 2017;21:232-9.
18. Tan YI, Metwaly M, Glegg M, Baggarley S, Elliott A. Evaluation of six TPS algorithms in computing entrance and exit doses. J Appl Clin Med Phys 2014;15:229-40.
19. Venselaar J, Welleweerd H. Application of a test package in an

intercomparison of the photon dose calculation performance of treatment planning systems used in a clinical setting. Radiother Oncol 2001;60:203-13.
20. Zabihzadeh M, Fadaei M, Hoseini M, Arvandi SH, Tahmasbi M. Characterization of wedge factors and dose distributions in radiotherapy with symmetric and asymmetric physical wedged beams of 6 MV photon beam. Iran J Med Phys 2020;17:213-9.
21. Zeinali A, Molazadeh M, Ganjgahi S, Saberi H. Collapsed cone superposition algorithm validation for chest wall tangential fields using virtual wedge filters. J Med Signals Sens 2023;13:191-8.
22. Raghavi S, Ravari ME, Tajik Mansoury MA, Behmadi M. Evaluation of dose calculation accuracy for ISO gray treatment planning system in wedged treatment fields. Int J Radiat Res 2024;22:303-8.
23. Petti PL, Siddon RL. Effective wedge angles with a universal wedge. Phys Med Biol 1985;30:985-91.
24. Muhammad W, Maqbool M, Shahid M, Ahmad M, Matiullah M. Erratum to "technical note: Accuracy checks of physical beam modifier factors algorithm used in computerized treatment planning system for a 15 MV photon beam". Rep Pract Oncol Radiother 2010;15:25.
25. Dawod T. Treatment planning validation for symmetric and asymmetric motorized wedged fields. Int J Cancer Ther Oncol 2015;3:030118.
26. Berris T, Mazonakis M, Stratakis J, Tzedakis A, Fasoulaki A, Damilakis J. Calculation of organ doses from breast cancer radiotherapy: A Monte Carlo study. J Appl Clin Med Phys 2013;14:4029.
27. Howell RM, Scarboro SB, Taddei PJ, Krishnan S, Kry SF, Newhauser WD. Methodology for determining doses to in-field, out-of-field and partially in-field organs for late effects studies in photon radiotherapy. Phys Med Biol 2010;55:7009-23.
28. Wang L, Ding GX. Estimating the uncertainty of calculated out-of-field organ dose from a commercial treatment planning system. J Appl Clin Med Phys 2018;19:319-24.
29. Asnaashari K, Nodehi MR, Mahdavi SR, Gholami S, Khosravi HR. Dosimetric comparison of different inhomogeneity correction algorithms for external photon beam dose calculations. J Med Phys 2013;38:74-81.
30. Fraass B, Doppke K, Hunt M, Kutcher G, Starkschall G, Stern R, *et al*. American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning. Med Phys 1998;25:1773-829.
31. Nath R, Biggs PJ, Bova FJ, Ling CC, Purdy JA, van de Geijn J, *et al.* AAPM code of practice for radiotherapy accelerators: Report of AAPM Radiation Therapy Task Group No. 45. Med Phys 1994;21:1093-121.
32. Pasquino M, Borca VC, Tofani S, Ozzello F. Verification of Varian enhanced dynamic wedge implementation in masterplan treatment planning system. J Appl Clin Med Phys 2009;10:11-20.
33. Momennezhad M, Bahreyni Toosi MT, Sadeghi R, Gholamhoseinian H, Nasseri S. A Monte Carlo simulation and dosimetric verification of physical wedges used in radiation therapy. Int J Radiat Res 2010;7:223-7.
34. Behjati M, Sohrabpour M, Shirmardi SP, Bouzarjomehri F, Mosleh Shirazi MA. Dosimetric verification of the Elekta motorized wedge. Arch Adv Biosci 2018;9:32-41.
35. Gamit J, Nair S, Charan S, Dsouza R, Sharan K, Chandraguthi S. Validation of motorized wedge effective isodose angle with a 2D array detector. Iran J Med Phys 2020;17:380-5.