Original Article

Evaluating the Impact of Various Parameters on the Gamma Index Values of 2D Diode Array in IMRT Verification

Abstract

Background: MapCHECK2 is a two-dimensional diode arrays planar dosimetry verification system. Dosimetric results are evaluated with gamma index. This study aims to provide comprehensive information on the impact of various factors on the gamma index values of MapCHECK2, which is mostly used for IMRT dose verification. **Methods:** Seven fields were planned for 6 and 18 MV photons. The azimuthal angle is defined as any rotation of collimators or the MapCHECK2 around the central axis, which was varied from 5 to −5°. The gantry angle was changed from −8 to 8°. Isodose sampling resolution was studied in the range of 0.5 to 4 mm. The effects of additional buildup on gamma index in three cases were also assessed. Gamma test acceptance criteria were 3%/3 mm. **Results:** The change of azimuthal angle in 5° interval reduced gamma index value by about 9%. The results of putting buildups of various thicknesses on the MapCHECK2 surface showed that gamma index was generally improved in thicker buildup, especially for 18 MV. Changing the sampling resolution from 4 to 2 mm resulted in an increase in gamma index by about 3.7%. The deviation of the gantry in 8° intervals in either directions changed the gamma index only by about 1.6% for 6 MV and 2.1% for 18 MV. **Conclusion:** Among the studied parameters, the azimuthal angle is one of the most effective factors on gamma index value. The gantry angle deviation and sampling resolution are less effective on gamma index value reduction.

Keywords: *Gamma index, intensity modulated radiation therapy verification, MapCHECK2, two-dimensional array*

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Introduction

Intensity modulated radiation therapy (IMRT) is an accurate and efficient technique in radiotherapy treatment considering the high-dose conformity to the target volume, whereas it allows for the sparing of dose to the organs-at-risk.[1-5] IMRT provides further improvements in maximizing the ratio between tumor control and normal tissue complication. It allows the clinical performance of highly conformal nonconvex dose distributions.[6] The IMRT beam-delivery system generally provides a dose distribution that includes high gradient regions that need to be evaluated before delivery.

IMRT plans with highly modulated beams require additional dosimetric verifications as compared to three-dimensional conformal radiation therapy.[7-12] A large number of quality assurance (QA) methods have been developed to verify the accuracy of IMRT fields. The QA process generally consists of verifying the absolute dose delivered to a reference point, and also the relative planar isodose distribution. To perform an IMRT QA, one can use either a composite irradiation using an ion chamber and film with actual gantry angles, or a beam-by-beam perpendicular irradiation in a constants gantry angle.[13]

Pretreatment IMRT verification based on film dosimetry and ionization chamber measurements is a time consuming task, particularly when multiple QA measurements need to be made. Film dosimetry also generates limited information in real time and results in delay related to processing time.

One of the most convenient patient-specific IMRT QA techniques is the use of two-dimensional detector arrays for the comparison between planned and measured dose distributions.[14] These techniques produce an accurate dose distribution of IMRT field in a very short span of time.

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One of the available two-dimensional arrays is MapCHECK2 from Sun Nuclear Corp., Melbourne, Florida, USA which has been developed for routine QA of IMRT planar dosimetry.[15] The early version of this device, MapCHECK, had a smaller number of detectors with 7.07 mm diode spacing in 10×10 cm^2 central portion of the detector with the spacing being increased to 14.14 mm outside of this area. MapCHECK2 contains 1527 n-type diodes distributed over an area of 32×26 cm^2. The distances between diodes are 7 mm in the entire area. The MapCHECK2 can make both relative and absolute dose measurements that reduces the workload of QA.[16] The diode array detectors are relatively small (0.8×0.8 mm^2), making them ideal for measuring complex IMRT planar dose distributions with high-dose gradient.[17,18] There are also disadvantages in MapCHECK2. The measured results are limited by intrinsic dosimetric characteristics of diode, such as energy dependence, radiation damage, differential response to scattered radiation, angular dependence of dose sensitive field size, and dose-rate dependencies.[19]

The approved plan is transferred to the phantom where each beam is delivered perpendicularly to a surface of the phantom. A planar dose at a specified depth can be calculated from the treatment planning system (TPS) and compared with measurement.

Using two-dimensional detector arrays in the same geometry at the depth of interest, a comparison can be made on a beam-per-beam basis or compositely by adding dose from all the beams. Two-dimensional dose distribution analysis instruments based on the percent dose difference, distance-to-agreement (DTA), or the gamma index are available for comparison of the plans.[15,20] The acquisition of a two-dimensional dose distribution and the actual-time analysis capabilities have made two-dimensional detector arrays superior to the single ion chamber or film measurement for IMRT pretreatment verification.[21] The criteria that are usually used for gamma test are percent dose difference of 3% and DTA of 3 mm.[22-24]

Detector arrays implementation in IMRT dosimetry have been studied in some other works. Jursinic and Nelms[15] and Létourneau *et al.*[16] examined the linearity of the MapCHECK detectors and found that the diode response was linear within the range of the radiation dose up to 300 cGy. The MapCHECK device should be perpendicular to the radiation central axis and for the oblique angle of gantry, it is placed in a special holder that rotates with gantry rotation. Another group showed that there was a 25% over response of MapCHECK diode for 6 MV with the beam incidence gantry angles of 90 and 270°.[25] In addition, MapCHECK2 (which is calibrated using the standard 10×10 cm^2 field) underestimates dose when the field sizes are small due to higher sensitivity of diode to scattered radiation (~1% for 2×2 cm^2 field using 6 MV beam).[13] Keeling *et al.*[14] showed that the MapCHECK2 device had large angular dependency, especially at gantry angles of 90 and 270°, which could affect the rate of gamma passage. Li *et al.*[21] measured the dependence of the response of detectors on field size, dose rate, and radiation energy and compared with reference measurements using a Farmer-type ionization chamber. Keeling *et al.* determined the dependency of the planned dose perturbation algorithm (used in Sun Nuclear 3DVH software) on a spatial resolution of the MapCHECK2 detectors. They concluded that the high resolution (HR) measurements may not be necessary for conventional two-dimensional planar IMRT QA, except for the small fields. They recommended to use the high-resolution measurement for small targets (i.e., PTV < 5 cm^3) and multiple targets with complex geometry with minimum setup error.[26] Jin *et al.* investigated an effect of angular dependence and calibration field size of MapCHECK2 on RapidArc (Varian Medical Systems, Palo Alto, CA) (RA) QA for 6, 8, 10, and 15 MV. The angular dependence of 6 MV beam significantly deteriorates the gamma passing rate; however for 8, 10, and 15 MV, the angular dependence does not make any clinically meaningful impact on the MapPHAN (Sun Nuclear Corporation (SNC), Melbourne, FL) QA.[27] Rinaldin *et al.* evaluated the use of MapCHECK2 in a patient-specific QA procedure for RA radiotherapy and to obtain reference values of gamma index for various irradiation geometries.[28]

In most of the clinics, the gamma index has been used as a part of IMRT plan verification. The typical criterion of 3%/3 mm is used for gamma index to determine the percentage of points passed for each treatment beam.

The main purpose of this study was to accurately investigate the gamma index behavior and its sensitivity versus various setup factors. In a realistic clinical QA for IMRT field, the gamma index might be lower than acceptable values. Detailed and comprehensive studies of these parameters are useful for a physicist to change these factors for improving the gamma factor according to the influencing priorities when the gamma index is lower than the expected value.

Materials and Methods

IMRT verification plans

IMRT verification plans were generated by TPS for a nasopharynx treatment site with step-and-shoot technique. Seven fields from various directions were used for treatment planning. To be able to compare the effect of energy on gamma index all fields were planned separately with 6 MV as well as 18 MV beams from the same direction. The inverse planning was performed for both energies separately to derive the beam sequencing for each direction. A total dose of 7000 cGy at 180 cGy per fraction was prescribed.

IMRT delivery and device

All IMRT verification plans were delivered using a Siemens Oncor Impression linear accelerator which was equipped by 41 leaf pairs with 1 cm thickness at the isocenter. The photon beams with nominal energy of 6 and 18 MV is available in Oncor Impression linac.

The IMRT plans dose distributions were measured on a MapCHECK2 model 1177 diode array. The dimensions of this device are 28.7 cm in width, 56.0 cm in length, and 4.3 cm in thickness. The MapCHECK2 is a two-dimensional array including 1527 solid state (silicon), n-type, and radiation-hardened diode detectors, which were arranged in a 26×32 cm^2 grid with 7 mm diagonal spacing. The spacing between detectors parallel to X and Y axes is 1.0 cm. Each detector has an active area of 0.8×0.8 mm^2. MapCHECK2 hardware has the ability to save data every 50 ms. The depth of the detector's layer from top of overlay is 1.20 ± 0.1 cm. This top layer is equivalent to the inherent buildup of 2.0 g/cm^2 for all photon energies. MapCHECK2 calibration was performed step-by-step as per the detailed description of the array calibration process in MapCHECK2 manual.

It is possible to use additional buildup to MapCHECK2's inherent buildup of 2 cm to create a larger depth equal to the planned dose depth as well as for capturing the backscatter radiation.

In this study, for most cases, 3 cm additional water-equivalent buildup was placed below the MapCHECK2 for capturing backscatter radiation. Verification plans were delivered to three phantom setups. The MapCHECK2 with various slab thicknesses of 0, 1, and 3 cm on the top and 3-cm slab below were scanned using a 64 slices Siemens SOMATOM Sensation CT scanner (Siemens, Aktiengesellschaft, Werner-von-Siemens-Straße 1 80333, Munich) (512×512 matrix with pixel size of 0.78 mm; slice thickness of 3 mm). The CT images of MapCHECK2 and additional slabs were transferred to the TPS for dose calculations of IMRT plans.

The IMRT treatment plan, including seven beams in the nasopharynx site, was approved by a radiation oncologist and each beam was then transferred perpendicularly to the surface of MapCHECK2. This is a standard option in most of the TPSs, which enables one to irradiate the various beams at the same gantry angle for QA purposes.

The diodes plane was placed on 100 cm source-to-axis distance (SAD). After dose calculation and determination of the isodose distribution in TPS, the planar isodose in 4.2-cm depth from the top of the 3-cm equivalent-water slab was selected for comparison with measurements.

The approved IMRT QA plan of nasopharynx was exported to linac to be delivered on MapCHECK2. For measurement set up, the 100-cm distance from the source was set on the diodes plane. This position is marked with a black line in the outer wall of the MapCHECK2. After irradiation, measured isodose distribution by two-dimensional detector arrays was compared with calculated isodose in the same geometry at the similar depth. A comparison was made on a beam-per-beam basis based on the gamma index parameter. The gamma criteria of 3%/3 mm were used to determine the percentage of points passed for each treatment beam.

Factors affecting the diode detectors reading

Gamma index is defined as the percentage of points, which are in agreement between calculated and measured dose distributions under certain conditions. This factor is used in most of the IMRT QA procedures.

In this study, five factors, including azimuthal angle (defined as the rotation angle of table or the rotation angle of collimator around the central axis), the depth of isodose sampling, gantry angle, buildup thickness, and sampling resolution (the number of measurement points per unit area) were studied. In the clinic, usually the small deviation of these parameters might happen; however, the wide range of variation is considered to evaluate the general behavior of gamma index with respect to each factor.

Azimuthal angle

As mentioned before, any rotation around the central axis of radiation in the plane perpendicular to radiation is defined as azimuthal angle. Any deviation in matching the coordinate of MapCHECK2 and the X, Y lasers of accelerator causes as an error in setting of the azimuthal angle. The lasers have been calibrated with appropriate QA, and it is aligned with linac axis. The first step in setup was putting MapCHECK2 on the treatment table and matching the coordinate axes of MapCHECK2 with X and Y room lasers.

After adjusting the MapCHECK2, any rotation in couch or MapCHECK2 can lead to an error in azimuthal angle. One of the most important cases leading to this error is putting and adjusting RW3 slabs on the MapCHECK2 as additional buildup. When it is required to place several slabs of RW3 on the MapCHECK2, the adjustment can displace the MapCHECK2 from the correct position.

In this study by changing the turn table angle in TPS from −5 to 5° in 1° increments, the effect of deviation in azimuthal angle in gamma value was evaluated.

Isodose sampling depth

Nominal detector position from the surface of the MapCHECK2 is in 1.2-cm depth, and it is aimed to determine the sensitivity of gamma index to selected depth. A 3-cm buildup was placed on MapCHECK2 to investigate the effect of the isodose sampling from different depths on gamma index. Isodose sampling depth was changed from 6 mm under the plane of the detectors to 4 mm above the detectors. The goal was to determine whether the mistake in selecting the desired depth could have a considerable effect on gamma results.

Buildup thickness

Putting an additional RW3 layer to MapCHECK2's 2-cm inherent buildup is needed to achieve the desired depth in treatment planning [Figure 1]. On a routine basis, the additional buildup of 1 to 5 cm is used in measurements. Using a very thick buildup is not recommended as it would result in damaging the electronic area of instrument because of higher scatter radiation.

The effect of additional buildup on the gamma index in three various cases were assessed:

(1) No slab on the top and 3 cm RW3 slab under the MapCHECK2;
(2) 1 cm above and 3 cm under the MapCHECK2; and
(3) 3 cm above and 3 cm under the MapCHECK2.

Gantry angle

To have a correct reading, the top surface of the MapCHECK2 should be perpendicular to the central axis of the beam, because the deviation from this direction can reduce gamma index. It should be noted that gantry angle effect is different from azimuthal angle effect. A large gantry angle deviation from 0° can completely interrupt detector's response. In azimuthal angle, the detector can respond to radiation and create an isodose line even if the MapCHECK2 rotation around central axis is 180°. For example, if the gantry rotates at 80° with respect to MapCHECK2 surface, no isodose curve can be measured. In deviation to the azimuthal angle, the MapCHECK2 detectors give a strong signal and complete rotated dose distribution; however, in the case of high gantry rotation, the signal becomes weaker. Gamma index dependence to gantry angle in the range of 8 to −8° was evaluated. The MapCHECK2 rotation with respect to the horizontal axis along the couch is similar to gantry angle. Therefore, any MapCHECK2 imbalance can also result in error and reduce the gamma index in this way. There are three adjustment screws under the MapCHECK2 for proper aligning of the MapCHECK2 surface with horizontal surface.

Resolution of the calculated points

Resolution is defined as the surface density of measurement points which are selected in TPS for dose sampling. The detectors spacing is 7 mm which is related to inherent resolution of MapCHECK2.

The MapCHECK2 resolution is different from TPS resolution. The user can change TPS resolution up to 10 mm from calculated data. MapCHECK2 software will not accept a grid resolution greater than 4 mm. In the present study, the isodose sampling resolution was considered to be in the range of 0.5 to 4 mm to compare measured and calculated dose distribution. The main purpose of selecting various resolutions was to investigate whether gamma value increases significantly with better resolution. The smaller resolution takes more time from TPS software to do the calculations.

For the evaluation of resolution effect, the following settings were chosen: the isodose sampling depth equal to 4.2 cm, gantry angle equal to 0°, turn table equal to 0°, and an additional buildup thickness of 3 cm.

Results

Azimuthal angle

The setup of experiment for the evaluation of the effect of the azimuthal angle is similar to Figure 1. The SAD is the constant value of 100 cm, whereas the device is rotated in around central axis. Figures 2 and 3, illustrate the effect of azimuthal angle changes on gamma factor for all seven beams in 6 and 18 MV, respectively. The gamma index criteria for all beams were 3%/3 mm criteria. Figure 4 illustrates the mean value of gamma factor for all seven fields in 6 and 18 MV photons. As illustrated, the maximum gamma factor value for all beams is observed in azimuthal angle of 1,° although it is expected to be at 0°. This is related to the fact that the MapCHECK2 was already 1° offset in our experiment.

The mean values of gamma factor at both edges of the curves are approximately 8% for 6 MV and 10% for 18 MV, respectively. The slope of curves is nearly equal at the both sides. Figure 4 depicts the mean values of gamma

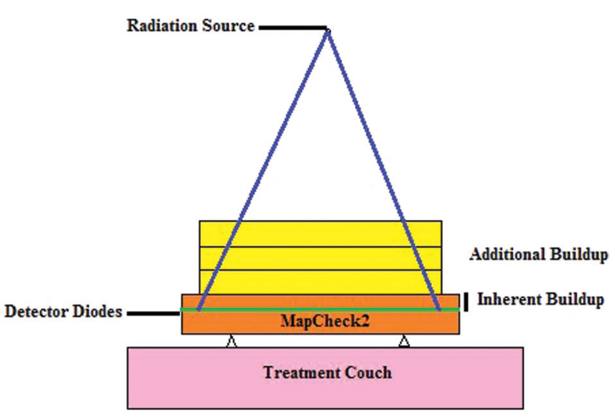

Figure 1: Experimental setup of the MapCHECK2 and additional slabs on the surface. The diodes plane is placed at 100-cm SAD

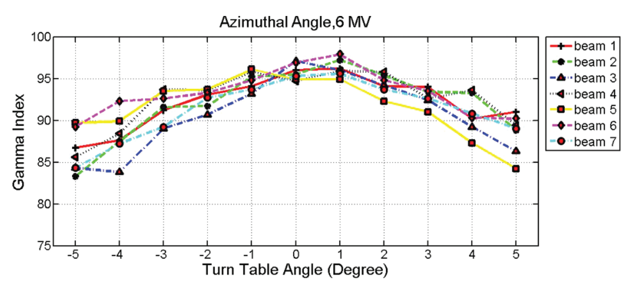

Figure 2: Variations of gamma factor versus azimuthal angle for the seven IMRT beams in 6 MV photons

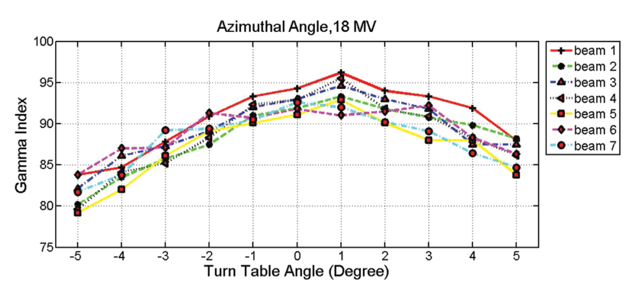

Figure 3: Variations of gamma factor versus azimuthal angle for the seven beams in 18 MV photons

factor for the seven beams in all azimuthal angles in 6 and 18 MV photons. All the measurements were done with an inherent buildup of 2 and 3 cm additional RW3 slab.

Isodose sampling depth

Figure 5 displays the effect of isodose sampling depth on gamma factor. In all measurements, an additional buildup of 3 cm was placed on the MapCHECK2. Detectors position is 1.2 cm under the MapCHECK2 surface. As a result, the detectors distance to top surface of phantom is 4.2 cm. The aim is to evaluate the effect of the offset for this parameter on the gamma index. As it is observed in Figure 5, for example, if there is a 2-mm distance between the depth of dose sampling in treatment planning and real depth of the diodes, the change of gamma index is up to 0.6 and 1.9% for 6 and 18 MV photons, respectively.

Buildup thickness

Figure 6 shows the changes in gamma factor with respect to buildup thickness. Generally by adding additional buildup, the gamma index is increased for both energies. As Figure 6 shows, for 18 MV by adding 1-cm extra buildup, the gamma factor rises by 20%, which is quite considerable. For larger thicknesses of the slabs, the gamma factor increases slowly. In both 6 and 18 MV photons, by increasing the buildup from 3 to 5 cm, the average gamma factor for all seven beams increase by about 3.6 and 8.5%, respectively [Figure 6].

Gantry angle

The impact of gantry angle on gamma index is illustrated in Figure 7 for 6 and 18 MV beams. The behavior of the curves with respect to gantry rotation is identical in both clockwise and counter-clockwise directions. The gamma index value is changed in the small range of 0.41 and 1.1% when the gantry rotation is in the range of −4 to 4° for 6 and 18 MV photons, respectively. Therefore, the gantry angle deviation is less effective in gamma index value reduction.

Resolution

Figure 8 illustrates the effect of resolution on gamma factor. The behavior of gamma factor for 6 MV is similar to 18 MV. The change of resolution from 4 to 2 mm results in an increase in gamma index by about 3.7%. However, a further reduction of grid size or sampling resolution had no significant increase of gamma value. For lower resolutions, the calculation of dose samples is more time consuming in TPS. According to these results, a grid size smaller than 2 mm is not recommended.

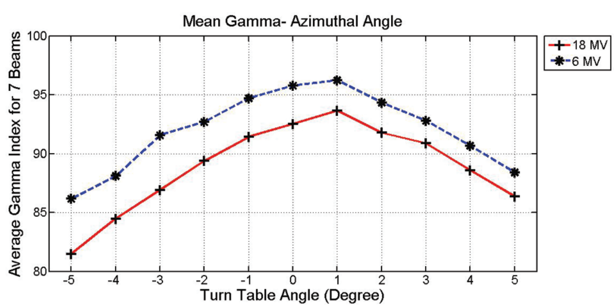

Figure 4: Mean values of gamma factor for seven beams with respect to azimuthal angle in 6 and 18 MV photons

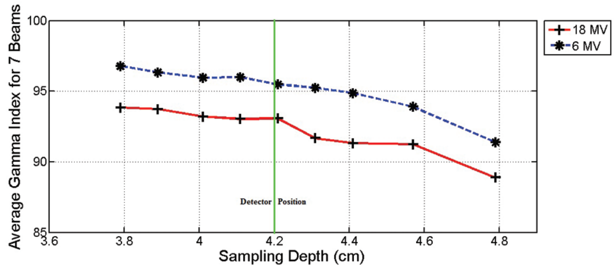

Figure 5: Mean values of gamma factor versus isodose sampling depth in 6 and 18 MV photons

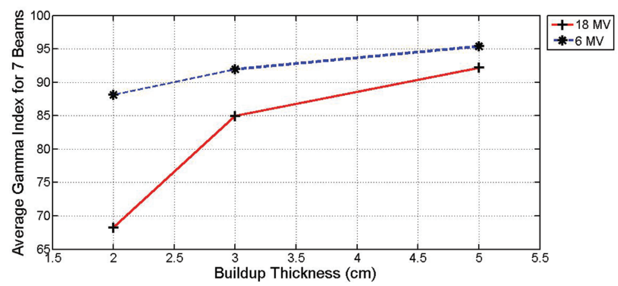

Figure 6: The mean values of gamma factor with various buildup thickness in 6 and in 18 MV photons

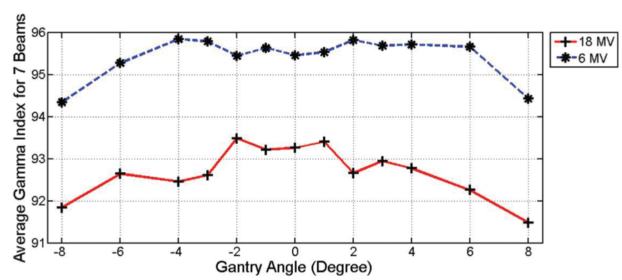

Figure 7: Mean values of gamma factor with respect to gantry angle in 6 and 18 MV photons

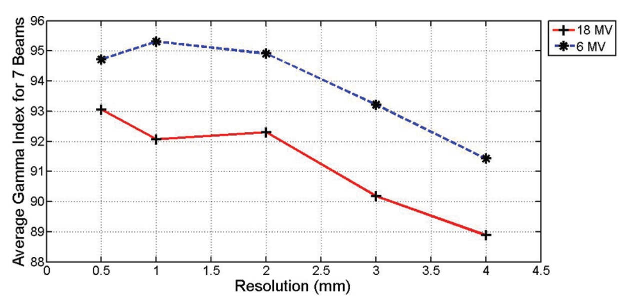

Figure 8: Mean values of gamma factor versus resolution in 6 and 18 MV photons

Discussion

The IMRT plan in this study was performed with step-and-shoot technique. The correspondence between measured and planned doses was inspected using gamma tests. The difference between measured and planned dose distributions may occur due to these four reasons: (1) delivery techniques, (2) MapCHECK2 calibration field size, (3) TPS dose calculation algorithm or algorithm weakness, (4) scattering and back scattering, and (5) the gamma test itself.[14]

Several papers have reported on the dose angular dependence. In these studies, the beam is orthogonal to the surface of the MapCHECK2 when the gantry rotates. The MapCHECK2 is attached to the gantry with a holder and therefore, it rotates with the rotation of the gantry. Jin *et al.*[27] Rinaldin *et al.*,[28] and Keeling *et al.*[14] reported that MapCHECK2 had a considerable angular dependence at gantry angles of 90 and 270°. Their results showed that angle dependency due to gravity sagging caused the reduction of gamma values.

In this study, the MapCHECK2 is assumed to be fixed on couch and the gantry angle is rotated in small intervals. The goal of this experiment was to investigate the effect of the misalignment of MapCHECK2 surface with respect to the horizontal surface.

With the rotation of gantry the X-ray beam path through the phantom is slightly longer in the buildup. The projection of the radiation field shape on the MapCHECK2 surface is also slightly changed with gantry rotation.

Fluctuations of gamma values are observed in Figure 8 when the gantry angle is changed. The curve's behavior for a gantry rotation is identical in both clockwise and counter-clockwise directions in both 6 and 18 MV photons energy. As a result, the deviations of gantry angle in both directions are similar. The gamma index changes about 1% when the gantry rotates negligibly by about 4°. Therefore, the gantry angle deviation is less effective in gamma index value reduction.

Although the maximum gamma index is expected to be at 0° gantry angle, it has a local minimum at 0° for both 6 and 18 MV photons. A small gantry angle rotation in both clockwise and counter-clockwise direction creates maximum gamma value. This entails that the MapCHECK2 was not aligned with respect to horizontal surface at the time of the measurements.

The effect of azimuthal angle on gamma factor in 6 and 18 MV photons was then investigated. Any rotation of device or collimators around the central axis of radiation in the plane perpendicular to radiation is defined as azimuthal angle. Given that the slope of curves are nearly equal on both sides, the clockwise and counter clockwise, the rotation of MapCHECK2 in the plane perpendicular irradiation has a similar effect on gamma factor [Figures 2 and 3]. Figure 4 depicts that the mean values of gamma factor for the seven beams in all azimuthal angles is higher in 6 MV as compared to 18 MV. All the measurements were done with a minimum inherent buildup of 2 cm. Therefore, all measurements of 6 MV were at least 5 mm outside the buildup area. The electron contamination is mostly removed at this depth for 6 MV electrons.

The gamma value varies up to 2% when the deviation of azimuthal angle is considerable at 2°. Therefore, the azimuthal angle is one of the most effective parameters on gamma value and small deviations can create significant changes.

Given that during the change of azimuthal angle MapCHECK2 rotates around the radiation axis, the source-to-detector distance is constant. With MapCHECK2 rotation, all isodose lines rotate around the central axis in this case. The delivered dose to specific area is completely different from planned dose, although the entire shapes of isodose lines remain the same. Therefore, the gamma index is reduced considerably.

The appropriate depth for sampling from isodose curves in TPS was studied. As illustrated in Figure 6, there is a need for at least 3 cm of total buildup for 18 MV photons to achieve acceptable gamma values. As it is observed in Figure 5, the gamma index is not very sensitive to the variation of the sampling dose depth. It should be noted that in a realistic clinical case it is not likely to have large errors in the selection of sampling depth, and therefore in small errors, there is not a big change in gamma index.

The effect of sampling resolution was investigated in a study by Keeling *et al.*[26] Keeling *et al.* reported measuring small fields (about 1 cm^3) with low-resolution detectors such as MapCHECK2 due to the limitation of the gamma test. With increasing field size, the chance of undersampling effect is less. This is because the number comparison points of a larger field size are more.[26] MapCHECK2 resolution is defined as the surface density of measurement points and it is constant. Resolution can improve by smarterpolation.

In this work, the impact of the isodose sampling resolution in TPS to be compared with measured value was investigated. As shown in Figure 8, changing resolution from 4 to 2 mm results in an increase in gamma index by about 3.7%. However, further reduction of grid size or sampling resolution to 0.5 mm had no significant increase of gamma value, whereas the time of calculation is increased. As a result, for the sampling from dose calculation in TPS, the grid size with 2-mm resolution is recommended.

The effect of additional buildup thickness on gamma index value was investigated. As Figure 6 shows, the gamma factor for both 6 and 18 MV photons increases continuously by adding an extra buildup. The depth of maximum dose in 6 MV Oncor electric is 1.5 cm. Inherent MapCHECK2 buildup is equal to 2-cm solid water which is 0.5 cm more than maximum dose depth. Therefore, by adding extra buildup on the surface, the detectors are placed in the larger depth at which the PDD is more flat. The gamma curve for 18 MV appeared to have steeper gradients in comparison to the 6 MV gamma curve. The reason for this behavior is that at a particular depth, the dose gradient is less for 6 MV as compared to 18 MV. Therefore, the changes of the dose are less, and there are larger agreements between dose distributions. The results from various depths of measurement illustrated that when the distance of the selected depth from the depth of the maximum dose increases, the gamma index value is increased.

In all measurements of this study and in all parameters, for each particular depth, the gamma index of 6 MV was larger as compared to 18 MV. As mentioned in previous sections, the depths of the maximum dose for 6 and 18 MV in our linac were 1.5 and 3 cm, respectively. Therefore, in each particular depth, there is a larger distance from maximum dose in 6 MV as compared to 18 MV, and the dose gradient is less for 6 MV.

Conclusion

In this study, the plan verification of seven IMRT fields was performed for 6 and 18 MV energies. The gamma index was used for the evaluation of an agreement between calculated and measured dose distribution with MapCHECK2 two-dimensional array detector. The sensitivity of gamma index with respect to various setup parameters was also investigated. Considering the significant changes of the gamma index due to the deviation of azimuthal angle, it was illustrated that this factor is one of the most effective parameters on results. For measurements, even a small deviation of the MapCHECK2 around the central axis of the beam should be avoided at the time of setup.

The effect of using various thicknesses of additional buildup on the MapCHECK2 surface is evaluated. The results illustrated that for 18 MV photons, placing additional buildup increased the gamma factor up to 26%, and therefore, it is necessary to put at least 3-cm additional build up in this energy. The 2-cm inherent buildup of MapCHECK2 is adequate for 6 MV photons.

Among the evaluated parameters, the gantry angle was the least effective parameter and a small deviation of gantry angle does not have any significant effect on gamma index results. For the resolution of isodose sampling in the TPS, it was illustrated that the resolution less than 2 mm has no major improvement in gamma index results.

In a realistic clinical case, the error of all these parameters can combine with each other, and in the case that the gamma index values is not satisfactory, these results aid the physicist to select and change the parameters in order of importance.

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Conflicts of interest

There are no conflicts of interest.

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