



Comparison of Progressive Resolution Optimizer and Photon Optimizer algorithms in RapidArc delivery for head and neck SIB treatments

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ABSTRACT

Background: The aim of this study is to analyze and verify characterization of two different algorithms using simultaneous integrated boost (SIB) in head and neck (H&N) plans.

Materials and methods: In our study 15 patients were selected, who received radiation therapy by using Eclipse volumetric modulated arc therapy (VMAT) Progressive Resolution Optimizer (PRO) algorithm 15.1. The same cases were re-optimized using a Photon Optimizer (PO) algorithm 15.6. A total of 30 treatment plans (15 PRO-VMAT plans and 15 PO-VMAT plans) were produced in the present study. All plans were created using double full arcs, keeping the identical constraints, cost functions and optimization time. Plan evaluation was done using planning target volume (PTV) parameters (D98%, D95%, D50%, D2% mean dose and V105%), homogeneity index (HI), conformity index (CI), Monitor unit (MU) per degree with control points (CP), organ at risk (OAR) doses and gamma verification (Portal dosimetry and ArcCHECK) values were evaluated. Treatment was delivered in Varian Truebeam 2.5, energy 6 MV with Millennium 120 multileaf collimator (MLC).

Results: The PTV coverage (D95%) for PRO and PO were 98.7 ± 0.8 Gy, 98.8 ± 0.9 Gy, HI were 0.09 ± 0.02 and 0.09 ± 0.02 , CI were 0.98 ± 0.01 and 0.99 ± 0.01 . Monitor units (MU) for PRO and PO were 647.5 ± 137.9 , 655.2 ± 138.4 . The Portal dose results were [3%, 3mm (%) & 1%, 1 mm (%)] for PO and PRO 100 ± 0.1 , 95.1 ± 1.4 and 100 ± 0.1 , 95.2 ± 1.3 . For ArcCHECK were 99.9 ± 0.1 , 94.7 ± 3.0 and 99.9 ± 0.1 , 93.5 ± 3.9 , respectively.

Conclusion: Results showed that PTV coverage and OAR doses were comparable. For individual patients CI and HI of PO showed slightly higher values than PRO. MUs for PO were slightly increased as compared to PRO. MU per degree with each individual control points generated by PO showed a high degree of modulation compared to PRO. Hence, new PO optimizer can produce a comparable degree of plan while using the same PRO objectives.

Key words: Progressive Resolution Optimizer; Photon Optimizer; rapid arc; VMAT

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Introduction

Important advancements in the treatment of head and neck (H&N) cancer have been achieved over the years, increasing our understanding of the disease, its treatment modalities, prognosis, and the loco-regional control. The use of availability of advanced treatment techniques has led to unprecedented survival benefits in locally advanced Head and Neck patients [1, 2].

H&N treatments require careful selection of one or more interventions such as Radiotherapy and Surgery based on tumor type, location and intensity. RapidArc or Volumetric modulated arc therapy (VMAT) being an advanced treatment delivery technique owing to its ability to achieve highly conformal dose distribution to the target volume while minimizing the dose to Organ at risk (OAR), can be a better option while considering the treatment technique for H&N cases [3, 4]. H&N being a complex site because of the presence of a number of critical structures and density discontinuities, accurate dose calculations are essential for minimizing the toxicity of normal tissues in RapidArc (VMAT) plans [5, 7]. One can achieve the desired dose objectives or optimal treatment plans with the help of predefined dose objectives through an optimization algorithm. The performance of the treatment planning system's optimizer can therefore have a significant effect on the dosimetric quality and deliverability of the resulting treatment plans and should be evaluated carefully before adoption for clinical use [5].

The multi leaf collimator (MLC) shapes are conformed to the targets and the dose rates are equal for all segments in the beginning stage of the optimization. The MLC shapes and dose rates are then optimized, in the successive stages. During the initial phase bigger adjustments are made in leaf sequencing. The size of these adjustments decreases as the optimization progresses through the levels [10]. The algorithm proceeds through multi-resolution levels progressively increasing the accuracy of the dose calculation. At the first multi-resolution level, only a few dose calculation segments are used to model the dose. Each multi-resolution level contains progressively more dose calculation segments [9, 10, 21].

Our study evaluated the differences of the Eclipse's Photon Optimizer (PO) algorithm

Ver. 15.6 (Varian Medical Systems, Palo Alto, CA), against the established Progressive Resolution Optimizer (PRO) Ver. 15.1 [8, 9].

During optimization, planning target volume (PTV) and OAR volumes are represented with either point clouds PRO or are spatially defined by using 1 single matrix over the image PO [9]. An optimization objective uses input parameters that are dosimetric and geometric characteristics of each field [8]. Both optimizers yield a control point sequence, defining MLC configurations and monitor unit count at each of the arc's control points [9]. Each optimization objective has an optimization priority, a dose and volume goal represented by a 2-dimensional (2D) position on a dose volume histogram (DVH) graph, and an objective weighting using a heuristic power-law formula. A multi-resolution dose calculation (MRDC) algorithm is used for a fast estimation of dose during the optimization phase of planning [8].

We used analytical anisotropic algorithm (AAA) to perform the final dose calculation. All the plan specific parameters such as energy, dose prescription, arc-geometry in RapidArc plan, penumbra margin and optimization parameters such as upper dose objective; lower dose objective, mean dose objective, normal tissue objective (NTO) and priority values were kept similar while optimizing the plan with PO versus PRO [8].

Our primary aspect was to compare the optimization efficiency of the two algorithms and to evaluate the agreement between the dose distributions computed from the two optimizations and the delivered doses, by means of pre-treatment quality assurance methods. The objective of this study was to present the comparative analysis of PRO and PO optimizers used for RapidArc/in Eclipse TPS quantitatively and qualitatively.

The study was conducted with the latest version of algorithms. This study compared plan optimization outputs for the two optimizing algorithms Photon Optimizer and Progressive Resolution Optimizer in terms of dose conformity and OAR doses primarily focusing on head and neck site which has not been done earlier. Recent papers which were published have covered different sites as they compared only the entire calculation algorithms like Acuros XB and the Analytical Anisotropic algorithm used in volumetric modulation arc therapy, not in the area of dose optimization algorithms [23].

Materials and methods

Planning

Clinical cases

The study was performed using the Eclipse Planning System 15.6 (Varian Medical Systems, United States). Tests were performed for 15 clinically relevant H&N cases compiled from the library of treated patients in our institutional database. Head and neck cases were the choice of interest because of the known complexity of differences in typical target shape, size, and location with respect to its critical structures for the simultaneous boost planning. A total of 30 treatment plans (15 PRO-RapidArc (VMAT) plans and 15 PO-RapidArc (VMAT) plans) were produced in the present study.

Planning strategy

Organs at risk were contoured and cropped from the target (with no margin) since this would compromise the target coverage in the overlapping region. To improve spatial targeting of dose and to allow for improved sparing of the associated OAR while not giving conflicting optimization inputs, additional physics structures were created apart from standard contours. For each patient, the dose volume constraints, priorities and arc geometries were defined in a preliminary phase. The same strategy was applied as a class solution for all patients and optimization algorithms (both PO and PRO).

Technical delivery aspects

The treatment machine model used in this study was Varian Truebeam SVC V2.7 linear accelerator (Varian Medical Systems) equipped with Millennium MLC 120 leaves with 0.5 cm width for 20 cm inner side, 1 cm width for outside 20 cm at field size isocenter. A VMAT plan was generated for each case according to our institutional protocol using 2 full arcs with 6 MV photon beam to deliver two dose levels of 65.0 Gy and 54.0 Gy in 30 fractions. The first arc was set in the clockwise direction and the other one in the counterclockwise direction. The maximum dose rate was set at 600 MU/min. The collimator was rotated between 10° and 350° for all the plans, to cover the entire tumour and to reduce the cumulative effects of tongue and groove leakage throughout gantry rota-

tion, and to allow spatial modulation in the transverse plane. The collimator was set to be open to the largest PTV, throughout the entirety of the gantry rotation, with an extra margin of approximately 10 mm. The total numbers of control points are 177 for each arc. All the plans used in the study were planned as per the above strategy.

All optimizations were performed on the same hardware (a Dell T5400 workstation equipped with Windows 7, 64 Bit operating system and 24 GB of RAM) running distributed calculation framework Eclipse 15.6 client and database server using PO and PRO optimizers. A plan template using the same objectives for the same number of iterations was used for each optimized plan without planner's intervention. Plans were generated optimizing the cropped OAR with the mean objective. The plan objective in the TPS for all plans was designed using the Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC) protocol [11]. This empirical strategy has been adopted through extensive planning experience and modifications made to the many planning parameters involved across a range of patients.

Optimization algorithms

Progressive Resolution Optimizer (PRO)

The arc optimization algorithm, PRO used in RapidArc (VMAT), optimizes leaf position, dose rate and gantry speed [10] based on dose-volume objectives which is performed using progressive sampling in five resolution levels. For each sector, a temporary fluence is created and optimized from all the Control Points (CP) within the sector. It is assumed that the control points are delivered from a static gantry position in the middle of each sector. PRO does not restrict the total number of points. Leaf motion and the leaf tongues are modelled by interpolating leaf positions between the control points and by modifying the MLC aperture, respectively. This is done to effectively account for the tongue and groove effect. The angle resolution of the dose calculation segments gets more accurate as the optimization progresses, and in consequence, the dose also gets more accurate. During the whole optimization the number of control points remains the same. As the phases progress, the arc sectors become smaller with fewer control points. From the optimal fluences trial leaf

sequences are produced, and actual fluences from the leaf sequences.

The MLC shapes are conformed to the targets and the initial dose rates are equal for all dose calculation segments at the beginning of the optimization. The size of these adjustments decreases as the optimization progresses through the levels. From the combined fluence at the control points, within a certain sector of the arc, the dose in a dose calculation segment is calculated. The angle resolution of the dose calculation segments gets more accurate as the optimization progresses and, in consequence, the dose also gets more accurate. At the first multi-resolution level, only a few dose calculation segments are used to model the dose, and each multi-resolution level contains progressively more dose calculation segments. The angle between the resulting dose calculation segments on the multi-resolution level 4 will be approximately 2° to 4° [10]. The total number of dose calculation segments used depends on the span of the arc. At the end of the optimization, the entire set of CP is sent for dose calculation to the photon dose calculation algorithm. Final dose calculation could be performed with a gantry sampling equal to the number of machine CP, or with a specified value selectable by users. The dose calculation is based on the multi resolution 3D convolution of Monte Carlo (MC) generated point spread function kernels. The PRO algorithm has features for inhomogeneity and air cavity correction.

Photon optimization algorithm (PO)

PO determines the optimal field shape and intensity by iteratively conforming the dose distribution until an optimum solution is reached. It uses a new structure model, where structures, dose volume histogram (DVH) calculation and dose sampling, are defined spatially by using one single matrix over the image. This matrix defines the locations of the structures and the sampling of the dose, and it substitutes the previously used point clouds. It generates a sequence of control points which define MLC leaf positions and MU/deg as a function of gantry angle [8, 9]. MU/deg is encoded in Digital Imaging and Communications in Medicine (DICOM) and the Varian system database with the cumulative meter set weight, which defines the increase in MU

between control points relative to the total MU in the field. This information is transferred to the treatment machine as such, and the machine control system determines how dose rate and gantry speed will be modulated to deliver the plan. The main difference of the PO algorithm from PRO is that the PO uses a point cloud model for defining structures [8].

The PO creates RapidArc (VMAT), plans based on dose-volume objectives. The fluence is fitted to the target projection with a 5 mm margin and is expanded symmetrically to the field isocenter (by adding fluence pixels with 0 value). The maximum size of the fluence object is 40×40 cm [8]. The fluence object size determines the region where the planner can edit the fluence. From the combined fluence, through the MLC apertures at the control points located within a certain sector of the arc, the dose in a dose calculation segment is calculated [8, 16, 19]. By interpolating leaf positions between the control points, the leaf motion is modelled. To effectively account for the tongue-and-groove effect, leaf tongues are modelled by modifying the MLC aperture outline. Once the doses at the points of the point clouds representing the patient volumes are determined, the objectives at the points and the derivatives of the point objectives can be obtained. Each point in each volume of the cost functional are evaluated [8, 9].

Multi-resolution dose calculation (MRDC)

The multi-resolution dose calculation (MRDC) algorithm is used for fast dose estimation inside the PO, PRO algorithms [8, 9]. The high speed of the MRDC algorithm allows the optimization algorithms to perform full dose computation during each iteration. The MRDC algorithm is based on the convolution superposition principle.

Optimization objectives

The inverse planning process is achieved through the definition of optimization objectives through upper or lower objectives that define the input data for optimization penalty functions. Each objective corresponds to a point in the dose-volume data space. The exploration gEUD objectives is out of the scope of the present work, which aims to evaluate the capability of this tool to modulate, with one single objective, the shape of an OAR DVH.

Optimization

Initially, high priority was given only to the target structures. Once PTV coverage was adequate, organ objectives were added to spare the associated OAR as much as possible without compromising the PTV coverage. As the optimization is initiated, it is first allowed to stabilize to what is achievable through the initial starting objectives and the NTO. Throughout the final two resolution levels, the ability of the optimizer to meet the PTV objectives will improve. This will be at the cost of reduced OAR sparing but will be of minimal effect. The optimization is only completed if the total objective function gradient is close to zero and the desired results are met. The optimization resolution was set to 2.5 mm (normal setting).

Dose calculation is done following the optimization, using the optimized MU value (rounded to machine precision) and the Anisotropic Analytical dose calculation algorithm (AAA) with a dose grid size of 2.5 mm.

Analysis

The first objective of the study was to assess the mutual quality of plans optimized with PRO and PO. This was aided by means of conventional DVH and standard evaluation parameters of target and organs at risk.

Plan evaluation was done using the PTV parameters (D98%, D95%, D50%, D2%, Dmax, mean dose and V105%), homogeneity index (HI), conformity index (CI), MU per degree with control points (CP), OAR doses and gamma verification (portal dose and ArcCHECK). The homogeneity of the treatment plans was expressed in terms of (D5%–D95%)/D50% according to The International Commission on Radiation Units and Measurements report 83 (ICRU 83) [12].

ArcCHECK, a cylindrical acrylic phantom with a three-dimensional array of 1386 diode detectors with 10 mm spacing is used as a QA tool for all the plans [12, 14]. It measures radiation in real time with 50 ms update rate, saves all relative and absolute dose measurements as a function of time. Verification plans were created for all the plans with the PMMA density overridden [13, 14]. For the purpose of QA in this paper, the phantom is set with couch rotation zero, and the measurements were taken in the same geometry. Gamma evaluations were performed

in the absolute dose mode. The global and local gamma indices (γ index) were both computed for 3 mm/3% and 2 mm/2% criteria using the SNC software. Treatment planning system (TPS)-calculated dose was used as the reference for the ArcCHECK evaluation testing.

Results

All the plans sufficiently respected the planning objectives and can be clinically accepted. Evaluated parameters include the PTV (maximum, minimum, mean) dose, OAR (maximum, mean) dose, conformity index, quality index, homogeneity index, PTVD_{95%}, PTVD_{98%}, PTVD_{50%}, PTVD_{2%}, V_{105%}, OAR_{100%}, integral plan MU and beam on time. All the data in this study were obtained with the Anisotropic Analytical Algorithm for dose calculation.

Table 1 provides an overview of the numerical findings from an average DVH analysis on PTV and OARs and are reported as mean values \pm standard deviation (SD). The average volume of the PTV₁ was 34.1 to 12.5 cc, PTV₂ was 30.8 to 18.1 cc for 65 and 54 Gy treatments, respectively. The target coverage (D95%) for PTV₁ and PTV₂ were 98.6 ± 0.8 , and 98.6 ± 1.7 , respectively, for the plans delivered with PRO based optimization and for PO based optimization it was 98.8 ± 0.9 and 98.8 ± 1.5 . The PTV₁ and PTV₂ volumes receiving 105% of the dose were 4.6 ± 6.8 , 5.9 ± 5.1 for PRO plans and 5.0 ± 9.9 , 3.8 ± 3.4 for PO plans.

In PRO optimization, the maximum dose received by the spinal cord was 39.8 ± 6 Gy, brain stem was 38.8 ± 8.4 Gy, mandible was 66.1 ± 5.1 Gy, and thyroid was 53.6 ± 10.0 Gy. The mean dose received by the left parotid was 34.0 ± 13.1 Gy, right parotid was 31.8 ± 10.9 Gy, larynx was 39.3 ± 8.7 Gy, oral cavity was 59.2 ± 2.8 Gy.

In PO optimization, the maximum dose received by the spinal cord was 39.1 ± 6.3 Gy, brain stem was 38.9 ± 7.9 Gy, mandible was 66.1 ± 5.2 Gy, and thyroid was 59.8 ± 2.8 Gy. The mean dose received by the left parotid was 34.3 ± 13.4 Gy, right parotid was 32.5 ± 10.8 Gy, larynx was 39.5 ± 9.3 Gy, oral cavity was 58.4 ± 4.8 Gy.

The independent agreement of the calculated versus delivered dose distributions for both optimization algorithms is verified with different passing criteria. Quality assurance with the portal dosimetry method was performed and the fraction of

Table 1. Planning target volume (PTV) dosimetric parameters from the optimizer-based plan [Progressive Resolution Optimizer (PRO) and Photon Optimizer (PO)] presented together

Comparison of target dose coverage													
S.No	Diagnosis	PRO						PO					
		PTV ₁ [Gy]			PTV ₂ [Gy]			PTV ₁ [Gy]			PTV ₂ [Gy]		
		D _{95%}	Mean dose [Gy]	V _{105%}	D _{95%}	Mean dose [Gy]	V _{105%}	D _{95%}	Mean dose [Gy]	V _{105%}	D _{95%}	Mean dose [Gy]	V _{105%}
1	Ca tongue	99.1	60.9	1.2				99.1	60.7	1.0			
2	Ca tongue	98.6	60.7	2.4	99.0	54.6	2.7	99.3	60.6	0.7	99.5	54.6	1.5
3	Ca tongue	97.7	65.5	1.8	95.2	54.5	6.9	99.2	65.6	0.4	98.6	54.7	4.3
4	Ca retro molar trigone (RTM)	98.9	65.6	0.8	99.4	54.7	4.3	99.1	65.6	0.2	99.5	54.8	4.6
5	Ca larynx	99.2	66.1	1.9	99.1	55.2	13.6	98.0	65.8	0.9	97.4	54.7	6.8
6	Ca buccal mucosa (BM)	98.1	66.0	5.5	99.9	55.1	1.5	97.0	65.4	2.3	99.9	54.7	0.3
7	Ca left lower alveolus	99.6	64.3	9.4	99.4	55.4	13.9	99.6	64.5	9.5	99.4	55.4	13.0
8	Ca buccal mucosa	99.1	60.7	1.0				99.6	60.7	1.1			
9	Ca lower gingivo buccal sulcus (GBS)	97.4	70.6	15.6	94.3	60.5	8.3	97.6	70.4	10.9	94.2	60.4	5.2
10	Ca tongue	99.7	65.6	0.2	99.6	63.9	2.6	99.9	67.8	39.2	99.6	66.0	2.8
11	Ca PFS	98.4	65.7	2.9	99.9	54.7	2.7	98.8	65.8	2.3	99.6	54.7	4.4
12	Ca hard palate	98.8	65.5	0.4	98.7	54.7	4.4	98.8	65.6	0.7	98.7	54.7	2.8
13	Ca tongue	98.4	63.7	2.2	99.5	60.0	0.0	98.2	63.7	2.5	99.7	60.1	0.1
14	Ca tongue	99.9	65.4	0	99.5	54.6	1.1	99.9	65.6	0.0	99.6	54.5	0.6
15	Ca buccal mucosa (BM)	97.1	66.6	24.	98.6	55.3	14.8	97.3	65.8	4.1	98.8	54.7	3.5
	Mean	98.8	64.7	3.2	98.6	56.5	5.2	98.9	64.8	5.1	98.8	56.6	3.9
	SD	0.7	2.6	4.3	1.8	3.1	4.6	0.8	2.7	10.3	1.6	3.6	3.5

Ca — carcinoma; SD — standard deviation

points in the 2D dose matrices passing the test with 3%, 3 mm passing criteria resulted to be 100.0 ± 0.1 and 100.0 ± 0.1 for PRO and PO, respectively. For 2%, 2 mm passing criteria, it resulted to be 99.6 ± 0.2 for PRO based optimization and 99.7 ± 0.2 for PO based optimization.

For ArcCHECK with 3%, 3 mm, 2%, 2 mm and 1%, 1 mm passing criteria, the results were found to be 99.9 ± 0.1 , 99.6 ± 0.6 and 94.6 ± 3.0 respectively for PO plans and 99.9 ± 0.1 , 99.6 ± 0.4 and 93.6 ± 3.9 for PRO plans.

Discussion

Both PO and PRO is based on the same principle. PO optimizer also incorporated MRDC dose calculation algorithm the same as in PRO to increase speed dose calculation during optimization. This can be predominantly understood with the help of fundamental change made in

PO optimizer [8, 9]. Our study shows that there is an increase in the monitor units produced by VMAT delivery plans optimized using the PO algorithm in comparison with plans produced by using the PRO algorithms. The PRO optimizer has point cloud of fixed 3-dimensional grid size feature which allows more degrees of freedom. Generally, inside the PRO optimizer creates grid size. depends on the volume of the contour (i.e., a larger volume has a higher grid size compared with smaller volumes), a high number of dose points is achieved. This enables the optimized distribution of MUs in keeping with manage point, ensuing in a decrease general MU in keeping with the arc. However, in the case of PO, only one grid size can be defined manually, and no liberty has been provided at the planner end individually as per structure for the number of dose points per volume leads to over-compensation of MU distribution per control point and,

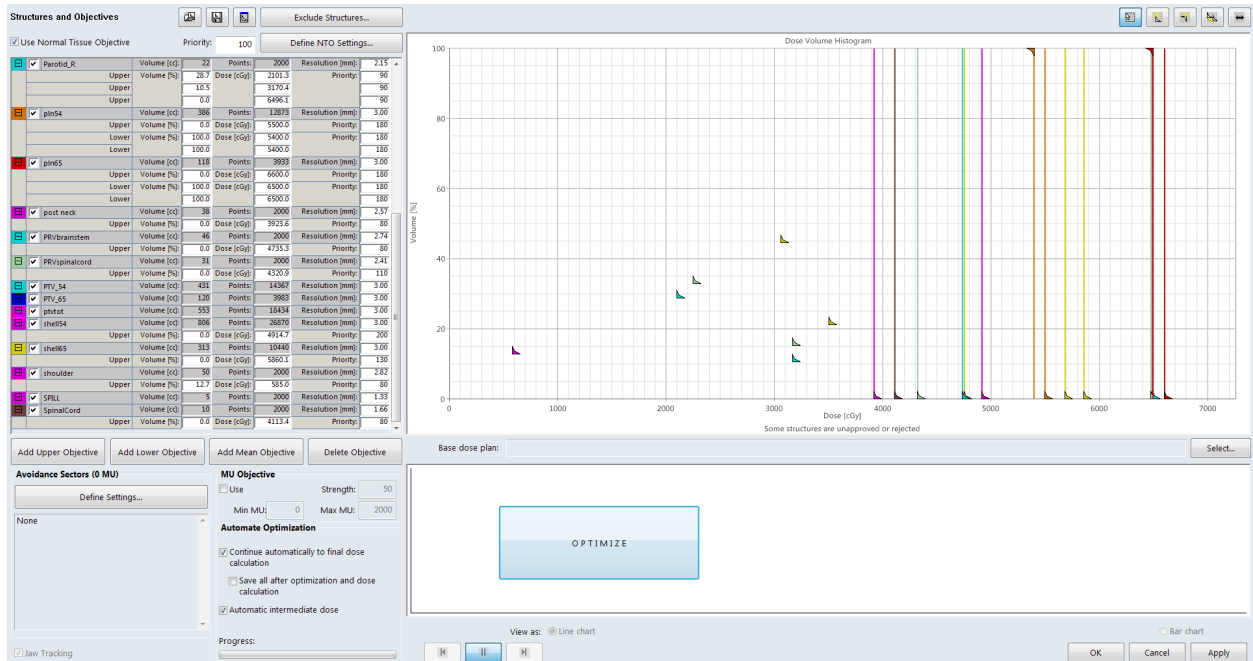


Figure 1. Progressive Resolution Optimizer (PRO) optimization window in Eclipse with objective functions and dose constraints

hence, a chance for higher total MUs. The number of dose points, i.e., the number of voxels generated based on the principle of point clouding with the same grid spacing inside the contour with PRO and PO optimizer are different [8]. The higher the number of dose points, the more accurate is dose the calculation. In PRO, depending on the volume of contour, grid size is defined automatically at time of optimization. Planner can also define grid size manually in the optimization window [8]. There are more dose points (i.e., number of voxels) at the periphery of the contour than at the center. However, in the case of PO, only one grid size can be defined manually, and no liberty has been provided at the planner end individually as per structure. When there is a high number of dose points a more accurate dose calculation will be predicted. For PO plans this calculation method could explain the relatively higher MU distribution per degree along the arc [18-20].

Binny et al. showed that for both algorithms almost the same MU is achieved for head and neck treatments, but our results showed that PO optimized plan MUs was higher than PRO produced plans in most of the cases [16]. Many papers' results showed PO plans MU higher than PRO [15, 22].

A comparable PTV coverage and OAR doses are achieved for PO when compared with PRO-optimized treatment plans. This can be attributed to the dose optimization strategies using the same constraints and cost functions for both PO and PRO optimizer. The constraints and objective functions are shown in Figure 1 for PRO and Figure 2 for PO optimizer windows. Quantitative analysis of the plan is shown in Tables 1 and 2. Both the DVH of plans optimized with the PO and PRO are almost overlapping. Target coverage was similar for both PRO and PO optimized plans. However, meaningful deviation was found towards the OAR side. Results shown in Table 2 indicate that the mean PTV doses for most cases were not significantly different for the two optimizers, which shows that the target coverage was not substantially affected by the choice of the optimization algorithm. Dosimetry results of gamma analysis demonstrated an overall agreement between ArcCHECK-measured and TPS-calculated reference doses. Figure 9 shows MU per degree comparison for both PRO and PO optimizer. MU per degree with each individual control points generated by PO showed high degree of modulation compared to PRO.

Qualitative investigation of PRO, and PO optimizer was performed based on estimated param-

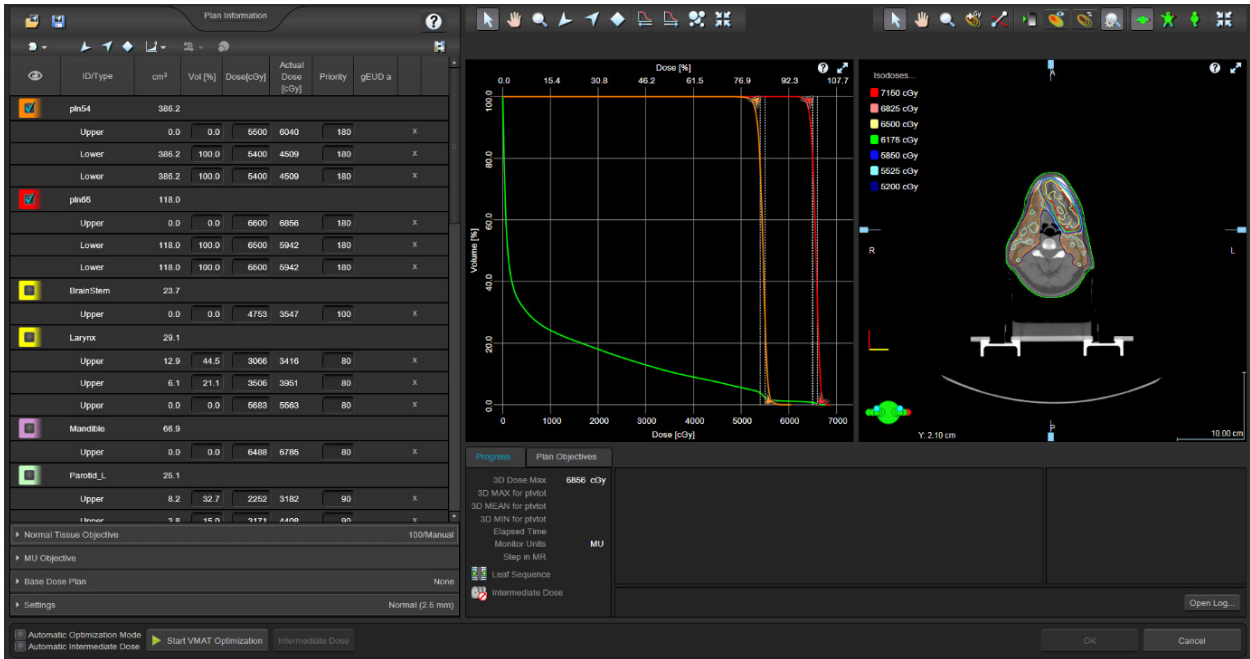


Figure 2. Photon Optimizer (PO) optimization window in Eclipse with objective functions and dose constraints

Table 2. A summary of the general features of dose optimization algorithms

Features	Photon Optimizer 15.6	Progressive Resolution Optimizer 15.1
Heterogeneity correction	Yes	Yes
Bolus	Yes	Yes
Support devices	Yes	Yes
Dose volume objectives	Yes	Yes
Mean dose objectives	Yes	Yes
Maximum dose	MU objective for VMAT	MU objective
Normal tissue objective	Interactive/ Automatic	Interactive/ Automatic
Restarting optimization	Yes	Yes
Intermediate dose calculation	Yes	Yes
Output	Fluences for static fields Leaf sequences for VMAT fields	Leaf positions and MU/deg as a function of gantry angle
Geometric optimization	Arc geometry tool for VMAT	Arc geometry tool
Dose calculation algorithm	MRDC	MRDC with progressive dose calculation segments
gEUD objective	Yes	No
Base dose support	Yes	Yes

MU — Monitor unit; VMAT — volumetric modulated arc therapy; MRDC — multi-resolution dose calculation

eters such as CI, QI, HI, total plan MU, and BOT. Insignificant differences were observed in the calculated values of CI. Results shown in Table 2 suggest that the treatment plans produced using PO were approximately as conformal as the treatment

plans produced during PRO. Marginal differences were found in values of HI. The inhomogeneity correction is taken into account by both optimizers; however, each optimizer deals with inhomogeneity correction very distinctly, thus leading to

Table 3. Comparison of various organ at risk (OAR) doses for the same objective. The dose inhomogeneity in planning target volume (PTV) was higher for Progressive Resolution Optimizer (PRO) with homogeneity index (HI) equal to 0.1 ± 0.0 when compared to Photon Optimizer (PO) with 0.1 ± 0.0 . CI were 0.99 ± 0.0 and 0.99 ± 0.0 for PRO and PO optimized plans, respectively

Comparison of critical organ doses [Gy]						
S.No	OAR	Type	PRO		PO	
			Mean	SD	Mean	SD
1	Spinal cord	Max dose	39.8	6.0	39.1	6.3
2	Brain stem	Max dose	38.8	8.4	38.9	7.9
3	Mandible	Max dose	66.1	5.1	66.1	5.2
4	Left parotid	Mean dose	34.0	13.1	34.3	13.4
5	Right parotid	Mean dose	31.8	10.9	32.5	20.8
6	Larynx	Mean dose	39.3	8.7	39.5	9.3
7	Oral cavity	Mean dose	59.2	2.8	59.8	2.8
8	Thyroid	Max dose	53.6	10.0	58.4	4.8

SD — standard deviation

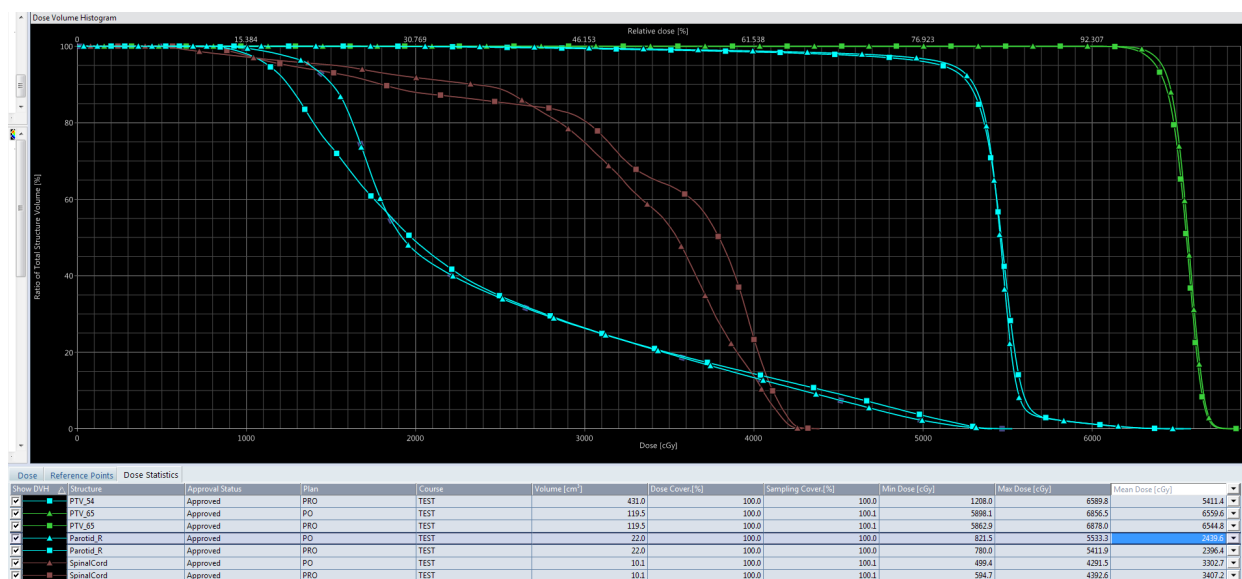


Figure 3. Dose volume histogram (DVH) comparison of the two sets of plans Progressive Resolution Optimizer (PRO) and Photon Optimizer (PO) for the parameters 95% of planning target volume (PTVD95%), organs at risk (OAR) — parotid, spinal cord

variation in integral planned MUs. PO has utilized slightly higher number of MUs for most cases than PRO.

Conclusion

To summarize, from plan quality perspective, the plans obtained with both PRO and PO algorithms were satisfactory, met optimization criteria and can be considered as clinically acceptable. PRO

confirmed to be beneficial in some of the cases with better sparing of OARs. The results presented in this study showed that PO generated plans were comparable with PRO in terms of dose conformity and homogeneity. The plans produced by the PO optimizer were more complex (with greater MLC leaf variability and more monitor units) than the plan produced by the PRO optimizer but seem justified when other clinical advantages of RapidArc (VMAT) are considered.

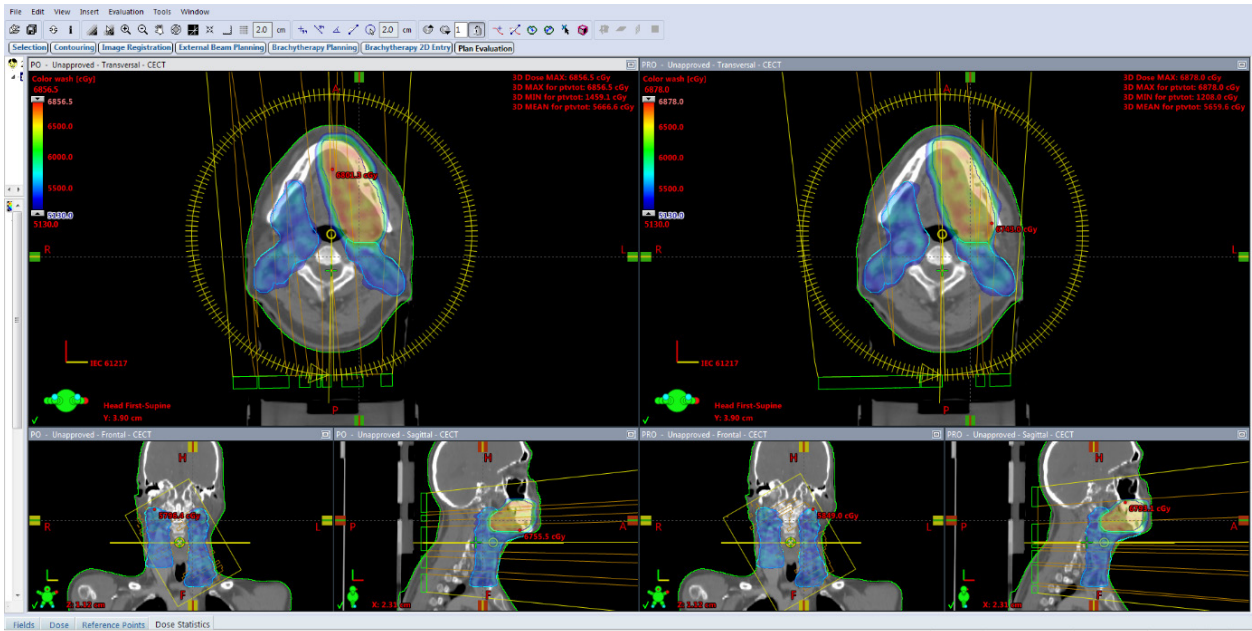


Figure 4. Comparisons dose distributions with dose level of 5130 cGy produced by Progressive Resolution Optimizer (PRO) and Photon Optimizer (PO) algorithms

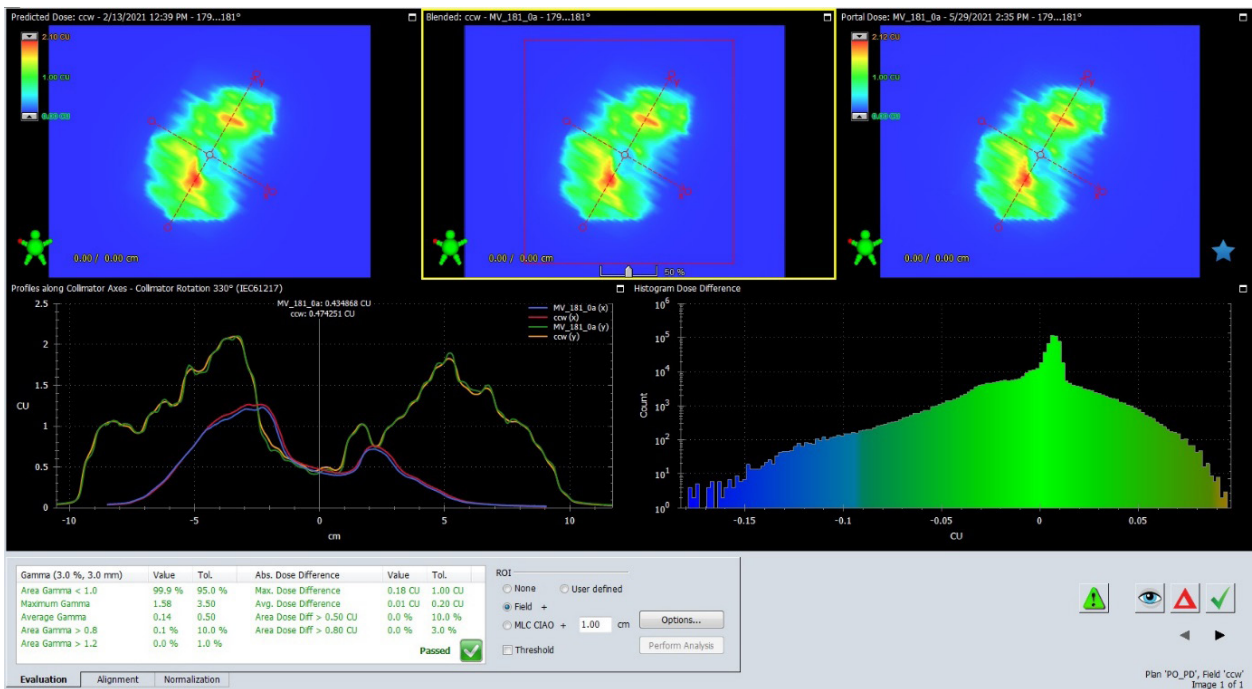


Figure 5. Portal dose analysis image obtained for Progressive Resolution Optimizer (PRO) plan

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Conflict of interest

There are no conflicts of interest

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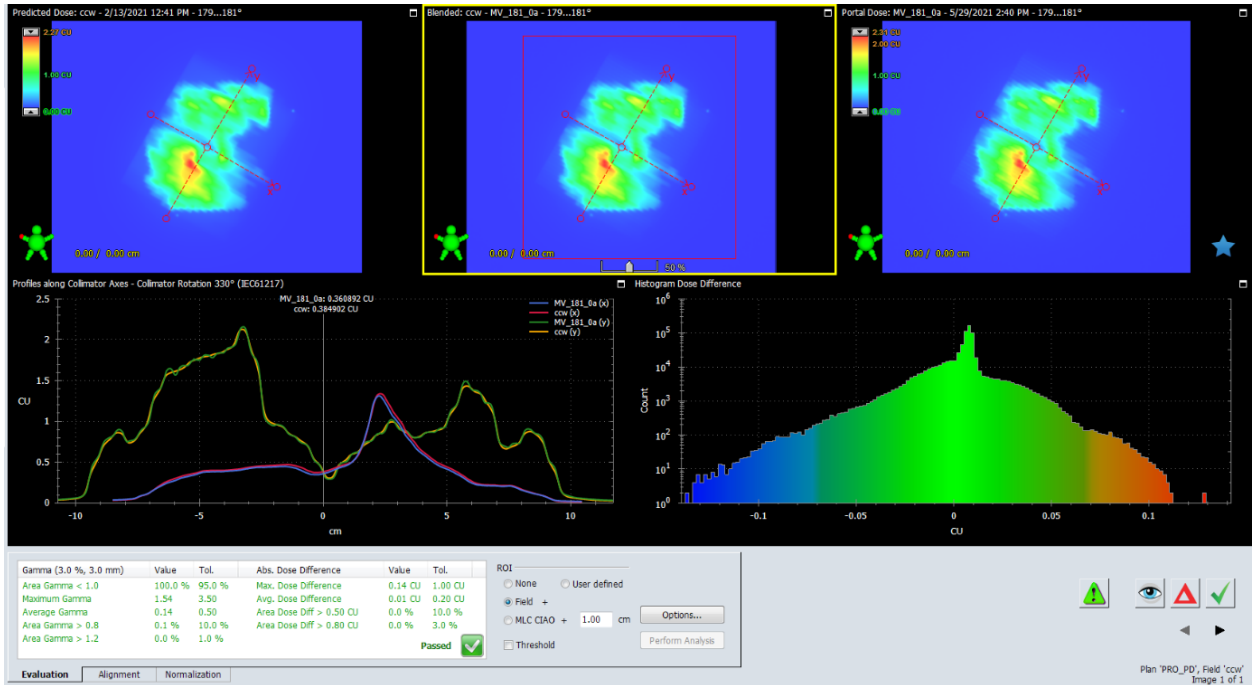


Figure 6. Portal dose analysis image obtained for Photon Optimizer (PO) plan

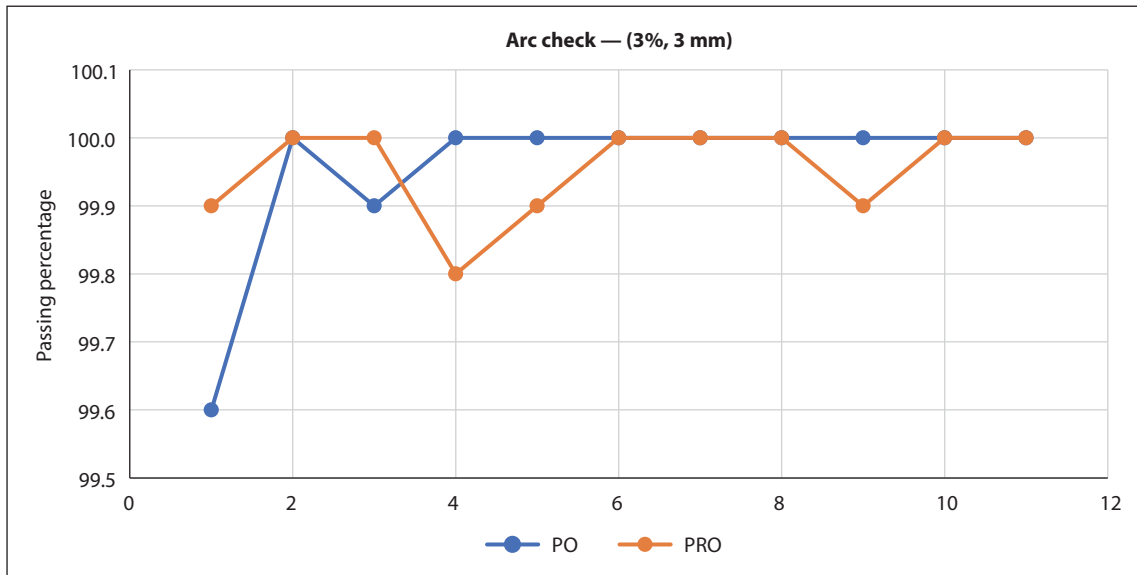


Figure 7. Graphical representation of Arc Check results for 3%/3 mm pass criteria. The average Monitor units (MU) needed to deliver the dose of 200 cGy per fraction was 647.5 ± 137.9 , 655.2 ± 138.4 for Progressive Resolution Optimizer (PRO) and Photon Optimizer (PO), respectively, and the Beam on Time (BOT) for PRO and PO was 1.1 ± 0.2 and 1.1 ± 0.2 , respectively

Ethical approval

Not applicable.

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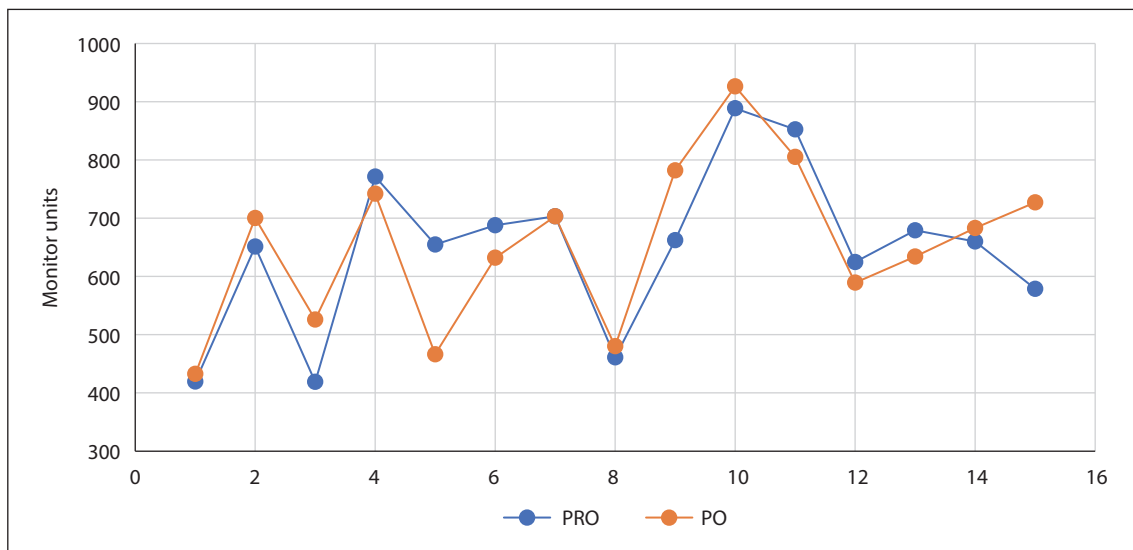


Figure 8. Graphical chart representation of the average and standard deviations of total Monitor units (MUs). PRO — Progressive Resolution Optimizer; PO — Photon Optimizer

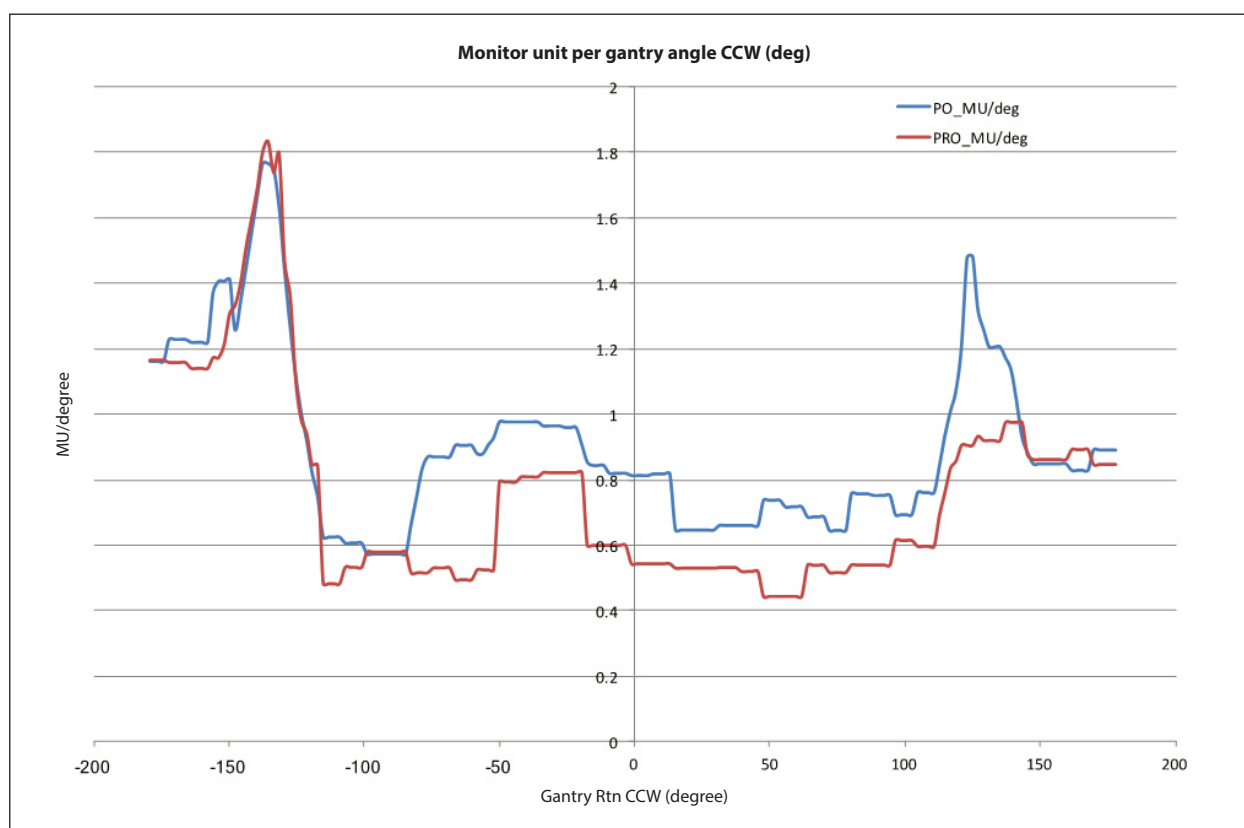


Figure 9. Monitor units (MU) per degree comparison for both Progressive Resolution Optimizer (PRO) and Photon Optimizer (PO). MU per degree with each individual control points generated by PO showed high degree of modulation compared to PRO

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