# Clinical Implementation of a Virtual-Micro MLC for Smoothing MLC Field Edge

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A Siemens HD-270 MLC™, a virtual-micro MLC, allows to the application of a smooth field edge method due to the finite leaf-width of MLC. This technique was implemented into a Pinnacle planning system in order to evaluate the dose distributions during the planning stage. The necessary dosimetric aspects, such as undulation and effective penumbra, were investigated with variations in the resolutions of a virtual-micro MLC and field edge angle. The positional accuracy of the couch movement was also assessed for clinical implementation. The overhead time for planning and treatment was confirmed as negligible.

**Key Words**: Virtual-micro MLC, Isodose undulation, Effective penumbra, Treatment planning

## INTRODUCTION

Whereas the use of MLC has many advantages over traditional alloy blocks[1], the well-defined edge obtained with divergent custom blocks is not duplicated with the MLC. The irregularly shaped field defined by leaves with finite width may result isodose undulation and increased effective penumbra in dose distribution, compared with that of alloy block (refer to Fig. 1).

Leavitt[2] and Galvin et al[3] suggested that the scalloping effects could be smoothed and the effective penumbra width reduced by treating a single field as the sum of segmented fields in which the central axis of each segment is shifted by a fraction of the leaf width, each leaf adjusted to redefine the field edge, and a fraction of the total MU irradiated.

The technique is implemented on the Siemens HD-270 MLC™ [4] by automatically moving the treatment table inferiorly or superiorly by a distance that is a fraction of the leaf width. To achieve the decreased effective penumbra as

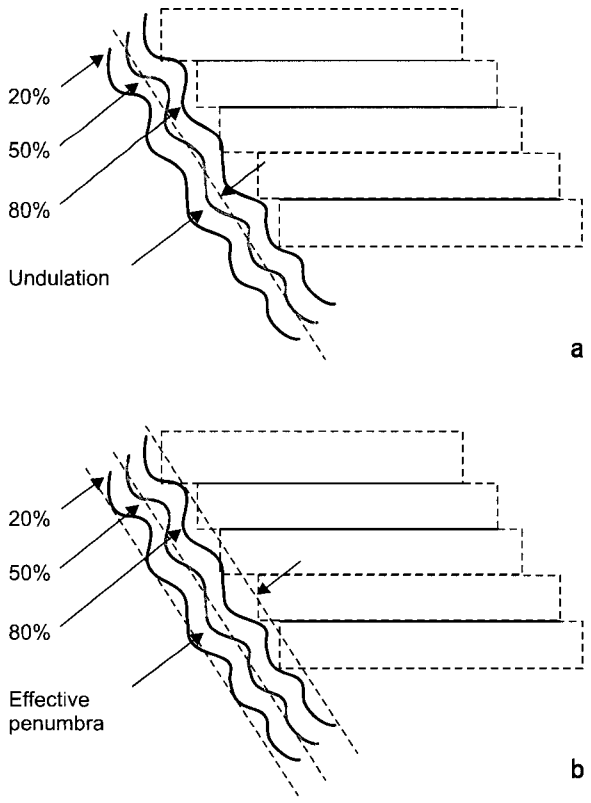


**Fig. 1.** Schematic representation of (a) isodose undulation and (b) effective penumbra. Isodose undulation is defined as the maximum distance measured from the mean position of the 50% isodose line. Effective penumbra is defined as the perpendicular distance between the line joining the peaks of the 80% isodose lines and the valleys of the 20% isodose lines.

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compared to a single MLC field, the field segments are created by effectively dividing the 1-cm leaf width at isocenter into 5, 3, and 2 mm resolution. If a 1-cm leaf is repositioned to maintain the same field edge border while the field is shifted 5 mm in the direction perpendicular to the leaf direction and the monitor units are split between the two segments, then what was once a 1-cm stair step now will become a 5-mm stair step. By increasing the number of segments to three with a 3-mm shift, then the premise would be that the stair step now becomes 3 mm, or analogously 2-mm stair steps with 5 shifts.

There exists some works about dosimetric characteristics of HD-270 MLC™ and an incorporation of the feature into a treatment planning system.[5] Woo et al.[6] also reported QA procedures on this technique. In the present work, another implementation of this technique into a commercial treatment planning system and some dosimetric features are presented. Clinical example of the HD-270 MLC™ application is also presented.

## MATERIAL AND METHODS

### 1. Implementation of the isocenter-shift technique on a 3D treatment planning system

To emulate HD-270 MLC™ technique on the stage of treatment planning process, we made a software module simulating this functionality, and integrated on the Pinnacle$^3$ ™ (Philips, USA) treatment planning system using the 'Hotscript' utility provided by this commercial treatment planning system. The table shifts required to execute the HD-270 MLC™ treatments always move the patient perpendicular to the MLC leaf plane. The table shift is three-dimensional and varies depending upon the gantry, collimator, and table angles. When emulating this technique into 3D treatment planning system, a geometric algorithm for calculating the amount of isocenter translation in any of the three planes in the patient coordinate system was adapted from that of Xue et al.[5]

The geometric algorithm is derived as follows to calculate the amount of table translation in any of the three planes (x, y, and z direction):

table lateral shift: $\chi\ (\theta, \alpha, \varphi)$

$= -S \times \sin(\theta) \times \cos(\alpha) \times \cos(\varphi) + S \times \cos(\theta) \times \sin(\varphi)$

table longitudinal shift: $y\ (\theta, \alpha, \varphi)$

$= S \times \sin(\theta) \times \cos(\alpha) \times \sin(\varphi) + S \times \cos(\theta) \times \cos(\varphi)$

table vertical shift: $z\ (\theta, \alpha)$

$= S \times \sin(\theta) \times \sin(\alpha)$

where $\theta$ is collimator angle, $\alpha$ gantry angle, $\varphi$ table angle and $S$ step size for the shift of patient's isocenter (i.e., 5, 3, or 2 mm).

After creating new segment with the shifted isocenter, each MLC leaf of the segment was automatically readjusted to conform the shifted field edge viewing in the beam's eye view coordinate system. This automatic readjustment was performed by the autoblock shaping function of the Pinnacle.

### 2. Dosimetry of HD-270 MLC™

To assess the efficacy of HD-270 MLC™ technique and determine the appropriate resolution, we investigated how does the isodose undulation and effective penumbra change with various field edge angle and resolution. If the field edge angle becomes more parallel to the direction of leaf motion, the side of the leaf becomes more prominent in forming the field edge. A polygon were created that produced field edge angle from 0 degree to 75 degrees with a step of 15 degrees. The experiment was carried out on Primus, a Siemens linear accelerator configured with HD-270 MLC™. Each HD-270 MLC™ group was generated according to the allowed resolution, i.e., 5, 3, and 2 mm. The total 60 MU of 6 MV photon beam was delivered to Kodak XV radiographic film (Eastman Kodak Co., USA) at a SAD of 100 cm and 1.5 cm depth in solid water phantom. Exposed films were scanned by film scanner and analyzed by RIT software (Radiological Imaging Technology Inc., USA).

The sensitometric curve was obtained by exposing the film at 1.5 cm depth in phantom by $20 \times 20$ cm$^2$ square field of 6 MV photon beam from 0 to 100 cGy in 20 cGy increments. The isodose distribution of 20%, 50%, 80%, and 90% were extracted from each film, and then isodose undulation and effective penumbra were measured.

### 3. Mechanical accuracy of table shift

To test the mechanical accuracy of table movement, the translation motions of the Siemens ZXT treatment table in three orthogonal directions were measured using a dial gauge

with an accuracy of 0.001 inch. The table loaded with about 50 kg to simulate a patient. The transverse, longitudinal, and vertical positions of the table were controlled by a consol from −5 mm to +5 mm with 1-mm steps and real movements were measured and compared with corresponding setting positions.

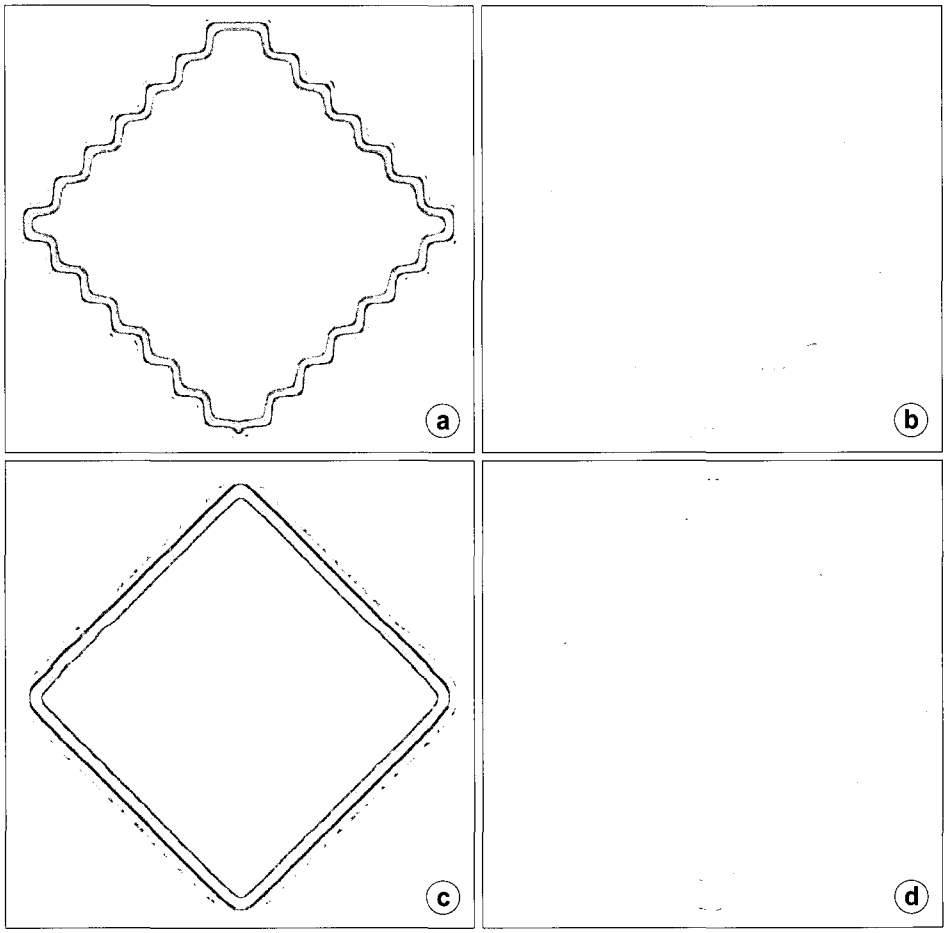


**Fig. 2.** Isodose lines obtained at dmax for a diamond shaped MLC field, with the 90, 80, 50 and 20% lines plotted outwards. The calculated (a) and film measured (b) lines are shown for a MLC of 10-mm leaf width and (c) and (d) represent a virtual micro MLC with a 2-mm width.

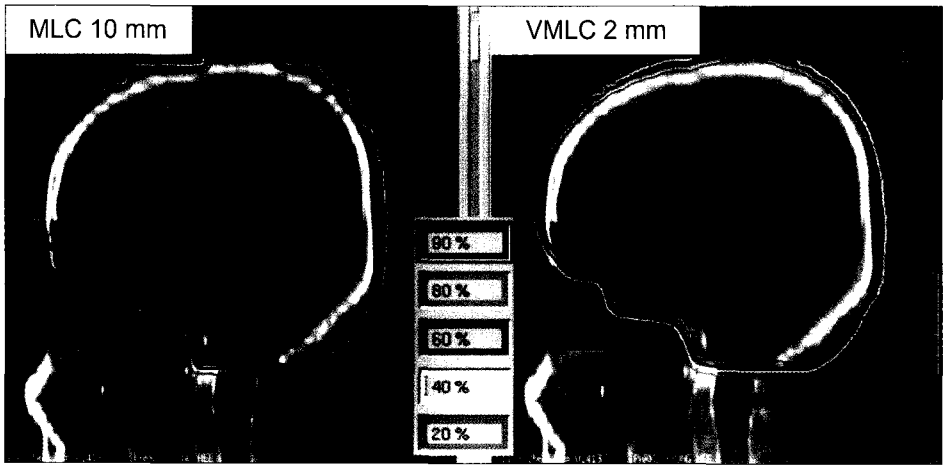


**Fig. 3.** Comparison of the isodose lines (90, 80, 60, 40 and 20% outward) for MLC resolutions of 10 (left) and 2 mm (right). The calculations were performed in Pinnacle by implementing the HD270 feature.

## RESULTS AND DISCUSSION

### 1. Implementation of the isocenter-shift technique on a 3D treatment planning system

It has been verified that the direction and amount of isocenter movements implemented on the Pinnacle planning system at any configuration of the collimator, gantry, and table angles is consistent with that of table movement during HD-270 MLC$^{TM}$ delivery.

The dose distributions for the 2-mm resolution of the HD-270 MLC$^{TM}$ technique applied to a MLC field of a diamond shape was shown at Fig. 2 (c) and (d), compared with that of the normal 10-mm resolution MLC field; (a) and (b). Presented in the figure is isodose lines obtained at dmax for a 6 MV photon beam and normalized to 100% at isocenter. The left panel is the result of simulation using the isocenter-shift technique implemented in Pinnacle, whereas the right panel is the film measurement by Primus treatment machine. The 20%, 50%, 80%, and 90% isodose lines are shown for observation of the change in isodose undulation and effective penumbra according to their resolution. Fig. 3 shows the results that was accomplished by Pinnacle on which HD-270 MLC$^{TM}$ function was implemented. It is evident from those figures that soomthing of MLC field edge is effectively accomplished by HD-270 MLC$^{TM}$ virtual-micro MLC technique.

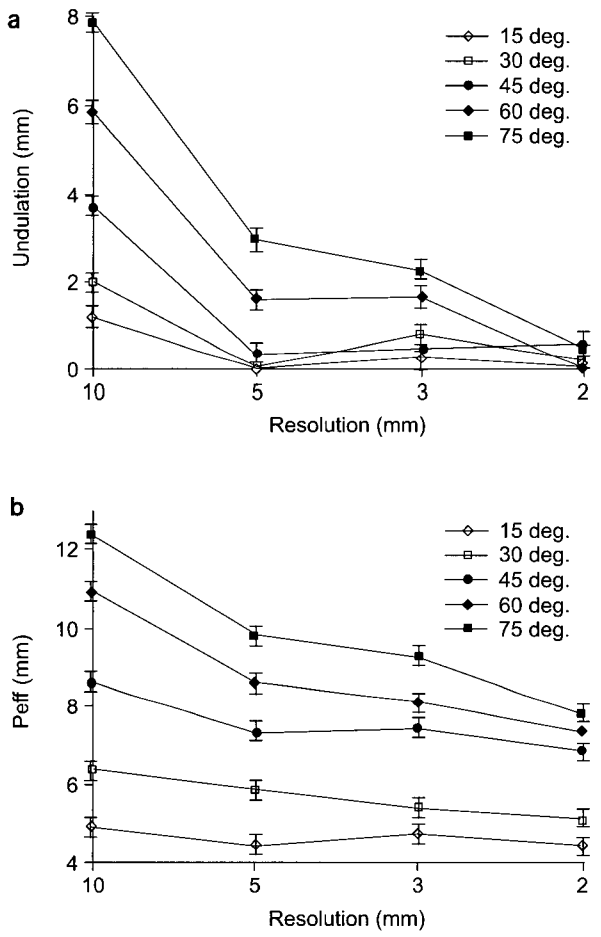


**Fig. 4.** The dependency of the isodose undulation (a) and effective penumbra, $P_{eff}$ (b) on the resolution of the HD-270 technique and the field edge angle. The isodose undulation and effective penumbra are defined in Fig. 1. The field edge angle is measured perpendicular to the leaf motion.

### 2. Dosimetry of HD-270 MLC$^{TM}$

Fig. 4 (a) shows that undulation deceases as increasing the resolution of leaf width and is more sensitive for larger field edge angle. For custom blocks, this effect is not appeared. While increasing the resolution, this effect becomes minimal but not zero due to the positional accuracy of couch that was found to be about 1 mm.

The effective penumbra decreases down to about 4 mm with increasing resolution and decreasing the field edge angle, as shown in Fig. 4(b). When using custom blocks, the penumbra is measured as about 3 mm because block is closer to the phantom surface.

### 3. QA of table shift

Fig. 5 shows the positional accuracy of a Siemens ZXT table. The movement in transversal direction is very good. However, the movement both in longitudinal and vertical direction shows about 1 mm discrepancy between the setting and actual position.

## CONCLUSION

In this work we implemented HD-270 MLC$^{TM}$ technique into a Pinnacle planning system in order to evaluate actual beam delivery at the planning stage. We also carried out dosimetric aspects of this technique in terms of undulation and effective penumbra. We also confirmed that overhead for planning and

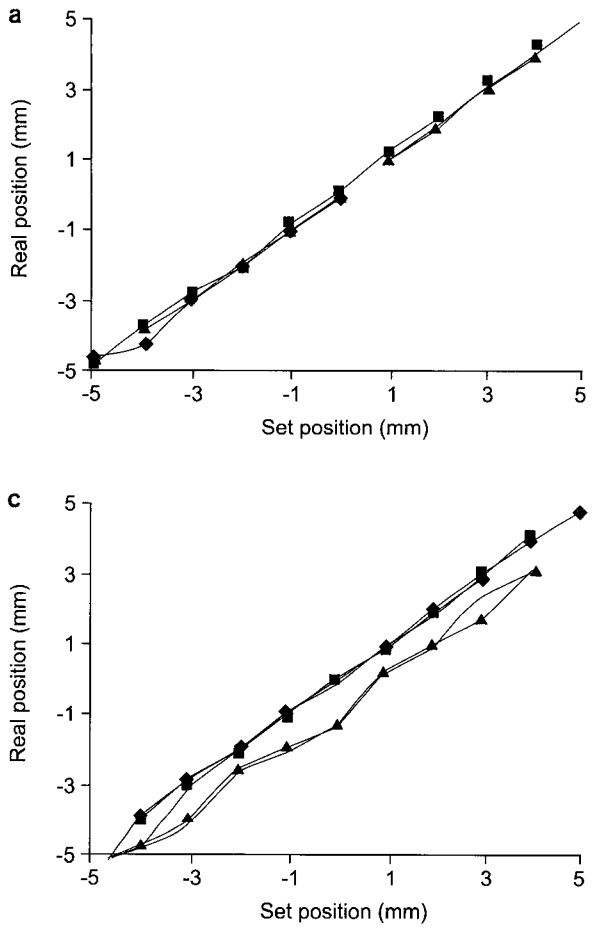


**Fig. 5.** The positional accuracy of a Siemens ZXT table for three orthogonal movements of (a) transverse, (b) longitudinal and (c) vertical directions, respectively. The table movement showed reasonable linearity of less than 0.2 mm. However, the positional accuracy in the longitudinal and vertical directions showed about a 1 mm discrepancy depending on whether the table was moving in (up) or out (down).

treatment due to subfields is negligible.

## AKNOWLEDGEMENTS

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## REFERENCES

1. **Boyer AL, Ochran TG, Nyerick CE, Waldron TJ, and Huntzinger CJ**: Clinical dosimetry for implementation of a multileaf collimator. Med Phys 19:1255-1261 (1992)
2. **Leavitt DD**: Dynamic treatment techniques. *Proceedings Varian Australian Users Meeting* (Sydney, Australia) 1991
3. **Galvin JM, Leavitt DD, and Smith AA**: Field edge smoothing for multileaf collimators. Int J Radiat Oncol Biol Phys 35:89-94 (1996)
4. ***Siemens HD-270 MLC users manual*** (2000)
5. **Xue J, Zhang P, Wu J, Wang Z, and Sibata C**: Implementation of the isocenter-shift technique for smoothing MLC field edge on a 3D treatment planning system. Med Phys 29:1413-1420 (2002)
6. **Woo M, Charland P, Kim B, and Nico A**: Commissioning, evaluation, quality assurance and clinical application of a virtual micro MLC technique. Med Phys 30:138-143 (2003)

# 다엽콜리메이터에 의한 조사경계면에서의 요동현상을 완화시켜주는 가상미세다엽콜리메이터의 임상 적용

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**조병철 · 박희철 · 배훈식**

지멘스(Siemens)사에서 개발된 가상미세다엽콜리메이터인 HD-270은, 전형적 다엽콜리메이터에 있어 폭의 유한성 때문에 불필요하게 발생하는 조사경계면의 요동현상을 완화시켜준다. 저자들은 이 기법을 사용했을 때의 선량분포의 변화를 확인하고, 치료계획단계에서 이를 평가해 볼 수 있도록 Pinnacle (Philips Radiation Oncology Systems, 미국) 전산화치료계획장치에 구현하였다. 그리고 임상적용에 앞서 선량학적 특성을 파악하기 위해, 가상미세다엽콜리메이터의 해상도, 조사경계면과 다엽콜리메이터가 형성하는 각도가 요동현상 및 유효반음영에 미치는 영향을 평가하였다. 또한 가상미세다엽콜리메이터 구현에 수반되는 치료테이블 움직임에 대한 위치 정확도를 평가하였다. HD-270의 임상적용을 위해 추가적으로 소요되는 치료계획과 치료 시간은 무시할 수 있음을 확인할 수 있었다.

**중심단어**: 가상미세다엽콜리메이터, 등선량요동현상, 유효반음영, 치료계획