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Dosimetry of cones for radiosurgery system

Dosimetria de cones para sistema radiocirúrgico

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Abstract

Dosimetry of small fields, such as cones for radiosurgery, requires a lot of care in its implementation. The acquisition of curves of Percentage depth dose (PDD) and profiles for nine circular cones with diameters from 4 to 20 mm for 6 MV photons was performed. Measurements with four types of dosimeters: diode, pinpoint ionization chamber, diamond detector and film were done. A comparison between the data obtained with the several detectors permitted to conclude that the diode is the detector more reliable. The effect of various methods to "smooth" the curves was studied and showed that there are methods that change very much the measured data. Interpolations were made in PDD curves in order to eliminate the noise of small fields due to low signal in the detectors. The most important conclusion refers to the choice of suitable detector, in this case the diode, and to a careful handling of obtained data to not disturb or modify the results of the measurements.

Keywords: cones, radiosurgery, commissioning, diode detector, diamond detector, pinpoint chamber, dosimetric film.

Resumo

A dosimetria de pequenos campos, como cones para radiocirurgia, requer muito cuidado em sua implementação. A aquisição das curvas de porcentagem de dose na profundidade (PDP) e perfis para nove cones circulares, com diâmetros de 4 a 20 mm para fótons de 6 MV, foi realizada. Foram realizadas as medidas com quatro tipos de dosímetros: diodo, câmara de ionização do tipo pinpoint, detector de diamantes e filme. Uma comparação entre os dados obtidos com diversos detectores permitiu concluir que o diodo é o detector mais confiável. O efeito dos diversos métodos para "atenuar" as curvas foi estudado e mostrou que existem métodos que realmente mudam os dados medidos. Interpolações foram feitas em curvas de PDP para eliminar os ruídos de pequenos campos, devido ao baixo ruído nos detectores. A conclusão mais importante refere-se à escolha do detector adequado, neste caso, o diodo, e ao manuseio cuidadoso dos dados obtidos para não transtornar ou modificar os resultados das medidas.

Palavras-chave: cones, radiocirurgia, comissionamento, detector de diodo, detector de diamantes, câmara detalhada, filme dosimétrico.

Introduction

The cones are precise accessories used to apply radiosurgery. With them, it is possible to obtain circular fields with diameter down to 4 mm. At the moment of treatment, the jaws aperture needs to be smaller than the external circumference of the cone, because this is the shielded region of this accessory. The recent accidents related to the use of cones were originated just because the jaws had been set wrong. As a manufacturer recommendation, the adequated jaw's aperture must be the same for all cones size; for our set of cones, it must be 26 mm x 26 mm. So, the use of this accessory demands a lot of attention and care. This care must be taken in the entire process of a radiosurgery with cones, beginning by the data acquisition.

The data needed to feed the planning system are numerous and must be obtained through direct measurements[1].This work presents the dosimetry data obtained with cones and the discussion about how to handle these data.

Materials and methods

The cones, showed in Figure 1, were commissioned in an accelerator Varian 6EX, 6 MV photon energy, equipped with micro-multileaf (mMLC) collimator m3 BrainLab.

With an automatic scanning system, it was obtained the Percentage depth dose (PDD) and the profile curves at 7.5 mm depth in transverse directions for nine cones with


1.a 1.b

Figure 1. Circular cone mounted at 6EX accelerator. 1.a shows cone 4 mm and 1.b, 20 mm.

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diameter from 4 mm to 20 mm. The measurements were made with diode, pinpoint chamber, diamond detector[2] and dosimetric film.

Table 1 presents the type and characteristics of the detectors used.

The diode, pinpoint chamber and diamond detector were positioned vertically in the water phantom, because the fields were too small. For the measurements with the diode and pinpoint chamber, it was used the 3D scanning Blue Phantom of IBA, and for the diamond detector, it was used the PTW MP2 phantom, because it has a particular insulation system.

The EDR2, an enveloped film, was put between slabs of solid water to obtain the buildup and lateral scatter. For the measurements of PDD, the film was positioned vertically and this positioning had to be done very carefully, because, as the fields are very small, it is very difficult to put the film exactly in the direction of the central axis especially for the cone of 4 mm diameter. For the measurements of profiles, the film was positioned horizontally.

The curves of PDD and profile obtained were smoothed.

Absolute measurements of output factor for a field 10 cm x 10 cm and for each cone were done, and the scatter factor was calculated.

The treatment planning system iPlan for radiosurgery with cones needs beam data used for the Clarkson dose calculation methods. The major beam data required for the commissioning of this unit include depth dose data measured at source-to-surface distance (SSD) of 98.5 cm, beam profiles measured at the depth of 7.5 cm with SSD of 92.5 cm and relative scatter factor data measured at the depth of 1.5 cm with SSD of 98.5 cm.

Results and discussion

Diode results

PDD curves

The curves presented in Figure 2 are the PDD for 9 cones obtained with diode, and Figure 3 is the same curves smoothed.

The Figure 4 shows curves, the original and the smoothed manually for cone of 4 mm. The original curve presents a lot of noise that may be perceived because, as the electric signal is small, the size of noise is proportionally big. We tried to smooth the curves using several methods presented as tools in the software OmniPro-Accept, but finally it was chosen to do manual interpolations and corrections. The same procedure was applied to all other PDD curves.

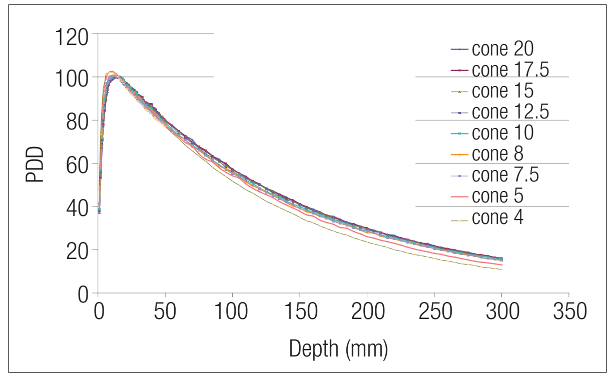

Figure 2. PDD curves for 9 cones measured with diode and not smoothed.

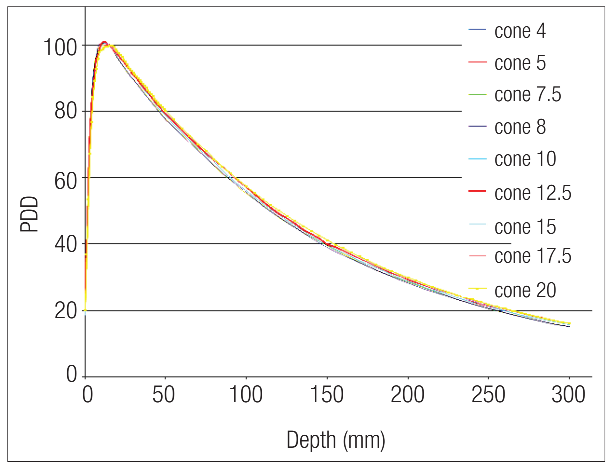

Figure 3. PDD curves for 9 cones measured with diode and smoothed.

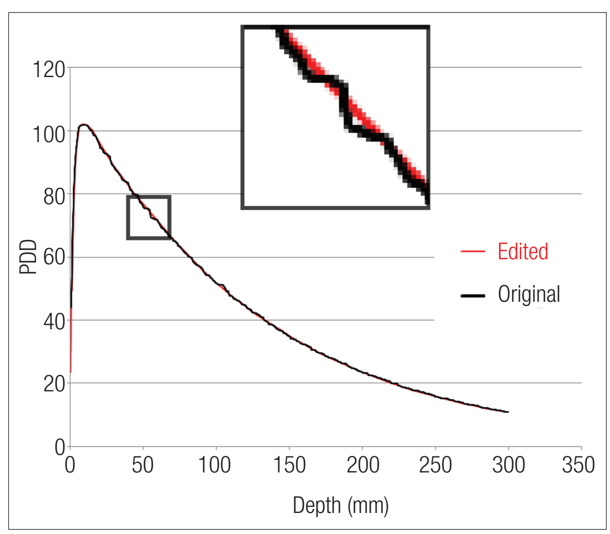

Figure 4. PDD curves for cone with 4 mm diameter: original and edited.

Table 1. Characteristics of the detectors

Detector type	Model	Brand	Effective measurement point	Thick ness (mm)	Diameter of active area
Diode	Stereotactic SFD	IBA	<0.9 mm	0.06	0.6 mm
Pinpoint chamber	CC01	IBA	2.3 mm from tip	3.6	2 mm
Diamond detector	60003	PTW	0.5 mm	0.3	3 mm
Film	EDR2	Kodak			

Profile curves

The curves presented in Figure 5 are halves of the profiles for 9 cones obtained with diode. These curves furnished the off axis factor for each cone inserted in the planning system.

Scatter factor

The relative scatter data were measured with diode at the depth of 1.5 cm with SSD of 98.5 cm. The relative scatter factor was calculated by dividing the measured data for each collimator setting, by the measured data at the same depth and same SSD for a field size of 10 cm x10 cm. Figure 6 shows the relative scatter factors for different circular cones with collimator jaws of 2.6 cm x 2.6 cm.

Pinpoint results

PDD curves

The same results of PDD were obtained with pinpoint chamber, but with much more noise because of the size of the chamber. (Figure 7)

Profile curves

The profile curves obtained with pinpoint chamber, showed in Figure 8, are like that obtained with diode, but also present a lot of noise.

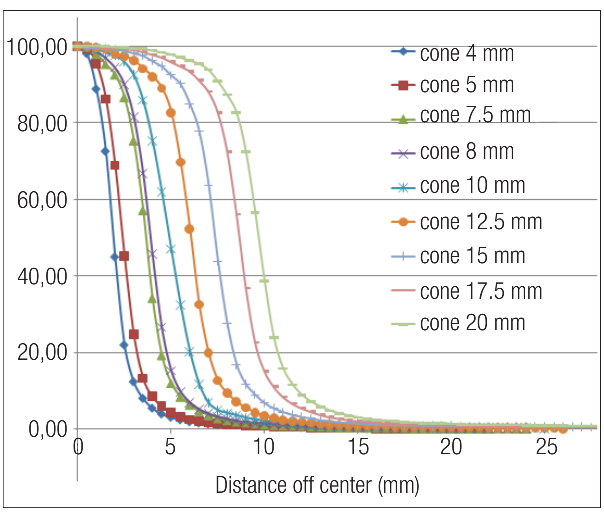

Figure 5. Profile curves for 9 cones measured with diode.

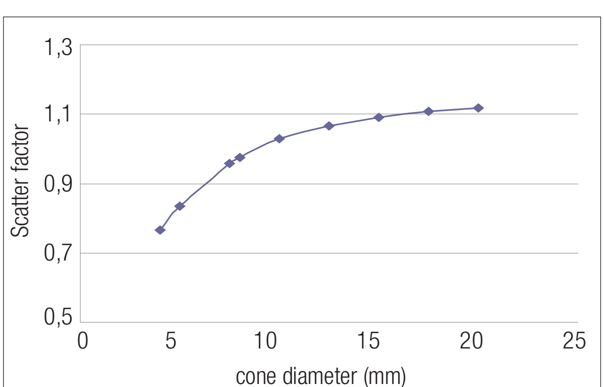

Figure 6. Scatter factor relative of 9 cones measured with diode.

Film results

Profile curves

The Figure 9 is the image obtained irradiating the film perpendicularly to the central axis at the depth of 7.5 cm with SSD of 92.5 cm.

This was scanned in an Epson Expression 10000XL device to construct the profile curves presented in the Figure 10.

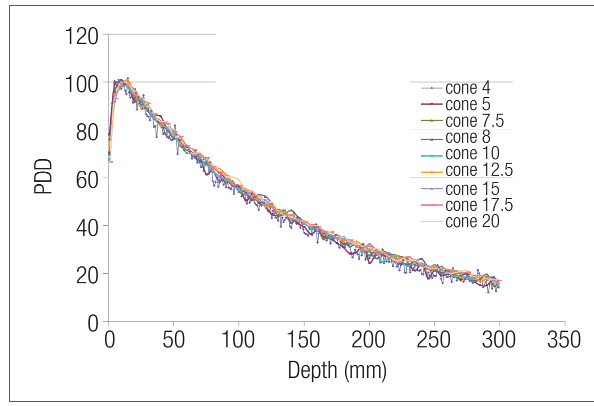

Figure 7. PDD curves for 9 cones measured with pinpoint chamber.

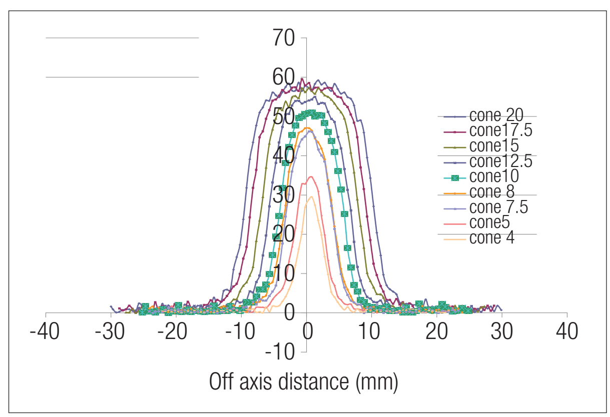

Figure 8. Profile curves for 9 cones measured with pinpoint chamber.

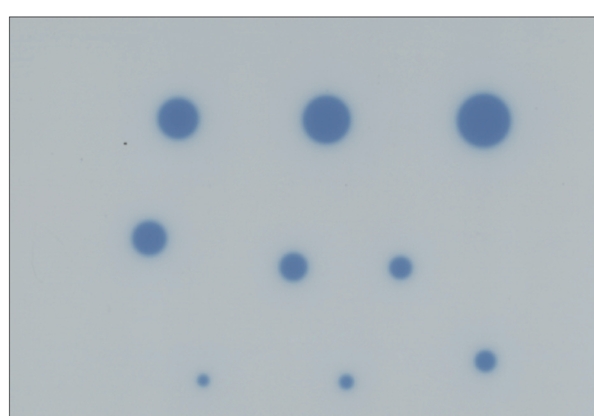

Figure 9. Image film irradiated to obtain profile curves for the cones 4, 5, 7.5, 8, 10, 12.5, 15, 17.5 and 20mm.

Diamond results

PDD curves

The Figure 11 represents the PDD curves obtained with diamond detector. In the enlarged detail, it is possible to see the noise presented by this detector.

Profile curves

In the Figure 12, we see the profile curves obtained with diamond detector.

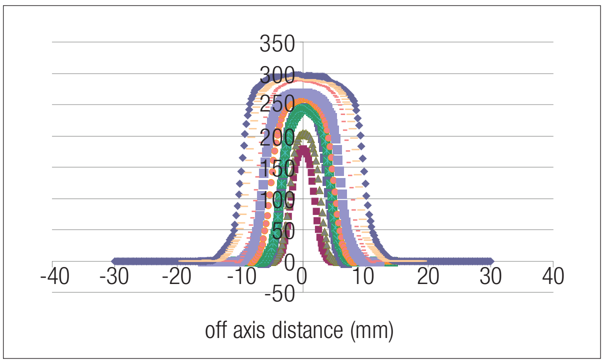

Figure 10. Profile curves for 9 cones obtained from the film.

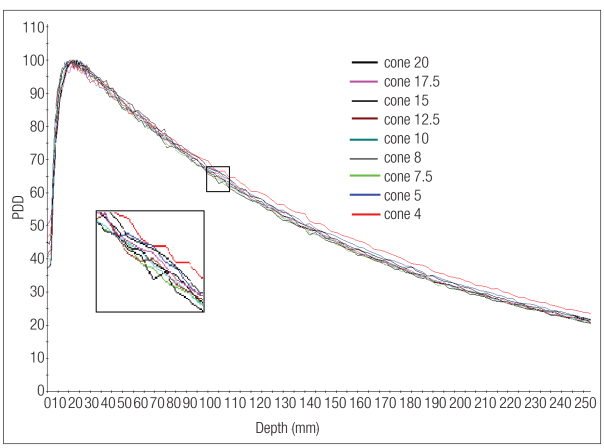

Figure 11. PDD curves for 9 cones measured with diamond detector.

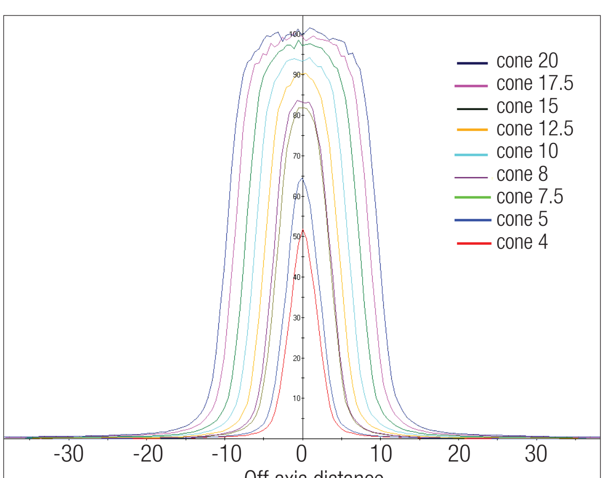

Figure 12. Profiles curves for 9 cones measured with diamond detector.

Comparison of PDD curves for different detectors

The Figure 13 is the representation of the PDD obtained with diode, pinpoint and film for cone of 4 mm. We may observe that they present different results: the measurements with pinpoint show more collection of charge and the film less than diode. This effect is important only in small cones. To establish a criterion to know what curve was the correct, we did measurements with diode, moving it manually and verifying after each movement if the diode was well positioned.

The comparison of the data obtained with automatic and manual movement is in the Figure 14. It is possible to see that the curves are very similar, almost coincident, what indicates that the measurements done with automatic scanning of the diode were correct. Otherwise, that data were compared with gold standards BrainLab library and were approved. So, we concluded that the diode is the best detector for small cones and we used this data to feed the planning system.

Effect of smooth curves

The smooth of the curves offered by the software is an interesting procedure, because even if the curves have some noise they are usable. However, it is necessary to make it carefully as each smooth is going to change the parameters of the curve. As an example, the Figure 15 presents

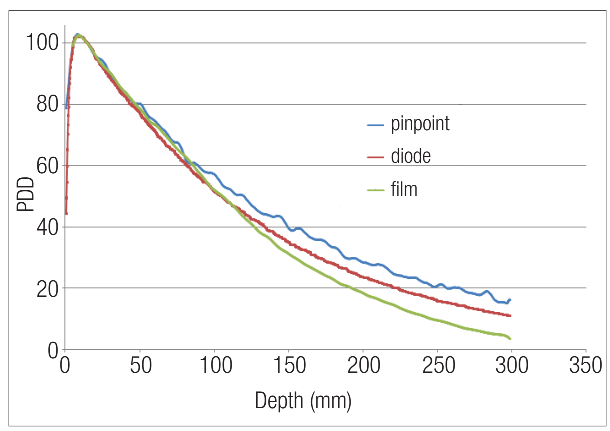

Figure 13. PDD curves for cone 4 mm obtained with pinpoint chamber, diode and film.

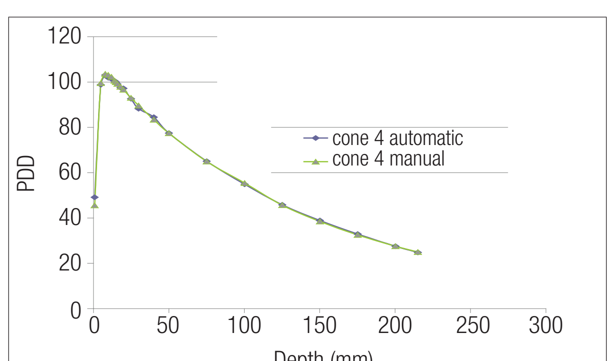

Figure 14. PDD curves for cone 4mm obtained with automatic and manual movement of the diode.

Quantity:	Dose	Dose	Dose
R100:	9 mm	9 mm	9.8 mm
D50:	74.3 %	74.4 %	75.2 %
D100:	50.8 %	50.3 %	51.1 %
D200:	23.1 %	22.9 %	23.2 %
Dmax:	132.5 %	132.7 %	132.2 %
TPR200/100:	0.516	0.516	0.516

Figure 15. Results of maximum dose depth (R100), depth maximum dose (R50), percentage of dose in 100 mm depth (D100), percentage of dose in 200 mm depth (D200), percentage of maximum dose (Dmax), ratio of Tissue-phantom ratio depth 200 mm to 100 mm (TPR) for three types of smooth: colunm 1 - without smooth, column 2 - least square with mean value region of 5 mm, and column 3 - envelope with mean value region of 5 mm.

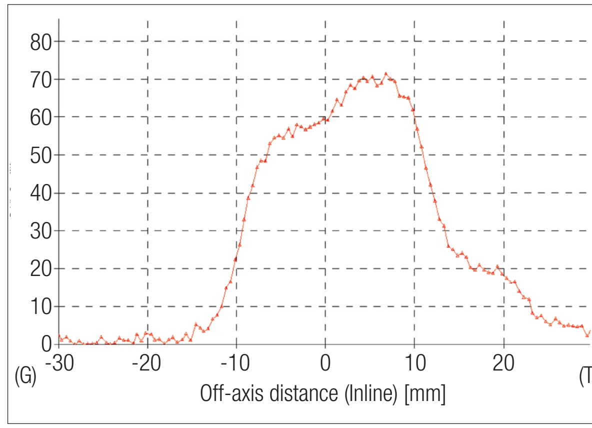

Figure 16. Profile curve for cone 20 mm obtained with pinpoint chamber in the horizontal position.

the effect of different type of smooth and it is possible to see a difference of almost 10% in the position of the maximum (R100) with the smooth envelope.

Orientation of the detector

The Figure 16 represents a profile curve obtained with pinpoint chamber in the horizontal position for the cone 20 mm. A comparison with the corresponding data of the Figure 9 shows that, if the chamber is put in the horizontal orientation, it cannot do the collection of charge properly.

Conclusions

The decision about the best dosimeter to data acquisition in small fields is a serious task. It involves each center's needs and availability of the equipments. For our purpose, the diode was the best detector for measures with small cones (4 to 7.5 mm). The best positioning of chambers for these measurements is vertical orientation, and the speed to acquisition is important to charge collection; it is convenient to use step by step instead of continuous measurements. It is also necessary a carefully handling of obtained data to not disturb or modify the results.

The dosimeter size and its orientation can increase the signal's noise and disturb the results, and, as high speed, may result in wrong values. Another important concern is the evaluation of the data, because the smoothing tools can produce big distortions to the final results.

References

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