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Technical note

Granulate of stainless steel as compensator material

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Abstract

Compensators produced with computer controlled milling devices usually consist of a styrofoam mould, filled with an appropriate material. We investigated granulate of stainless steel as filling material. This cheap, easy to use, clean and re-usable material can be obtained with an average granule diameter of 0.3 mm, enabling an accurate and reproducible filling. No wax or other sealing material is added. The density of the granulate is ~4.5 g/cm^3, which allows an accurate production of compensators in a sufficiently wide transmission range without the compensators becoming too thick. Transmission and surface dose measurements show that the dosimetric properties of stainless steel granulate are suitable for use as compensator material.

Keywords: Granulate; Stainless steel; Compensator material

1. Introduction

Compensators have already been used for decades to obtain a more homogeneous dose distribution in the target volume [6]. At first, compensators were only used to compensate for the irregular patient surface but later also internal inhomogeneities were compensated, facilitated by the advent of CT-based treatment planning systems. Recent developments in three-dimensional (3D) treatment planning, conformal radiotherapy and computerized treatment optimization, requiring intensity modulated beams, make the use of compensators even more interesting [3,8,10,11,14].

The production of compensators is greatly facilitated by the availability of computer controlled milling devices. These apparatus make it possible to manufacture compensators with a minimum of operator interference. Compensators produced with such machines usually consist of a styrofoam mould, filled with an appropriate material.

Many different materials have been used for the production of compensators. Ellis used aluminium and brass [6]. Others used low density materials such as wax [2] and tissue equivalent plastics [7], or high density materials such as low melting point alloys [13] (as used for the production of shielding blocks), solid lead [5] and lead sheets that were directly fixed to a tray [1,9]. As medium density materials, sheets of polyethylene-lead [12], a mixture of tin granulate with wax [4], and gypsum with and without stainless steel added [15] to it have been used.

A material that is to be used for the production of compensators has to fulfil a number of conditions:

1. The density should not be too high: this would make the transmission of the compensator very sensitive to small inaccuracies in the thickness. This criterion makes the use of lead or a high density, low melting point alloy, such as Cerrobend, less attractive.
2. The density should not be too low: this would yield relatively thick compensators, making it difficult to find a suitable location for them at the accelerator head or, if the maximum thickness is limited, the variations in allowed transmission would be too small. Wax and low density plastics have this disadvantage.
3. The material should be suitable for an accurate and reproducible production of compensators.
4. The use of the compensator material should not result in too high a skin dose.
5. Preferably, the material should be re-usable and not too expensive. This makes the use of the expensive leaded polyethylene unfavorable.

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6. The material should not cause health problems for the technologists, e.g. due to dangerous vapors or chemicals released during production.

The material we have tested is stainless steel granulate. This material is used for 'sand'-blasting and can be obtained in very small granule sizes (e.g. 0.3 mm). The density of the granulate is ~4.5 g/cm^3. The chemical composition of the stainless steel is 72% Fe, 18% Cr and 10% Ni. The material is re-usable, cheap (~US$7 per kg) and clean.

2. Materials and methods

2.1. Reproducibility of filling of a mould

To assess the reproducibility of filling a compensator mould with this material, several moulds were filled ten times and after each time the weight of the complete compensator was determined. The filling method consisted of filling the styrofoam mould with the stainless steel granulate until it was almost full. Then a sheet of lucite, with a thickness of 5 mm, with a hole in one of the corners (out of the beam), was fixed to the mould using double-sided adhesive tape. More granulate was poured into the mould through a funnel which was fixed in the hole. Complete filling of the mould was obtained by tapping it so that the granulate was distributed all over the mould. Finally the hole in the lucite sheet was covered with adhesive tape (see Fig. 1). No wax or other sealing material was added.

2.2. Dosimetric accuracy

For the calculation of the thickness required to obtain a certain transmission, an effective attenuation coefficient, μ_{eff}, is used [15]. A set of values for μ_{eff} was determined from measured values of the transmission T for different compensator thicknesses t, using Eq. 1:

$$\mu_{\text{eff}} = -\frac{\ln T}{t} \qquad (1)$$

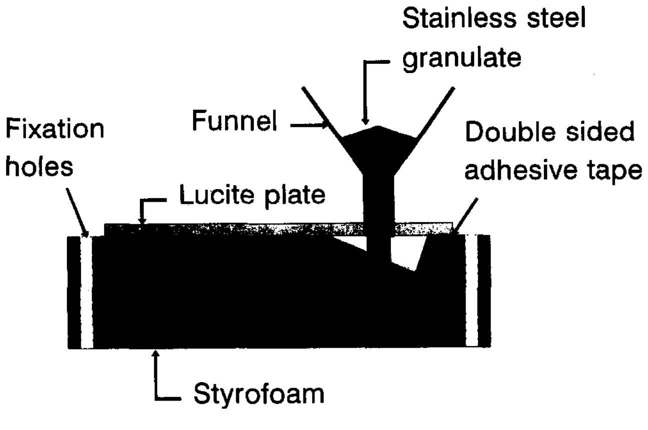

Fig. 1. Schematic drawing of the filling method, used to fill the compensator mould with the stainless steel granulate (see text).

Transmission measurements were performed using an NE 2571 ionization chamber in a polystyrene phantom, connected to a Keithley 35617 electrometer. The measurements were performed using a fixed focus-chamber distance of 100 cm. The compensators were fixed to a tray that could be inserted in the wedge slot of a Siemens KD-2 accelerator. This resulted in a focus-compensator distance of 42 cm.

Mainly because of beam hardening and scatter, the value for μ_{eff} is dependent on the field size, depth in the phantom and the compensator thickness itself. To determine the dependence of μ_{eff} on these variables, transmission measurements were performed for three different field sizes, four different depths, four different compensator thicknesses and the two photon energies (6 and 23 MV) available at our Siemens KD-2 accelerators. The transmission values were calculated by dividing the readings for the different thicknesses by the readings of the corresponding open fields. The values for μ_{eff} were calculated from the transmission values using Eq. 1 and fitted to:

$$\mu_{\text{eff}} = (a_0 + a_1) \times (d + a_2) \times A \qquad (2)$$

with d = depth in the phantom (cm), A = square of the equivalent square field size (cm^2), a_0 to a_2 = fitted coefficients (cm^{-1}, cm^{-2} and cm^{-3}, respectively).

The parameter t was left out of the fitting procedure because during the compensator calculation it is not known what the thickness will be. The fitting was performed using a multivariate regression analysis.

2.3. Dose in the build-up region

Measurements were performed in 6 and 23 MV photon beams to determine the influence of a compensator of stainless steel granulate on the dose in the build-up region. For this purpose we used a compensator of 2 cm thickness. The field sizes were 10 × 10 cm^2 and 30 × 30 cm^2 at isocenter distance. The measurements were performed in a lucite phantom with a PTW 23344 ionization chamber. A Keithley 35617 electrometer was used. The TMR curve of an open field at a focus detector distance of 100 cm was compared with fields with the compensator at a focus-detector distance of 100 cm and 80 cm.

3. Results and discussion

3.1. Reproducibility of filling of a mould

The observed variation in the weight of the compensators was 0.8% (one standard deviation, 1 SD). Assuming that the variation in weight can be totally attributed to a variation in the thickness (which probably is an overestimation), this results in an SD for the transmission of <0.3%.

3.2. Dosimetric accuracy

Values for μ_{eff} for 6 and 23 MV have been determined according to the method described above. The fit to Eq. 2 yields for 6 MV:

$$\mu_{\text{eff}} = (0.2181 - 9.5 \times 10^{-4}) \times (d - 2.0 \times 10^{-5}) \times A \qquad (3)$$

And for 23 MV:

$$\mu_{eff} = 0.1684 - 4.4 \times 10^{-4} \times d - 2.2 \times 10^{-5} \times A \qquad (4)$$

When these equations are used to calculate the transmission for each field size and depth for which it was also measured, the SD of the difference between measured and calculated transmission is 0.5% for 6 MV and 0.3% for 23 MV. The mean difference was 0% for both energies.

The inaccuracy of the PAR Scientific ACD-5 milling machine is specified to be smaller than +/− 0.5 mm. With the values for μ_{eff} that we found, we can calculate the effect on the transmission and thereby on the dose that such an inaccuracy has. With Eq. 1 we can write:

$$T = \exp(-\mu_{eff} \times t) \qquad (5)$$

And using this equation:

$$\frac{\Delta T}{T} = \mu_{eff} \times \Delta t \qquad (6)$$

with Δt = error in compensator thickness, ΔT = error in transmission because of Δt.

Using Eq. 6 we can see that $\Delta T/T$ changes with ~1.0% (6 MV) or 0.8% (23 MV), due to an error in the thickness of 0.5 mm, slightly dependent on depth and field size.

3.3. Dose in the build-up region

The results of the measurements for the 10 × 10 cm^2 field showed that differences in build-up dose because of the compensator are < ~2%, both for 6 and 23 MV. Even at a focus-detector distance (FDD) of 80 cm, the build-up dose with compensator does not differ by >2% from the open field at 100 cm. At FDD = 100 cm, the dose is even a little lower when a compensator is used. For the 30 × 30 cm^2 field, the differences are somewhat larger with a maximum of 5%, which occurred at the surface of the 23 MV compensator field at FDD = 80 cm, compared to the open field at 100 cm. The compensator field at FDD = 100 cm had a build-up dose which was ~1% lower for both energies.

4. Conclusions

Stainless steel granulate is an appropriate material for the production of compensators. The way of producing the compensators is sufficiently accurate and easy to allow routine clinical use. When mounted on a tray that can be inserted in the wedge slot of the accelerator, the use of a compensator is as easy as the use of a wedge. When provisions are made to encode each compensator so that it can be recognized by the record and verify system, there are sufficient safeguards against misadministration.

The density, and therefore also the attenuation coefficient, of the material is in a range that allows its use in practically all clinical situations: for a compensator of 4 cm thickness, the transmission is as low as 45% for 6 MV and 55% for 23 MV. The attenuation coefficient can be predicted with good accuracy without the need for very extensive measurements. The effects of errors in the thickness of the styrofoam mould produced with the ACD-5 milling machine, and thereby of the compensator, are <1%, which we consider to be acceptable.

The surface dose measurements show that the skin-sparing effect is preserved completely, in the geometry that we use.

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