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PATIENT SPECIFIC RADIATION FIELD SHAPING MASKS THROUGH LOW TEMPERATURE THERMAL-SPRAY

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Abstract: *Healthy tissue surrounding superficial cancer affected areas need to be protected during radiation therapy. Healing of the cancer wound after treatment takes place through regenerative growth of this healthy tissue. This paper describes the development and implementation of an innovative thermal-spray radiation field shaping technique. This new technique makes it possible to produce effective field shaping masks at reduced cost and time compared to traditional field shaping techniques.*
Key words: *Radiotherapy, 3D photography, Laser sintering, Woods alloy, Thermal-spraying*

1. PROBLEM STATEMENT

Superficial cancerous lesions are commonly treated through low energy X-ray or electron radiation in radiotherapy (Khan, 2003). The treatment units that produce the radiation are equipped with square, rectangular and round applicators of different sizes. These applicators attach to the treatment units and define the radiation field size applied during treatment. An applicator is chosen to fit the shape of the cancerous lesion on the patient as closely as possible. Since cancerous lesions are irregular in shape, there will always be an area of healthy tissue between the edge of the lesion and the edge of the standard field shape. This healthy tissue will be irradiated along with the lesion during treatment which is undesirable since the cancer wound heals through reparative growth of the surrounding healthy tissue after treatment. Various techniques were developed to shield this healthy tissue and thus shape the radiation field to the shape of the lesion. Lead masks, used for shielding around small treatment areas in the facial area, are time consuming and labour intensive to produce. Radiotherapy departments in general are not equipped to recycle the lead making this technique expensive while the used masks contribute to environmentally unfriendly waste (Sanghera *et al*., 2001). Wax castings, used with large treatment areas, are time consuming to produce. Shaped end-frames, also used with large treatment fields, do not conform to the contours of the treatment area (Smith, 1991). A stand-off may result in radiation scatter beyond the defined treatment field's borders which is undesirable.

2. METHOD

An investigation was undertaken to determine the feasibility of producing radiation field shaping masks through a thermal-spray process. Wood's alloy (50% Bi, 26.7% Pb, 13,3% Sn and 10% Cd) was considered to be the ideal medium for this application because of its low melting point of 70ºC, high density and availability in most cancer departments (Reade Advanced Materials, 1997). Since none of the commercially available thermal-spray equipment was well suited to the intended application, it was decided to develop new equipment tailor made to producing radiation field shaping masks. Fig. 1 shows the newly developed and patented thermal-spray cabinet.

Fig. 1. Thermal-spray cabinet

Different techniques to determine the geometry of the treatment area on the patient were evaluated. These included traditional plaster bandage impressions as well as 3D scanning using a Konika Minolta™ VI-910 laser scanner. The latter presents the advantage that no physical contact with the patient is required to determine the treatment area's geometry. Plaster models can be produced directly from the plaster bandage impressions while the scanning data can be used for various Rapid Prototyping (RP) techniques. RP model fabrication techniques investigated were: Computer Numerical Control (CNC) milling in polyurethane (PU) foam as well as Laser Sintering (LS) in nylon polyamide on an Electro Optical Systems™ P380. Wood's alloy was sprayed onto the respective models with the results shown in figures 2, 3 and 4.

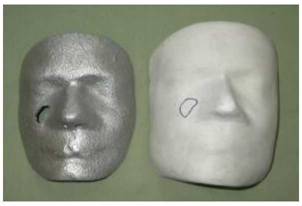

Fig. 2. Thermal-sprayed mask with plaster model

Fig. 3. Thermal-sprayed mask with CNC milled PU model

Fig. 4. Thermal-sprayed mask with LS nylon polyamide model

Evaluation of the thermal-spray technique was performed through a comparison of the shielding ability of thermal-sprayed masks to shields produced through traditional techniques. An electron boost to a post mastectomy scar was chosen as a setup to compare the different techniques. This is considered a difficult shielding setup since it combines a large treatment field with a stand-off at the field's edges. A Perspex™ phantom was manufactured to simulate a section of the torso where the radiation field will be applied. An arbitrary area was marked on the phantoms surface to resemble the shape of treatment fields often seen with boosting scar tissue. Radiation shields were prepared using the wax casting, shaped end-frame and sprayed mask techniques to shield around the arbitrary area. Fig. 5 shows the phantom positioned on an Elekta™ SL25 linear electron accelerator's (linac) table.

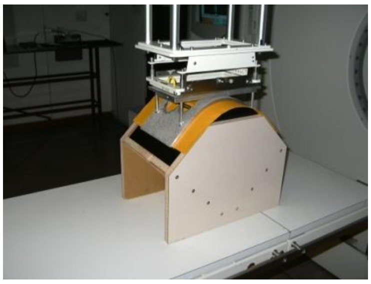

Fig. 5. Phantom setup in order to take a surface film under a thermal-sprayed mask with electron irradiation

Surface films were taken for the different field shaping shields at energies of 4, 6, 8 and 10 Mega electron Volt (MeV). Radiation shields were also prepared around a 20 x 10 cm² area using the different shielding techniques and the film taking procedure was repeated. Cross sectional films were also taken with the 20 x 10 cm² field with the films clamped between the two halves of the phantom. All the films were developed, scanned on a Vidar™ scanner and converted to iso density charts using Osiris software.

3. RESULTS

Fig. 6 shows the iso density charts for the arbitrary field shape at skin level for 4 MeV as an example. The original field shape (hatched areas) is shown superimposed on the surface iso-density charts to indicate the amount of scatter beyond the treatment field's borders. The iso-density charts for all the radiation energies showed that the sprayed masks compared favourably with the wax castings and are an improvement over the shaped end-frames in terms of field shaping.

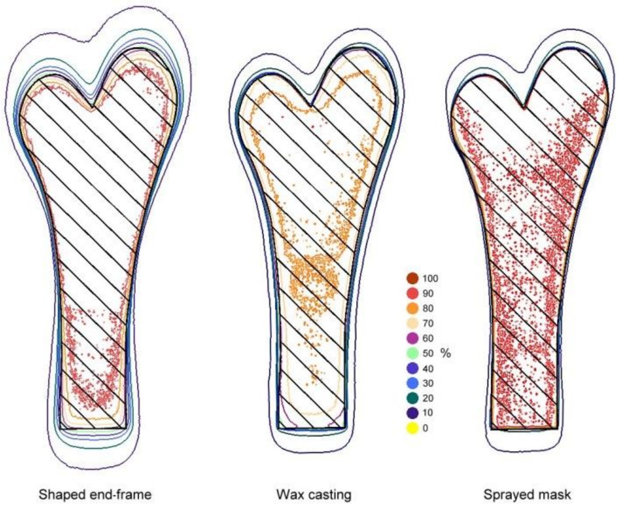

Fig. 6. Iso-density curves for an arbitrary field at skin level at a radiation energy of 4 MeV

To determine what thickness the thermal-sprayed masks need to be for effective shielding, sheets of Wood's alloy were produced to the required thicknesses to be able to do radiation transmission measurements of the alloy in 1 mm increments. X-ray imaging was used to verify that there were no defects such as porosity or cracks present in thermal-sprayed layers of Wood's alloy. Radiation transmission measurements through the sheets were performed at skin level (directly under the sheets) and also at the level of maximum dose transmission for electron energies of 4 - 15 MeV for field sizes of 10 x 10 cm² and 20 x 20 cm². All the measurements were expressed as relative percentages of the open beam measurements for the different radiation energies and plotted against thickness of the alloy in mm. Fig. 7 shows the relative percentage dose against depth curves for the 10 x 10 cm² field size measured at skin level as an example.

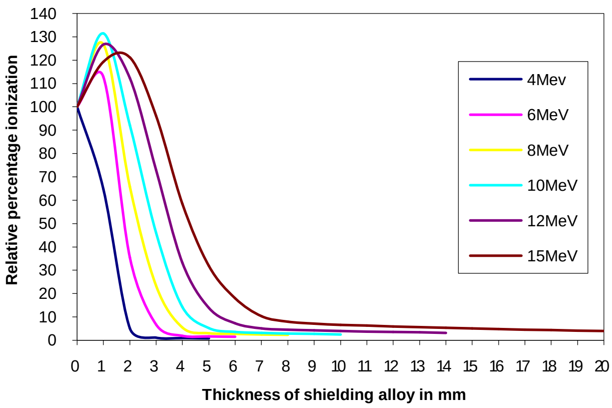

Fig. 7. Relative percentage dose against depth curves for a 10 x 10 cm² field size measured at skin level

From the graphs can be determined what the thicknesses of sprayed Wood's alloy need to be to shield different radiation energies. The shielding mask should attenuate the applied radiation by at least 95% to be considered acceptable. The material thicknesses determined through this research are similar to published results for thicknesses of Wood's alloy required for shielding (Purdy *et al*., 1980).

4. CONCLUSION

Low energy radiation field shaping masks produced through low temperature thermal-spray presents some clear advantages over traditional field shaping techniques used in radiotherapy. Effective shielding masks are safely produced within a reasonable time frame and at low cost. This is to the benefit of both the technologist producing the masks and patients affected by superficial cancerous lesions.

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