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APPLICATION OF 3D PRINTED BOLUS IN RADIOTHERAPY

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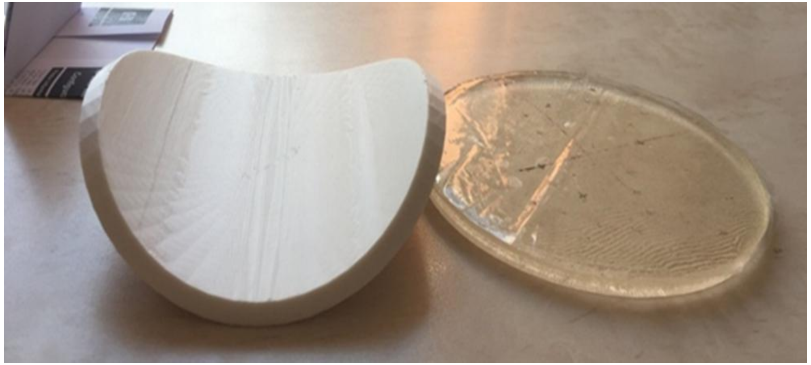
Introduction

High energy photon beams, especially megavoltage photon beams, generate a build-up region [1-2]. This leads to creation of a “skin sparing” effect (lower dose on the skin).

However, treating near surface tumours the surface dose (d_{surf}) usually has to be increased and for this is used boluses. This contributes to the better treatment outcome and allows to avoid the risk of recurrences.



1. Khan F.M., Gibbson J.P. The Physics of Radiation Therapy. Fifth edition, Wolters Kluwer, 2014.
2. Butson Martin J., Cheung T., Yu P., Metcalfe P. Effects on skin dose from unwanted air gaps under bolus in photon beam radiotherapy. Radiation Measurements, Vol. 32, 2000; p. 201-204.

Introduction. Pros of the individualized boluses

- Additional body for uneven and concaved surfaces (head & neck), to compensate the missing tissue (post mastectomy) [1-2].
- Improvement treatment procedure outcome.
- Avoidance of unwished air gaps [3].
- Creation homogeneous dose distribution to the patient surface [4].
- “Skin Sparing” effect, generating lower dose on the irradiated surface. [2-3].

Today as an alternative for the standard silicone bolus could be used individualized 3D printed boluses.

1. Michiels S., Barragán A.M., Souris K., Poels K., Crijns W., Lee J.A., Sterpin E., Nuyts S., Haustermans K., Depuydt T. Patient-specific bolus for range shifter air gap reduction in intensitymodulated proton therapy of head-and-neck cancer studied with Monte Carlo based plan optimization. Radiotherapy and Oncology, Vol. 128, 2018, p. 161–166.
2. Fuse H.; Shinoda K.; Inohira M.; Kawamura H.; Miyamoto K.; Sakae T.; Fujisaki T. Note: Utilization of polymer gel as a bolus compensator and a dosimeter in the near – surface buildup region for breast – conserving therapy. Review of Scientific Instruments. Vol. 86, No. 9, 2015: 096103.
3. Khan Y., Villarreal-Barajas J. Eduardo, Udowicz M., Sinha R., Muhammad W., Abbasi Ahmed N., Hussain A. Clinical and Dosimetric Implications of Air Gaps between Bolus and Skin Surface during Radiation Therapy Journal of Cancer Therapy, Vol. 4, 2013, p. 1251-1255.
4. Park S.Y., Choi C.H., Park J.M., Chun M, Han J.H., Kim J.I. A patient-specific Polylactic Acid Bolus Made by 3D Printer for Breask Cancer Radiation Therapy. PLoS One, 2016, 2016, Vol. 11 no. 12:e0168063.

Why 3D-printed Bolus?

It is known, that using 3D printed technique it is possible to create patient related individualized boluses, which allow for avoiding or minimization of the air gaps between bolus and the patient surface, so eliminating the impact of the air gaps on the dose absorbed at the surface, so assuring the quality of the treatment procedure [1].

The aim

The main objective of this study was to evaluate the irradiation dose on the phantom's surface using individualized 3D printed polylactic acid (PLA) bolus, evaluating their suitability in radiotherapy.

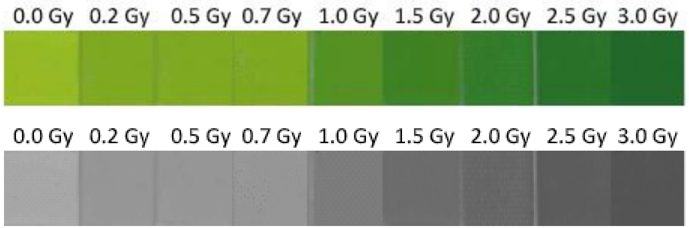
1. Michiels S., Barragán A.M., Souris K., Poels K., Crijns W., Lee J.A., Sterpin E., Nuyts S., Haustermans K., Depuydt T. Patient-specific bolus for range shifter air gap reduction in intensitymodulated proton therapy of head-and-neck cancer studied with Monte Carlo based plan optimization. Radiotherapy and Oncology, Vol. 128, 2018, p. 161–166.

Materials and Methods

Thickness: 1cm
Material : polylactic acid (**PLA**)
Infill ratio: 90% and 100%.
3D printer “Zortrax M300”.
Densities: Phantom ~ 1.19 g/cm^3
PLA ~ 1.2 **-** 1.43 g/cm^3
Silicone ~ 1.1 **-** 2.32 g/cm^3
Human tissue ~ 1.05 – 1.07 g/cm^3

Irradiation procedure and experimental setup:
Linear accelerator “Varian DMX” was used for irradiation with the high energy photons (E_{max} = 6 MeV). Instead of patient during the irradiation procedure was used solid Computed Tomography Polymethyl methacrylate head phantom.

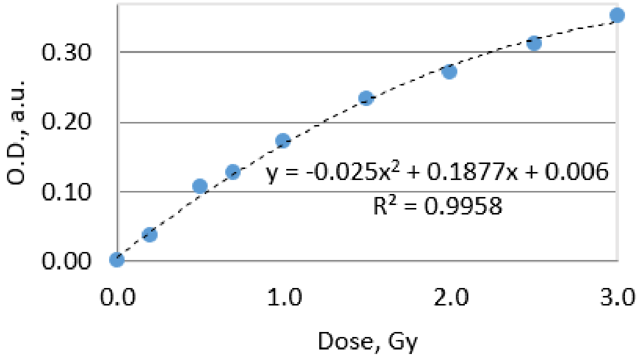
Materials and Methods. Gafchromic films dosimetry



$$OD = log_{10} \frac{PV_{unirradiated}}{PV_{after\_irradiation}}$$

$PV_{unirradiated}$- pixel value of the film, which was not irradiated.

$Pv_{after\_irradiation}$- pixel value after irradiation by specific amount of dose.

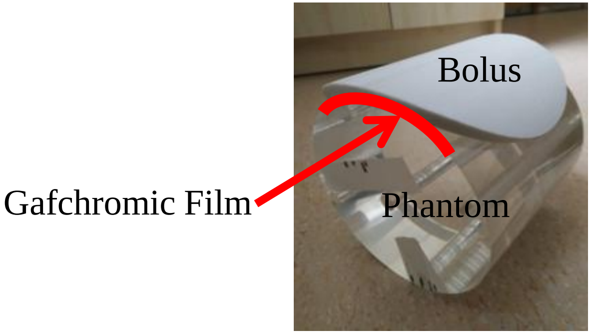


Calibration of gafchromic films EBR2:

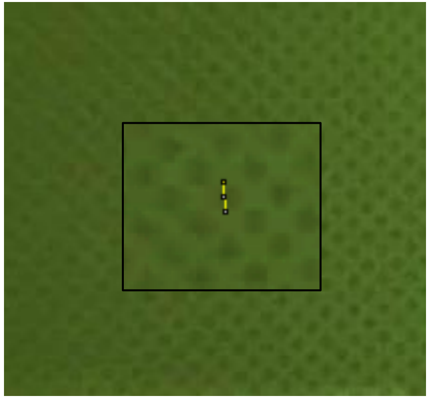
- pieces of the films 1.5 cm x 1.5 cm, were irradiated with 6 MeV photon beam in a dose range: 0 Gy -3 Gy.
- all films were scanned after 48h after the irradiation procedure.

Films for the irradiation doses measurements were placed between bolus and CT PMMA head phantom.

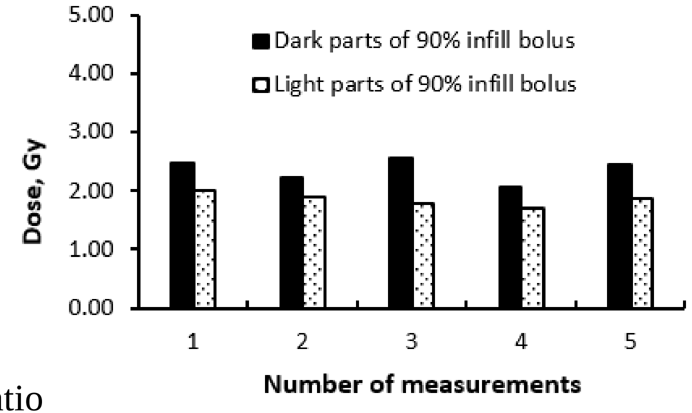
Analysis of the irradiated films were done using program *ImageJ*.



Results. Printing technique.

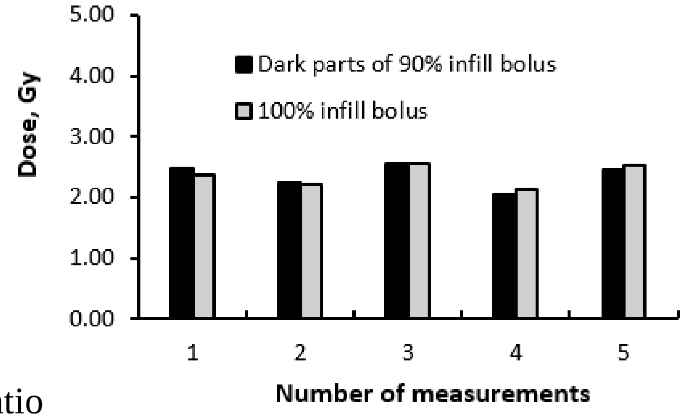


Bolus printed with 90 % infill ratio



90 % infill ratio reviled, that the infill plays an important role printing the phantoms and boluses for radiation medicine application, **according to this study it is recommended to use 3D printed bolus with 100 % infill ratio.**

Bolus printed with 100 % infill ratio



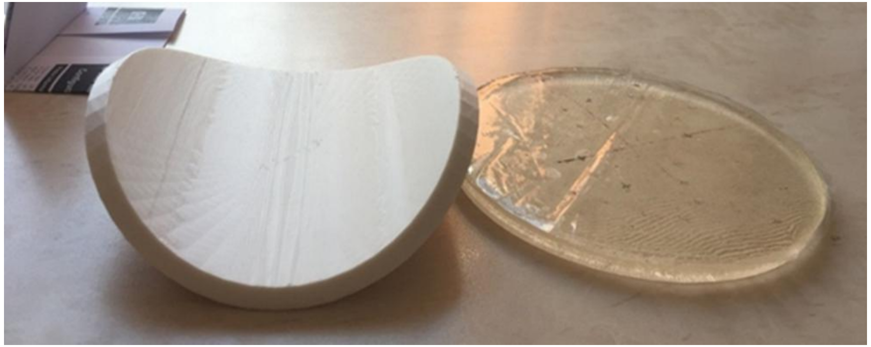
Difference between 100% infill ratio and 90% infill ratio darker regions were just 0.21%.

However, individualized 3D printed PLA bolus with 90% infill ratio, it is not recommended to use in RT, due to possible uncertainties evaluating measurement results.

Results. Individualized 3D printed PLA boluses and “sticking” boluses

3D printed PLA bolus with infill ratio 100 % showed a good agreement with the previous studies measurements [1] where have been used “sticking” bolus: the registered deviation were 3.34 % comparing results from the treatment planning system (TPS) using “sticking” bolus (mean dose on a surface 2.02 Gy) and 2D films dosimetry measurements using individualized 3D printed PLA bolus with 100 % infill ratio (mean dose 2.09 Gy).

The possible discrepancies using 2D film dosimetry in compare with TPS results could be related to the possible calibration uncertainties using gafchromic films.



1. Laurikaitienė, J., Tzirkalov, T., Dimitrova, T.L., Laurikaitis, M. Evaluation of skin dose under the bolus for post-operative breast cancer treatment. Medical physics in the Baltic States: proceedings of the 13th international conference on medical physics, Kaunas, Lithuania, 9-11 November, 2017. Kaunas: Kaunas University of Technology. ISSN 1822-5721. 2017, p. 69-72.

Conclusions

1. Evaluation of individualized 3D printed PLA bolus with 90 % infill reviled, that the infill plays an important role printing the phantoms and boluses for radiation medicine application, and according to the registered results it is recommended to use 3D printed bolus with 100 % infill ratio.
2. Analysis of the irradiation doses measured using individualized 3D printed PLA bolus with 100 % infill, showed that the results could be comparable with the results of the previous study, where so called “sticking” bolus was used. Registered deviation was 3.34% for 3D printed PLA bolus with 100 % infill ratio (2D films dosimetry) in compare with a “sticking” bolus (evaluated by TPS).
3. Therefore, possibility to use individualized 3D printed PLA bolus instead the standard silicone bolus, could be as an option in radiotherapy field, trying to avoid or minimize air gaps between the bolus and the phantom/ patient, so assuring the quality of irradiation procedure.

A day without radiation is a day without sunshine.

Thank you for your attention!
Questions?!

Reference list

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