Iranian Journal of Medical Physics

ijmp.mums.ac.ir

Dosimetric Characteristics of Transparent Bolus for External Beam Radiotherapy

Kesavan Govindaraj [1,2], Senthilkumar S[2,3]*, Jeevan Ram R K [4]

1. Department of Radiotherapy, Vadamalayan Integrated Cancer Centre, Madurai, India.
2. Research and Development Centre, Bharathiar University, Coimbatore, India.
3. Department of Radiotherapy, Madurai Medical College and Government Rajaji Hospital, Madurai, India.
4. Department of Medical Physics, Bharathidasan University, Tiruchirapalli, India.

ARTICLE INFO

Article type:
Original Article

Article history:
Received: Jan22, 2019
Accepted: May05, 2019

Keywords:
Surface Dose
Bolus
Radiotherapy

ABSTRACT

Introduction: In radiotherapy, the bolus is often used while treating the tumor under the uneven surfaces of the patients for correcting the anatomical irregularities and increasing skin dose. Wet cotton and wet gauze are still used in developing countries, since the use of wet cotton and wet gauze has certain disadvantages, there is a need for transparent bolus which should be similar to a universally accepted bolus in terms of properties with a lower cost (50% less expensive).

Material and Methods: The present study was conducted to investigate the characteristics of transparent bolus (Senflab) material, such as transmission factor, percentage depth dose (PDD), stability over time and high dose, homogeneity and transparency using 6 and 15 MV photons beam and 12, 15, and 18 MeV electrons beam. Moreover, the new bolus material was compared with those of the commercially available Superflab and RW3 slab.

Results: The percentage difference in the transmission factor of Senflab was less than ±1.9%, compared with Superflab and RW3. For PDD, the percentage difference was ±2.88% and ±1.26% for photons and electron beams, respectively. The performance of bolus remained constant both physically and dosimetrically after higher dose exposure. The percentage standard deviation was 0.0002% for a period of one month, and 0.0003% for the homogeneity. The transparency of the bolus material was good enough to display the set radiation treatment field.

Conclusion: This study shows the suitability of the new bolus for routine use in radiotherapy.

► *Please cite this article as:*
Kesavan G, Senthilkumar S, Jeevan Ram R K.Dosimetric Characteristics of Transparent Bolus for External Beam Radiotherapy. Iran J Med Phys 2019; 16: 410-415.10.22038/ijmp.2019.37129.1470.

Introduction

Megavoltage photon and electron beams produced by linear accelerators are widely used for external beam radiotherapy [1]. Bolus causes a shift in isodose curves towards the surface and modifies the distribution of dose to a patient [2]. While treating cancer patients with external beam radiotherapy over uneven areas, such as head, neck, breast, chest wall, and vulva region, a bolus material is used to correct the anatomical irregularities for delivering the prescribed dose to the tumour [3, 4]. The bolus has been used since 1920 [5], and during the early days, the bolus materials were paraffin wax and bee's wax. However, this method was a time-consuming process and also difficult to pour hot wax over the patient. Instead of pouring hot wax on the patient, it is better to pour the hot wax on the mold and then shape it with a knife to fit the patient's anatomy [6].

More than 80 products or compounds have been used as bolus material [5]. Several bolus materials are now available commercially, including Superflab, elastogel, brass mesh, superstuff, and paraffin wax [7-9]. Although many bolus materials are available in the market, some of the hospitals in developing countries use wet cotton and wet gauze as bolus material mainly to reduce the cost and also to overcome the non-availability of commercial bolus materials. It has been reported that the use of wet cotton and wet gauze has certain disadvantages, such as the changes that may occur in the wetness level of gauze and cotton [10, 11]. Another issue of concern is the air gap under the bolus affecting the dose build up [12]. In order to avoid the problems associated with wet gauze and wet cotton and also to reduce the cost of bolus material, it was considered necessary to go for inexpensive bolus. Moreover, most of the currently and commonly used bolus materials are opaque or semi-transparent. Therefore, there is a need to develop a transparent bolus material as it is required for electron radiotherapy, where the bolus is placed on the patient by visually observing the treatment field. The present

**Corresponding Author:* Mobile No: +91 9787792090; Email: senthilgh@gmail.com

study aimed to describe newly developed inexpensive transparent bolus (Senflab) and its performance in meeting all the properties required for good bolus material. The validity of the Senflab bolus also was assessed by comparing its properties with those of commercially available bolus materials, such as Superflab and RW3 slab. To the best of our knowledge, there has been a dearth of research in this regard.

Materials and Methods

Design of the study

The current study was conducted using the photon beams of 6 and 15 MV and electron beam energies of 12, 15, and 18 MeV provided by Clinac-iX linear accelerator (Varian Medical Systems, Palo Alto, CA) with 120-leaf millennium multi-leaf collimator (MLC). All measurements were performed at 100 cm source to surface distance (SSD), Gantry angle of 0^0, couch angle of 0^0, collimator of 0^0, and MLC in a parked position. The measurement was repeated for five times, and the mean and its standard deviation (SD) were calculated.

Transparent bolus (Senflab) material (polymer and paraffin oil, 80:20 ratios) was used for the present study [13]. Commercially available bolus materials, superflab bolus (Radiation Products Design Inc., Albertville, MN, USA), and RW3 slab (PTW-Freiburg, Germany), were implemented to compare the performance of the of 30×30 cm^2 Senflab bolus of two different thicknesses (0.5 and 1 cm). The density of the bolus was calculated through the measurement of the mass and volume of the bolus [10]. The density was 1.02 gm/cm^3 for both 0.5 and 1 cm thick bolus material, which was comparable to that of the commercially available Superflab and RW3 slab. Transmission factor, percentage depth dose, conformability, durability over time, and performance of bolus over high dose, uniformity, and transparency were analysed in order to verify the performance of Senflab bolus.

Transmission Factor

Transmission factor of the sample is defined as the ratio of the ionization chamber readings obtained at a reference depth in the presence of the sample to that obtained in the absence of the sample [14, 15].

Transmission factor of the sample was measured using slab phantom. The SSD was set at the surface of the slab phantom, and then the bolus was placed over the slab phantom. Transmission factors for different photon energies were measured using the Farmer ionization chamber 0.6cc (PTW-Freiburg, Germany, TM30013), which was placed at the reference depth of 10 cm from the surface of the phantom with the field size of 10×10 cm^2 at surface of the slab phantom. For the measurement of the transmission factor for the electron beams, the Marcus chamber (PTW-Freiburg, Germany, TM23343) was placed at the reference depths of 3, 3.7, and 4.5 cm for 12, 15, and 18 MeV with a 10×10 cm^2 applicator. To this end, the electrometer UNIDOS (T10008, PTW) was used for the measurement. In order to avoid the backscatter electrons from the measurement table, 10 cm of slab phantom was placed below the chambers. The attenuation was determined by calculating the ionization charges collected for 100 MU with and without bolus on the surface. The thickness of Senflab bolus used for transmission factor analysis was 0.5 and 1 cm, and it was compared with those of the reference Superflab bolus and RW3 slab.

Percentage depth dose (PDD)

The percentage depth dose of the Senflab bolus was calculated in slab phantom by setting the 100 cm SSD on the slab surface with the field size of 10×10 cm^2. The bolus was placed above the slab phantom, and Marcus chamber was used to collect the ionization at several depths [5]. The bolus thickness of 1 cm was used for 6 and 15 photon energies as well as 12, 15, and 18 high energy electrons [16]. The measurements were accomplished by delivering 100 MU at various depths in slab phantom with Senflab bolus on the surface. The same procedure of measurements was repeated for Superflab and RW3 slab as a bolus.

Durability of bolus over time

The durability as a function of time for the Senflab bolus material was investigated daily for a period of 1 month. Prior to the measurement, the bolus material was washed with soap water and applied talcum powder (this procedure is taken to check whenever the bolus is changed from one patient to another). The measurements of ionization at a depth of 10 cm in slab phantom under a 1 cm thick slab of Senflab bolus were taken for 6 MV photon beam.

Performance of bolus over high dose

The performance of the Senflab bolus to withstand a high amount of radiation dose was measured by placing the bolus over the surface of the slab phantom. A Farmer chamber (0.6cc) was placed at a depth of 10 cm. The field size of 10×10 cm^2 and SSD of 100 cm were set at the surface of the phantom. The 6 MV Photon was used to collect ionization chamber reading of 100 MU. In the next step, the Senflab bolus was irradiated to a dose of 1000 Gy, and the reading was taken again after placing the bolus on the surface of the phantom.

Homogeneity

To verify the homogeneity, a Senflab bolus of size 30×30 cm^2 (1cm thick) was taken, and the entire area was marked uniformly into 9 portions each having an area of 10×10 cm^2 as shown in Figure 1. Farmer ionization chamber (0.6cc) was placed at a 10 cm depth below the bolus on the central axis of the 6 MV photon beam with the SSD of 100 cm. The bolus was adjusted such that portion 1 matched with 10×10 cm^2 field size. The Farmer chamber reading was collected for 100 MU. The readings were taken for each of the remaining 8 portions of the bolus with the matched field size of 10×10 cm^2 without disturbing the Farmer chamber, slab phantom, and SSD.

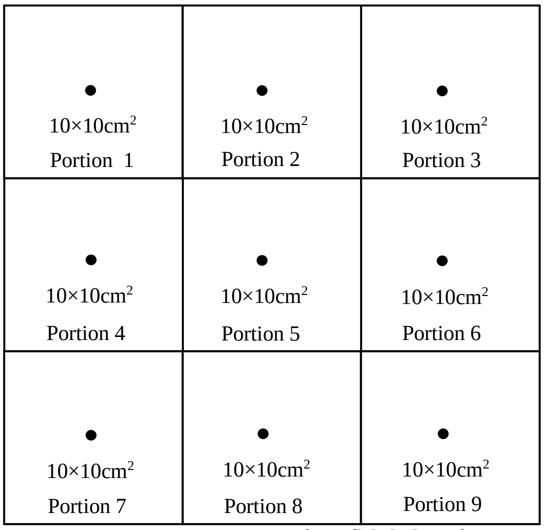

Figure1. Homogeneity measurement of Senflab bolus of size 30×30 cm^2 (1cm thick) marked uniformly into 9 portions each having an area of 10×10 cm^2

Transparency

In order to check the transparency of Senflab bolus, a person having 20/20 vision was requested to read black typing in size 12 Times New Roman font through at least 0.5 and 1.0 cm of the bolus material. It was ensured that the person was able to visualize the field light, cross-hair, and marker [17]. Superflab was checked in a similar way. The transparency of bolus material facilitates to reproduce accurate placing of the bolus on the patient's surface during the daily setup of radiotherapy. It also reduces the daily patient set up time in radiotherapy.

Results

Transmission Factor

Tables 1 and 2 show the transmission factor results obtained from 6 and 15 MV photons, and 12, 15, and 18 MeV electrons for different bolus materials in RW3 slab, Superflab, and Senflab with the thickness of 0.5 and 1 cm. The percent difference in the transmission factor of Senflab compared to other slab material was less than 0.20% for photons and less than 1.91% for electrons.

Percentage Depth Dose (PDD)

The PDD measured with Marcus chamber at different depths for 6 and 15 MV photons and 12, 15, and 18 MeV electron beams are shown in Figure 2. The PDD was almost the same for all the three bolus materials. Tables 3 and 4 show that surface dose and reference depth dose obtained from 6 and 15 MV photons and 12, 15 and 18 MeV electrons. The obtained percent variation in Senflab was less than 2.88% for photons and 1.26% for electrons.

Table 1. Transmission factors for 6 and 15 MV photons and as well as 12, 15, and 18 MeV electrons beam with 0.5 cm thickness of RW3 slab, Superflab, and Senflab bolus

Energy	Bolus thickness 0.5 cm Bolus Type			% of deviation	
	RW3 Slab (mean±SD)	Superflab (mean±SD)	Senflab (mean±SD)	Senflab vs RW3 Slab	Senflab vs Superflab
6 MV	0.9872±0.0002	0.9872±0.0001	0.9865±0.0001	-0.07	-0.07
15 MV	0.9900±0.0001	0.9900±0.0001	0.9900±0.0002	0.00	0.00
12 MeV	0.9859±0.0002	0.9844±0.0002	0.9838±0.0001	-0.21	-0.06
15 MeV	0.9853±0.0001	0.9848±0.0001	0.9833±0.0001	-0.20	-0.15
18 MeV	0.9828±0.0001	0.9828±0.0001	0.9823±0.0002	-0.05	-0.05

Table 2. Transmission factors for 6 and 15 MV photons as well as 12, 15, and 18 MeV electrons beam with 1 cm thickness of RW3 slab, Superflab, and Senflab bolus

Energy	Bolus thickness 1 cm Bolus Type			% of deviation	
	RW3 Slab (mean±SD)	Superflab (mean±SD)	Senflab (mean±SD)	Senflab vs RW3 Slab	Senflab vs Superflab
6 MV	0.9691±0.0001	0.9723±0.0001	0.9710±0.0001	0.19	-0.13
15 MV	0.9792±0.0001	0.9815±0.0001	0.9810±0.0001	0.18	-0.05
12 MeV	0.9150±0.0001	0.9312±0.0001	0.9328±0.0001	1.91	0.17
15 MeV	0.9405±0.0001	0.9505±0.0001	0.9516±0.0001	1.17	0.12
18 MeV	0.9491±0.0001	0.9565±0.0001	0.9565±0.0001	0.77	0.00

Table 3. Surface dose for 6 and 15 MV photons as well as 12, 15, and 18 MeV electrons of RW3, Superflab, and Senflab bolus

Energy	Bolus thickness (cm)	Surface Dose Bolus type			% of deviation	
		RW3 Slab (mean±SD)	Superflab (mean±SD)	Senflab (mean±SD)	Senflab vs RW3 Slab	Senflab vs Superflab
6 MV	1.0	96.38±0.02	94.40±0.03	95.35±0.02	-1.08	0.99
15 MV	1.0	84.00±0.03	81.51±0.03	81.65±0.03	-2.88	0.17
12 MeV	1.0	97.48±0.02	97.89±0.02	98.15±0.03	0.68	0.26
15 MeV	1.0	99.75±0.03	99.60±0.03	99.72±0.02	-0.03	0.12
18 MeV	1.0	99.90±0.03	99.42±0.02	99.81±0.02	-0.09	0.39

Table 4. Reference depth dose for 6 and 15 MV photons, as well as 12, 15, and 18 MeV electrons of RW3, Superflab, and Senflab bolus

Energy	Bolus thickness (cm)	Reference Depth (cm)	Reference Depth dose Bolus type			% of deviation	
			RW3 Slab (mean±SD)	Superflab (mean±SD)	Senflab (mean±SD)	Senflab vs RW3 Slab	Senflab vs Superflab
6 MV	1.0	10	62.00±0.03	62.80±0.02	62.30±0.03	0.48	-0.80
15 MV	1.0	10	73.10±0.02	73.50±0.03	73.40±0.03	0.41	-0.14
12 MeV	1.0	3.0	89.70±0.03	89.64±0.02	88.75±0.02	-1.07	-1.00
15MeV	1.0	3.7	90.75±0.03	91.45±0.03	91.91±0.03	1.26	0.50
18MeV	1.0	4.5	86.58±0.02	87.15±0.03	87.46±0.02	1.01	0.35

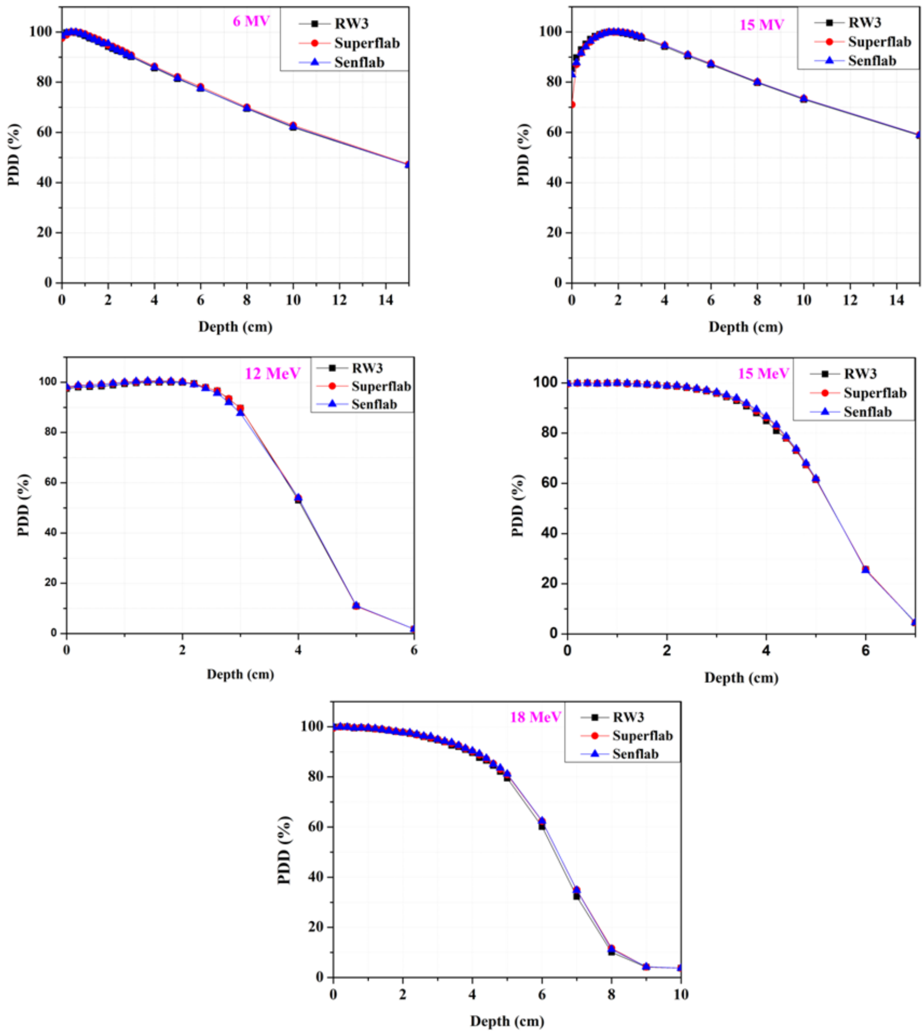

Figure 2. Figures a, b, c, d, and e showing the central axis percentage depth dose curve for photon and electron beams

Table 5. Electrometer reading before and after irradiation of Senflab bolus

Senflab Bolus	Meter Reading (nC)(mean±SD)
Before over high dose	11.63±0.1
After over high dose	11.63±0.1

Table 6. Comparison of visibility evaluation

Test	Senflab Bolus	Superflab	RW3 slab
Field visibility	Visible	Partially Visible	Invisible
Cross-hair visibility	Visible	Partially Visible	Invisible
Body marker visibility	Visible	Partially Visible	Invisible
12 point font size printed document	Readable	Partially Readable	Unreadable

Durability of bolus over time

The electrometer reading measured over a period of a month is shown in Figure 3. The figure shows consistent readings from day 1 to day 30. The percent standard deviation was 0.0002% for a period of 1 month.

Performance of bolus over high dose

Table 5 indicates that there was no variation in the value of bolus responses before and after the exposure to a high dose of 1000 Gy. The performance of bolus appeared well over a high dose. The bolus performance over a high dose are shown both physically (no observable damage in appearance) and dosimetrically.

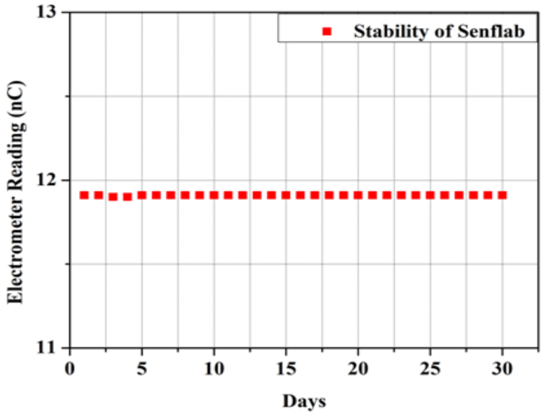

Figure 3. Durability of bolus over time

Homogeneity

Regarding the homogeneity of bolus, Figure 4 indicates that there is no major variation in the stability, and the percent standard deviation is estimated at 0.0003%.

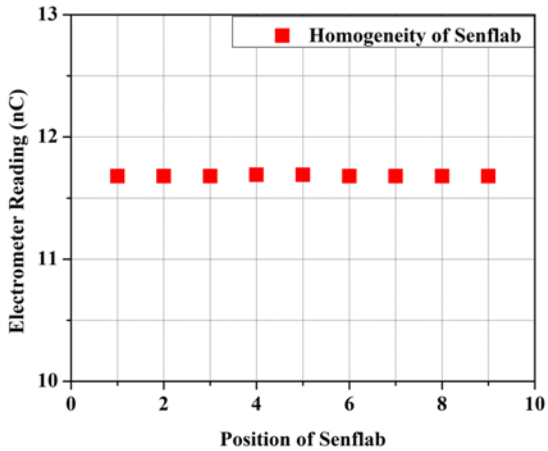

Figure 4. Homogeneity of the bolus

Transparency

Transparency of the bolus material as measured by visibility test is shown in Table 6. Accordingly, the Senflab bolus was more transparent than Superflab and RW3 in all aspects, including field visibility, cross-hair visibility, body marker visibility, and visibility of size 12 font size printed document. Figure 5 shows the visibility of the hand through the bolus material.


Figure 5. Photograph showing the Senflab bolus placed over the hand

Discussion

The material used as bolus should have dosimetric properties similar to those of tissues, sufficiently flexible and comfortably fixed on the patient over the irregular anatomy. Generally, the bolus should conform nicely to the patient's body; otherwise, there is a possibility of an unwanted air gap between the patient and bolus [12], which in turn may lead to irregular dose deposition. On the contrary, some bolus materials, such as bees wax, dental wax, and paraffin wax are molded initially to the patient's anatomy and then made rigid. This might result better conformity to the patient's anatomy and avoid potential air gaps despite their lack of transparency. The other criteria of bolus material are low cost, non-toxic, easy to clean, non-flammable, and able to withstand high radiation dose. International Commission on Radiation Units and Measurements (ICRU) has defined bolus as a ''Tissue equivalent material placed around the irradiated object to provide extra scattering or build-up or attenuation of the beam'' [18].

The present study showed that Senflab bolus possesses desirable performance characteristics with respect to the investigated parameters. The cost of the Senflab bolus is 50% lower than that of the commercially available bolus. It was observed that the bolus was not only flexible but also had sufficient strength in withstanding its shape and size during the treatment procedure. The attenuation characteristic of Senflab bolus was comparable with that of commercially available Superflab with minimal variation (less than 1.91% difference).

The performance of the Senflab bolus was good over a period of time indicating that the Senflab bolus material was stable and durable over time both physically and dosimetrically. The stability of the bolus material following irradiation was checked by exposing the material to a high dose of 1000 Gy. The absence of any variation before and after a radiation dose of 1000 Gy indicated that a stable bolus withstanding high radiation dose level (Table 5). Transparent bolus material will improve the precision and accuracy of radiation treatment as it helps to accurately adjust the position of the patient on radiation beam such that the target is fully irradiated without affecting the surrounding normal tissue. However, the limitations of the present study included no comparison of the oblique field and no measurement of the effective electron density of the bolus material.

The authors also wish to highlight that all the bolus materials were tested under the same experimental conditions, and hence, the discrepancy in the obtained resulted from various materials associated with the intrinsic properties of the material itself. The bolus can be cut into any desired shape and also layered together for various thicknesses. The potential advantage of Senflab bolus included its transparency; a person with 20/20 vision was able to read black typing in size 12 Times New Roman font with 0.5 and 1.0 cm thickness of the bolus material and was also able to visualize the field, cross-hair, and body marker.

Conclusion

The obtained results of the present study indicated the possibility of using Senflab bolus routinely during radiotherapy. Senflab bolus revealed satisfactory results in producing almost similar electron build-up, compared to that of Superflab and RW3 slab. The dosimetric properties of Senflab bolus are comparable to those of Superflab and RW3 slab for both photon and electron beams of various energies. It is important to note that Senflab bolus is transparent, compared to that of the other commercially available bolus materials.

Acknowledgment

The author would like to thank Dr.Pugalagiri Vadamalayan, the Chairman and Managing Director of Vadamalayan Integrated Cancer Centre, Madurai, India, and extend gratitude to Dr. Sowmiya Sampathrajan, the Radiation Oncologist and Radiotherapy technologist at Vadamalayan Integrated Cancer Centre, Madurai, India.

References

1. Richmond ND, Daniel JM, Whitbourn JR, Greenhalgh AD. Dosimetric characteristics of brass mesh as bolus under megavoltage photon irradiation. The British journal of radiology. 2016; 89(1059):20150796.
2. Radiation oncology physics: A handbook for teachers and students. 2nd ed. Vienna: International Atomic Energy Agency; 2005.
3. Dubois D, Bice W, Bradford B, Schneid T, Engelmeier R. Moldable tissue equivalent bolus for high-energy photon and electron therapy. Medical physics. 1996; 23(9):1547-9.
4. Khan FM. The Physics of Radiation Therapy, 2nd ed. Williams and Wilkins. Baltimore, MD. 1984.
5. Walker M, Cohen N, Manchaca D. Play-Doh and water-soaked gauze sponges as alternative bolus material for cobalt-60 teletherapy. Vet Radiol Ultrasound. 2005; 46(2): 179-81.
6. Babic S, Kerr AT, Westerland M, Gooding J, Schreiner LJ. Examination of Jeltrate® Plus as a tissue equivalent bolus material. Journal of applied clinical medical physics. 2002; 3(3):170-5.
7. Banaee N, Nedaie HA, Nosrati H, Nabavi M, Naderi M. Dose measurement of different bolus materials on surface dose. J. Radioprot. Res. 2013;1(1):10-3.
8. Benoit J, Pruitt AF, Thrall DE. Effect of wetness level on the suitability of wet gauze as a substitute for superflab® as a bolus material for use with 6 MV photons. Veterinary radiology & ultrasound. 2009; 50(5):555-9.
9. Butson MJ, Cheung T, Yu P, Metcalfe P. Effects on skin dose from unwanted air gaps under bolus in photon beam radiotherapy. Radiation Measurements. 2000; 32(3):201-4.
10. Chang F, Chang P, Benson K, Share F. Study of elasto-gel pads used as surface bolus material in high energy photon and electron therapy. International Journal of Radiation Oncology* Biology* Physics. 1992; 22(1):191-3.
11. Manger R, Paxton A, Cerviño L. Dosimetric assessment of brass mesh bolus for postmastectomy photon radiotherapy. Journal of applied clinical medical physics. 2016 ; 17(6):86-96.
12. Humphries SM, Boyd K, Cornish P, Newman FD. Comparison of Super Stuff and paraffin wax bolus in radiation therapy of irregular surfaces. Medical Dosimetry. 1996; 21(3):155-7.
13. Smart Medical Solutions. PHANTOMS & DOSIMETERS. 2016. Available from: http://www.smartmedicalsolutions.in/product/phantoms.php.
14. Malaescu I, Marin CN, Spunei M. Comparative Study on the Surface Dose of Some Bolus Materials. International Journal of Medical Physics, Clinical Engineering and Radiation Oncology. 2015; 4(04):348.
15. Montaseri A, Alinaghizadeh M, Mahdavi SR. Physical properties of ethyl methacrylate as a bolus in radiotherapy. Iranian Journal of Medical Physics. 2012; 9(2):127-34.
16. Basri G, Gonul K, Ayse K. Determination of surface dose and the effect of bolus to surface dose in electron Beam. Med Dosim. 2003; 28(3): 193-8.
17. Adamson JD, Cooney T, Demehri F, Stalnecker A, Georgas D, Yin FF, et al. Characterization of water-clear polymeric gels for use as radiotherapy bolus. Technology in cancer research & treatment. 2017; 16(6):923-9.
18. Moyer RF, McElroy WR, O'Brien JE, Chamberlain CC. A surface bolus material for high-energy photon and electron therapy. Radiology. 1983; 146(2):531-2.