

Designing and Dosimetry of a Shield for Photon Fields of Radiation Therapy in Oral Cavity Cancer

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ABSTRACT

The cancer of oral cavity is related to lesions of mucous membrane of tongue and gum that can be treated with radiation therapy. A lateral photon field can be used to treat this kind of tumor, which has a side-effect on normal tissue in the opposite side of the oral cavity. In this study the dosimetric effect of the various shields in oral cavity is evaluated. In this study, a special phantom similar to the structure of oral cavity with capability of film dosimetry was designed and constructed. The various shield slabs were made of five materials: Lead, Plexiglas, Acrylic resin, Silicon and Plaster. For irradiation, Cobalt 60 (60Co) and 6 MV photon beams were used. The film dosimetry before and after the shield was performed using GAFCHROMIC EBT2 films. The film before the shield measures the magnitude of backscattering radiation from the shield. The prescribed dose was 150 cGy. Results showed that 3 cm of the lead in both energies had the maximum absorption of radiation. The absorbed dose to opposite side of shield for 6 MV photon beams and 60Co were 21 and 32 cGy, respectively. The minimum attenuation on radiation was observed in silicon shield for which the dose of opposite side were 116 and 147 cGy for 6 MV and 60Co respectively. The maximum backscattered dose was measured 177 cGy and 219 cGy using 3 cm thickness of lead, which was quite considerable. The minimum backscattering where for acrylic resin 101 and 118 cGy for 6 MV and cobalt. In this study, it was concluded that the amount of backscattering for 3 cm Lead shield is quite considerable and increases the dose significantly. A composite layer of shield with 1–2 cm lead and 1 cm acrylic resin can have the protective effect and low backscattering radiation at the same time.

Key words: Radiation therapy, Oral cavity cancer, Dosimetry, Photon, Shielding

INTRODUCTION

Oral cavity cancer involves the lesions occurred in the tongue, lip mucosa and floor of the mouth.^[1,2] One of the standard methods for control of oral cavity tumors is the external radiation therapy in which the Linac or Cobalt 60 source (60Co) is used for irradiation.^[3-7] Beside the positive effect of radiation in oral cavity tumors, the radiation may cause damages to the normal tissue such as dental caries, loss of taste, xerostomia, mucositis, trismus, and osteoradionecrosis, with significant impairment of the patient's quality of life. Therefore many techniques are considered to protect the sensitive organs of oral cavity during irradiation. There are few studies about the stents and shields, which can be placed inside the oral cavity.^[6,8-14]

Bobard *et al.* investigated a stent including thermal plastic molding patient jaws and two bars of acrylic resin for keeping the mouth open.^[15] Because this stent keeps the tongue below

the radiation therefore it prevents the tongue from extra dose. There is also less possibility of swallowing the stent. This stent makes an extra distance between upper and lower jaws and makes it possible to irradiate the tumor without irradiation of upper jaw. Two columns of acrylic resin keep the distances constant during treatment course and improve the reproducibility of the treatment setups. An important restriction of this stent is that it is not applicable to the patients with severe bone resorption with missing teeth.^[15]

Verrone *et al.* designed a stent from Acrylic resin that made a 1.5 cm opening between upper and lower jaws during treatment.^[14] In this method, a protective layer from acrylic resin on the lower jaw was used and patient was treated with IMRT (Intensity-modulated radiation therapy) technique. That this work carried out by dosimetric analysis of treatment planning system. For treatment planning, two CT scans were taken with and without the stent. The results of this study showed that with the use of this stent the

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average dose to normal tissue in oral cavity, parotids and salivary glands are reduced compare to the case without the stent. The dryness of the mouth and the ulcers were also reduced with the use of stent.^[14]

Kaanders *et al.* built a stent from Lipowitz alloy with an Acrylic resin cover. The Lipowitz alloy is a good absorbent of radiation, and the acrylic resin cover reduces the backscatter radiation. They concluded that with this kind of alloy the radiation to normal tissue around the tumor is reduced. In this study, the use of lead suggested, however, the 0.5 cm cover is needed to reduce backscattered radiation, which was high for the lead shield.^[16]

In this study, for optimization of the material and design of the oral cavity shield many combinations of various materials are investigated. The measurement of backscatter radiation is also performed with film dosimetry, which is very important aspect of any shielding since it might cause severe burn of the normal tissue.

MATERIALS AND METHODS

The shields which are used in treatment of the cancers in one side of the oral cavity is placed inside the cavity to protect the other side of the cavity, which is normal tissue. The purpose of the design of the shield is to keep the mouth open during treatment and reduce the absorbed radiation on the opposite side of tumor. The type of the radiation is photon beam with relatively low energy in radiation therapy. The shield (or stent) could be uniform material or layers of different materials. The combined materials may decrease the absorb dose to the opposite side and reduce the backscatter radiation at the same time.^[16] To avoid the toxicity of the metals in direct contact with the mouth and tongue metal shields are covered with thin layer of plastic.

In this study, a special phantom considering the geometry of the open oral cavity is built. The phantom is illustrated in Figure 1. The phantom has the approximate dimensions of $5 \times 4 \times 4$ cm³. All the details, dimensions and thicknesses

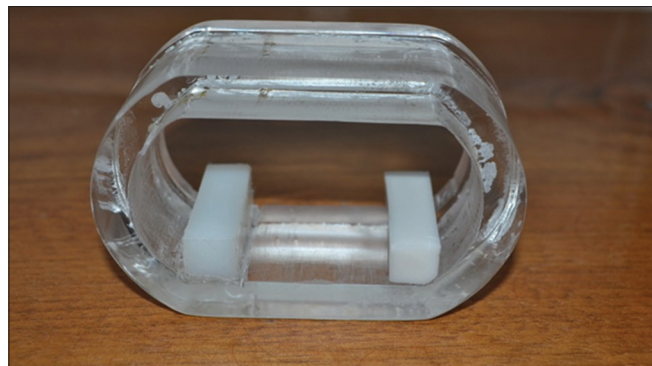


Figure 1: The designed phantom simulating the open oral cavity of a patient. The phantom is designed to be irradiated from left lateral or right lateral direction

of this phantom are designed similar to a real oral cavity of a patient undergoing a lateral radiation field.

The material of the phantom is plexiglass with a density of 1.19 g/cm³ which is close to water and soft tissue density. Inside the phantom, a long cubic piece with dimensions of $4 \times 1 \times 1$ cm³ is attached, which simulates the gum of the patient. The material of this part is Teflon (polytetrafluoroethylene or PTFE) with a density of 2.1–2.3 g/cm³ close to the density of the bone.

The shields that are built and used in this study were slabs with dimensions of $1 \times 4 \times 4$ cm³. There are few parameters that should be considered for designing of these shields. The maximum height of the shield should not be uncomfortable for the patient for opening the mouth. The length of the shield should not be too much that causes the nausea in the patient. The thickness of the shield also should be limited to make sure that it does not make a problem in patients breathing. The shields were made of five materials: Lead, plexiglass, acrylic resin, silicon and plaster. As it is illustrated in Figure 2, for each material we have three similar layers with 1 cm thickness.

For film dosimetry in this study, GAFCHROMIC EBT2 films were used. These films have a linear response over wide range of the absorbed dose.^[17] EBT2 is a radiochromic film which needs no cover and there is also no need for processing of the film. Because of these characteristics radiochromic films are very useful for this kind of dosimetry since the films are used in small pieces. It is very hard task to use a typical radiographic film in small parts since this kind of film is sensitive to visible light and cutting and covering of these films in small pieces is very sensitive and time consuming. However using radiochromic film one can easily cut the film to small sheets in a room with an ordinary day light. The instantaneous response of the EBT2 films is also very convenient for initial visual evaluation of the film dosimetry results. In this way with a simple visual check of the films one can evaluate the major problems and possible errors in experiment. The

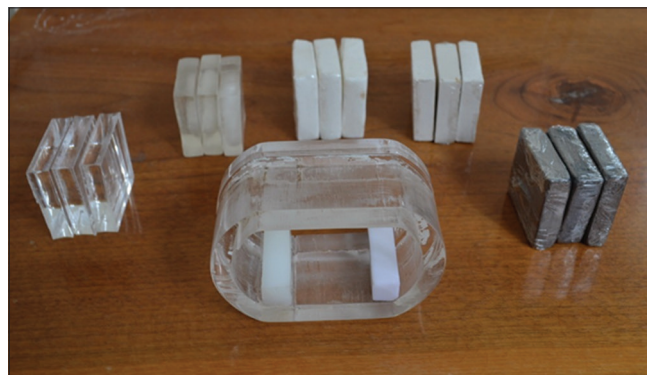


Figure 2: Illustration of shields with five different materials. Each slab has 1 cm thickness and for each material there are three slabs

films were scanned 1-week after the irradiation.^[17-22] The analysis of the results of film dosimetry is performed with MATLAB software.

For experiments and irradiation the Co-60 beam and 6 MV photon beam of Nepton 10 PC Linac in Seyed-o-Shohada Hospital, Isfahan, Iran, are used. These energies are selected according to the realistic cases in a typical oral cavity cancer in radiation therapy.

Experimental Setup

The setup of the radiation for this study is illustrated in Figures 3 and 4. The surface of the phantom is placed in 100 source to surface distance (SSD) for. The gantry of the machine field is placed in lateral position according to routine treatment plans. In each time of irradiation, two pieces of the films are placed in two points of the phantom as it is illustrated in Figures 3 and 4. Film 1 is placed in the opposite side of the tumor after the shield so it measures the absorbed dose in normal tissue of the mouth. Film 2 is placed right before the shield in contact with the shield to evaluate the amount of the backscattering radiation.

The first set of experiments was performed using the shields with uniform material and 3 cm thickness. For each of five materials, an irradiation was performed to deliver 150 cGy dose to isocenter. The field size was $6 \times 6 \text{ cm}^2$ to cover one side of the phantom which is supposed to be treated.

In the second step, the composite shields are used as it is illustrated in Figure 5. The shield in this case has two layers of the lead, and the third layer is one of four other materials such as acrylic, resin, and silicon. There is also a set of experiments for just two layers with the same material such as 2 cm lead. In this setting, the entire shield is thinner than 3 cm.

After the experiment, the irradiation films are scanned. It is recommended that the films are scanned at least 24 h after irradiation for self-development of film emulsion.^[22] In this study, the films were scanned 1-week after the experiment. Then, the films should be scanned with a special scanner (Mikroteck-ScanMaker-9800 plus) which has the capability to scan the films in transitional mode.

For dose measurement in film dosimetry it is needed to obtain the calibration curve of the EBT2 films. For calibration of the film a film was irradiated with $2 \times 10 \text{ cm}^2$ fields one above each other.^[17] Each strip with $2 \times 10 \text{ cm}^2$ dimensions was irradiated, which had a known dose and the doses are increased from 5 cGy to 2000 cGy. The dose steps were 10, 20, and 100 cGy from low dose to high dose. It should be noted that for calibration of the film with 6 MV photon beams, a 1.5 cm RW3 slab should be placed on the film to provide sufficient build up on the surface of the film. Below the

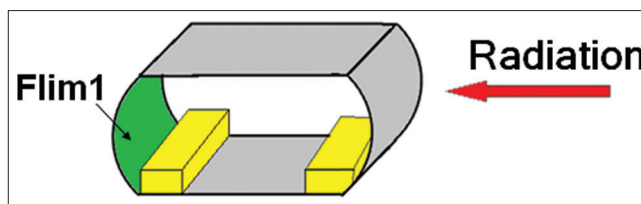


Figure 3: Location of film 1 in phantom. The film is placed in opposite side of the incident radiation

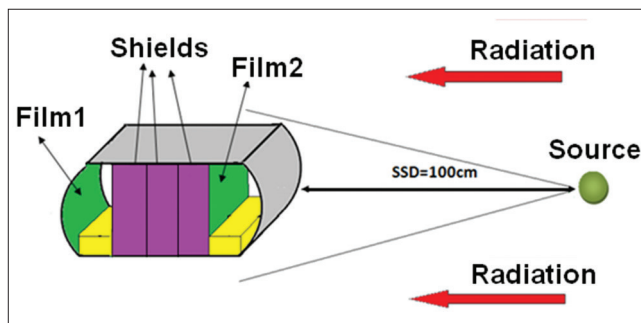


Figure 4: The setup of the film dosimetry and location of film 2 in phantom. The film is in direct contact with the shield

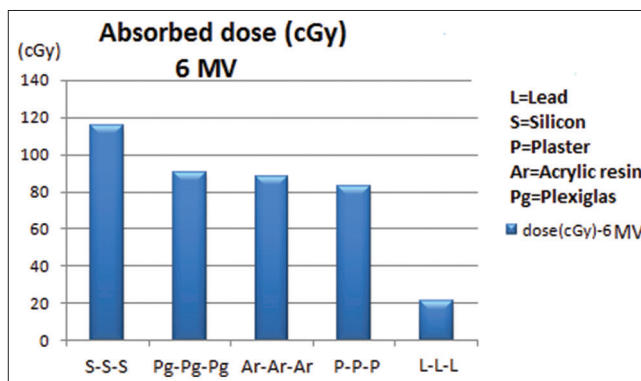


Figure 5: The comparison of absorbed dose in normal tissue after the shield for uniform shield of five material: Lead (L), Silicon (S), plexi glass (pg), acrylic resin (Ar) and plaster (P). The energy of photos is 6 MV

film there is also 30 cm of RW3 phantom to provide a full scattering condition. All the films should also be scanned five times before the irradiation to avoid the error due to no-uniform distribution of the background on the film.^[22,23] The average of the background in each point is then considered for obtaining the dose for that point. After obtaining the calibration curve of the films, all the irradiated films in above experiments were converted to absorbed dose using an in-house MATLAB routine^[17,24] The format of the images was Tiff to have a better quality since in jpeg format one loses the details of the image. The resolution of the scanner was set to 300 dot per inch (dpi). It should be noted that higher resolution produces very large images which is then hard to process in MATLAB. The original image of the film contains three channels of colors, red, green, and blue. Each color is related to one channel of the scanner.

For better results in all stages of film dosimetry such as calibration and the dosimetry of each point the red channel of the image is considered for measurements.^[25]

RESULTS AND DISCUSSION

The results of the absorbed dose in Film 1 which is related to the opposite side of the oral cavity and normal tissue is illustrated in Figures 5-8. Figures 5 and 8 are for experiments that all 3 layers are identical. Figure 6 is for experiments with two layers of lead and third layer of different materials. Figure 7 illustrates the various thickness of lead shield from 1 cm to 3 cm for 6 MV. In all figures, the abbreviation of materials is as follows: Lead (L), Silicon (S), Plexiglas (Pg), Acrylic resin (Ar) and Plaster (P).

As it is expected the maximum absorption of the dose to prevent the dose to the normal tissue on the opposite side is for 3 cm lead shield. For 150 cGy prescribed dose to the tumor side, the amount of the dose in film1 is 21 cGy for 6 MV and 32 cGy in 60Co photons. The minimum absorption of the dose was for Silicon shield in which the absorbed dose in films 1 was 116 cGy and 147 cGy for two energies. Therefore, Silicon shield or similar material is not an appropriate material for shielding.

Although for both energies three layers of Lead provide the best shielding for normal tissue in the opposite side of the oral cavity. However, the magnitude of backscattered radiation is quite considerable. The amount of the dose for film 2 was 116 and 147 cGy for 6 MV and 60Co respectively. This amount of radiation in practice goes toward the tumor. However it also has an effect on the jaw and other tissues around the tumor.

As it is illustrated in Figure 6, the absorbed doses in these samples are very close together and the difference between these cases is around 2 cGy. The reason is that there is less attenuation for larger energies of the photon. Therefore, two layers of Lead and one layer of other materials has no major difference in terms of the dose to the opposite side of the oral cavity. One can compare the backscattering of these cases and choose the proper shielding. In Figure 7 as it is expected with increasing the thickness of the shield from 1 cm to 3 cm there is a significant change in the dose of the normal tissue.

Backscattering Radiation

The measured dose in film 2 which is placed right before the shield consists of the primary beam which is constant and backscattering radiation from the shield. The results of the absorbed dose in film 2 are illustrated in Figures 9-13

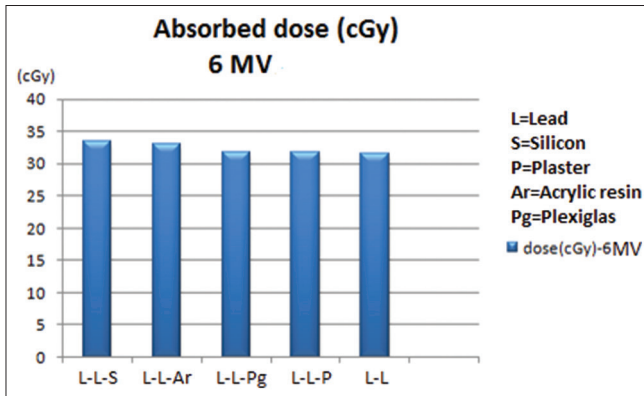


Figure 6: The comparison of the dose for shields with two layers of lead and third layer of different materials

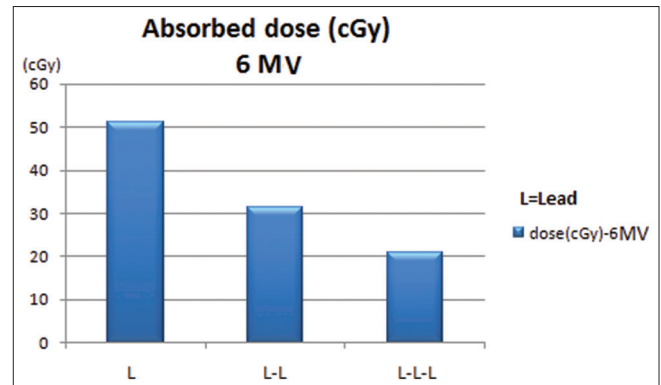


Figure 7: The absorbed dose in film 1 for various thickness of lead shield from 1 cm to 3 cm for 6 MV

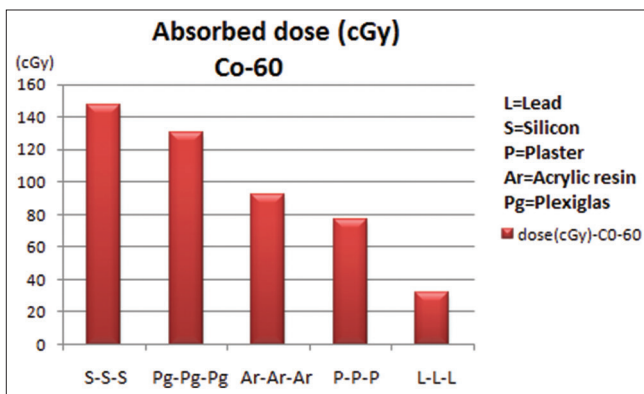


Figure 8: The dose in film1 for Cobalt 60 and uniform shields with 3 cm thickness

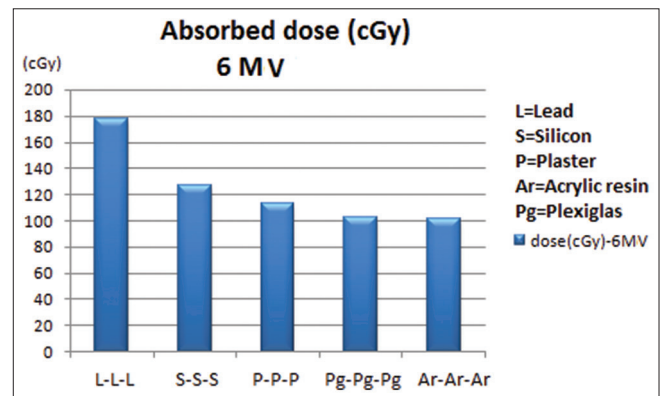


Figure 9: The comparison of absorbed dose in film 2 illustrating the backscattered radiation for various materials and 6 MV photons

for 6 MV and 60Co. Figures 9 and 11 are for the cases in which all three layers are identical. Figures 10 and 12 are for two layers of lead and third layer of different materials. For the Lead shield, the absorbed dose is 177 cGy and 219 cGy for 6 MV and 60Co respectively which is quite considerable. The minimum amount of the backscattering is related to resin Acrylic shield for which the absorbed dose in film 2 is 102 and 118 cGy for two energies.

With increasing the atomic number of shielding material (Z) the backscattering radiation is increase. As it is seen in the above numbers, although for 6 MV the amount of the monitor unit is the same, however the difference between the amount of the absorbed dose of Lead and Acrylic resin (177 and 102) is 75 cGy, which is a significant difference. This magnitude of difference for 60Co is 101 cGy, which is larger compare to 75 cGy for 6 MV photon beams. This is also reasonable since the magnitude of backscattering is reduced as the energy of the photon beam is increased. On the other hand if there in only the primary incident beam one expect to have the same amount of the dose for all cases in film 2 for each energy, since there is only a constant layer of the phantom is in the path of the film, which is assumed to be the tumor. The differences of the doses in the film 2 are only due to difference of backscattering radiation of various materials.

According to results of composite layers, Figures 10 and 12, two layers of Lead and an Acrylic resin together produced the minimum backscattering radiation. As it is illustrated a layer Acrylic resin absorbs a considerable amount of the back scattered radiation. The absorbed dose for two layers of Lead alone is 147 cGy and it is reduced to about 103 cGy with an additional Acrylic resin layer.

CONCLUSION

In this study, various shields for cancer of oral cavity is designed, and a film dosimetry is performed to evaluate the amount of absorption and backscattering for each shield.

The shield is used to keep the mouth open in irradiation of oral cavity and to prevent the dose to the opposite side of the cavity. The typical field for oral cavity cancer is a lateral field with low energy photons.

In terms of the protection of the opposite side of the oral cavity the uniform lead shield produces the better shielding compare to other materials. However, the magnitude of back scattering is significant and it may cause damage to the normal tissue and lower gum before the shield. The relative amount of the backscattering was larger for low energy photons as it is expected. The amount of the

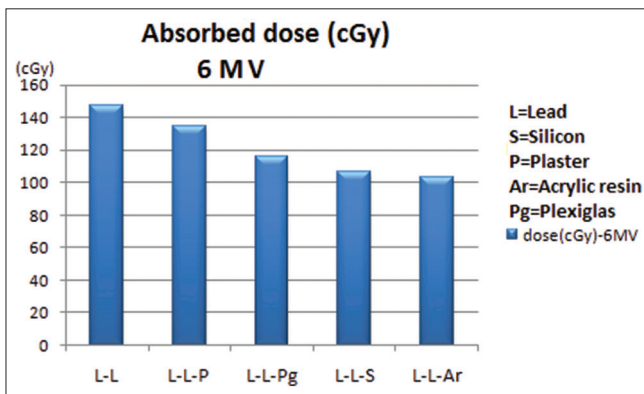


Figure 10: The backscattered dose for film 2 in two layers of Lead and third layers of different material and 6 MV photon beams

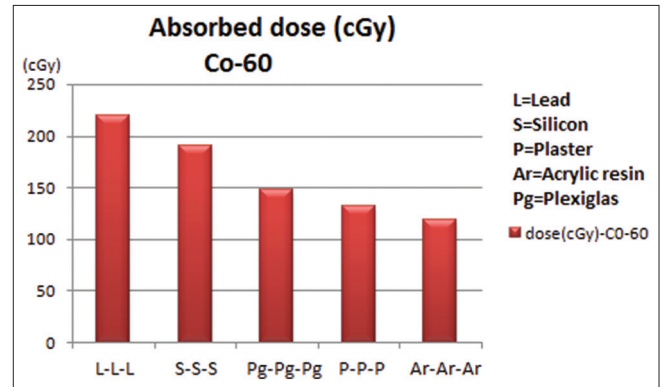


Figure 11: The comparison of absorbed dose in film 2 illustrating the backscattered radiation for various materials and Cobalt 60 photons

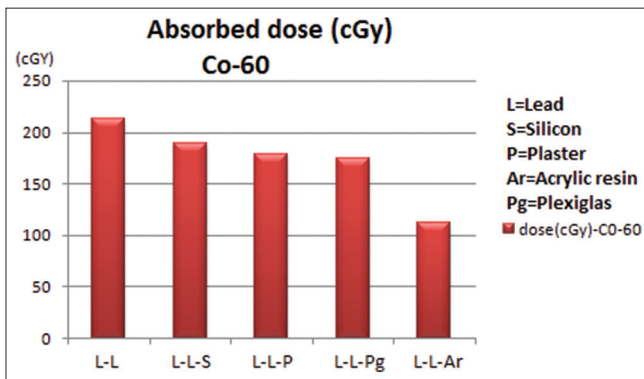


Figure 12: The absorbed dose in film 2, backscattered, in combination of one layer and two layer of Lead

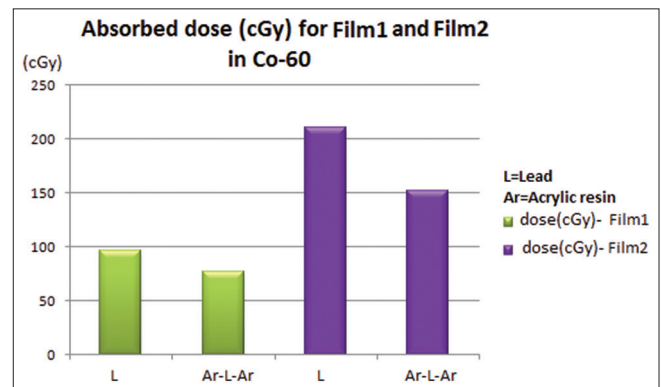


Figure 13: The absorbed dose in film 1 and film 2 various composition of shield in Cobalt 60

backscattering for ^{60}Co increased the dose to almost double of prescribed dose for lead shielding. The Silicon and other low Z materials have a negligible backscattering, however they cannot be used alone to protect the opposite side of the oral cavity. They have to be used as a combined shield with a layer of Lead and Acrylic resin to absorb the radiation in the opposite side of the oral cavity in lateral fields of radiation therapy. In our study, two layers of Lead and one layer of Acrylic resin had a good performance to reduce the backscattering radiation and absorb the dose in the normal tissue on the opposite side of oral cavity.

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