# Verification of the Protective Effect of Functional Shielding Cream for the Prevention of X-ray Low-dose Exposure

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**ABSTRACT**

In the case of radiation workers in medical institutions, radiation exposure is made for patient protection and accurate procedures, so they have a problem of low dose exposure. Low-dose radiation exposure occurs mainly in parts of the body other than the Apron area, and the most frequent place is the skin of the back of the hand. In particular, since the medical personnel's hands require senses and fine movements during the procedure, they are defenseless in the radiation exposure area and are at risk of exposure. It can solve the problem of shielding such as lead gloves, and it is difficult to use by suggesting the activity of the hand during the procedure. To solve this problem, a shielding cream capable of obtaining a functional radiation protection effect was developed and its shielding performance was compared with lead equivalent of 0.1 mmPb. In the process of manufacturing shielding cream, the shielding performance was improved by adding a defoaming process to reduce air holes to increase the density of the cream. Therefore, the shielding cream using barium sulfate as the main material has a lower shielding rate than the lead plate, and in the realm of effective energy, it is 59%, At high effective energy, a difference of about 37% was shown, indicating that there is a functional radiation protection effect. The advantage is that it can be used directly on the skin, and it is considered that it can be used before wearing surgical gloves and has a permanent protective effect.

Keywords: Radiation, Barium Sulfate, Radiation Exposure, Shielding Cream, X-ray

## I. INTRODUCTION

The only minimal way to protect medical personnel from radiation exposure in hospitals is to keep a safe distance and wear shielding clothing[1]. Shielding suits are manufactured using fabrics manufactured based on the minimum lead equivalent of 0.25mm[2]. Apron is a representative product of shielding suits used in medical institutions. The defense area is designed to be protected from the front to the neck, shoulders, abdomen, pelvis, and thighs, and the hands, arms, legs, and feet are out of the shielding range[3]. In particular, interventional procedures performed in clinical settings expose both doctors and patients to the risk of radiation exposure. Radiation exposure of operators in medical practices such as coronary intervention and angiography is often caused by scattered rays generated from patients[4]. Therefore, although the apron is defending, the operator's activity must be fully considered. In the case of the hand that directly performs the procedure, it is exposed in a defenseless state. The International Radiation Defense Commission regulates the amount of radiation that an operator can be exposed to for one year as 20 mSv for the whole body, 150 mSv for the lens, 300 mSv for the thyroid gland, and 500 mSv for the limbs. Therefore, it is recommended to wear lead-gloves

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during the procedure[5]. In the case of thick gloves made of lead, it is difficult to use after wearing them, and there is a possibility of infection during the procedure, so in many cases, only surgical gloves are worn and medical practice is performed in areas with scattered rays. Therefore, recently, surgical shielding gloves made of an eco-friendly shielding material other than lead have been developed and supplied, but there is still difficulty in commercialization due to high price competitiveness[6]. Therefore, in this study, a shielding cream that users can apply directly in a way that protects the skin on the back of the hand was developed. The production cost of surgical shielding gloves is related to the process technology of the product. It is also a difficult technical task to maintain the reproducibility of the shielding effect according to the degree of dispersion of the material during the mixing and molding process of the eco-friendly radiation shielding material and the polymer material[7]. Dispersion technology that uniformly distributes the content of the shielding material in the technology of dispersing the shielding material in the polymer has been extensively researched[8]. The shielding cream also has the same problem. In particular, when the shielding material is combined with an organism and coated, it poses a difficult problem in the same shielding reproducibility due to the thickness control on the skin, and the dispersion of the shielding material in the shielding cream is a very important task. Therefore, in this study, when mixed with an emulsifier, the ratio of the mixer was adjusted to solve this problem. Therefore, in order to improve the shielding performance and accessibility of the shielding cream, a coating dispersion method of shielding material with the same texture as the existing hand cream was applied and studied. In addition, we tried to verify whether it can be used as a shielding function by evaluating the shielding ray performance in direct X-rays. The radiation shielding effect was evaluated by comparing the shielding performance through lead, which is the standard of shielding. Through this, we tried to suggest a good method to prevent constant exposure to low doses of the skin.

## II. MATERIAL AND METHODS

The radiation shielding field defense is determined by the cross-sectional area, that is, the radiation interaction[9]. As for the incident energy intensity, the transmitted energy intensity is determined by the linear attenuation coefficient and the thickness as shown in Equation. 1[10]. As the linear damping coefficient is determined while passing through the thickness $x$, the theoretical background is as shown in Equation. 2[11]. The total probability for an interaction, called the total linear ($\mu$) decay coefficient, is equal to the sum of the partial probabilities. Here, $\tau, \sigma, k$ is the photoelectric absorption probability, Compton scattering probability, and electron pair generation probability, respectively, and can be obtained by the following Equation[12].

$$I = I_0 e^{-\mu x} \tag{1}$$

$I$ : X-ray intensity after passing through the shield
$I_0$ : Incident X-ray intensity
$u$ : linear damping coefficient ($cm^{-1}$)
$x$ : Thickness of shield (cm)

$$\begin{aligned} \mu &= \tau + \sigma + k \\ \sigma(cm^{-1}) &= NZf(E_\gamma) \\ k(cm^{-1}) &= NZ^2 f(E_\lambda, Z) \end{aligned} \tag{2}$$

$a$ : General constant
$m$ , $n$: Parameter
$N$ : Atomic density
$Z$ : Atomic number

Therefore, the defense condition for manufacturing radiation shielding cream in this study can satisfy the theoretical background that increases the effect of interaction by increasing the density of materials with high atomic numbers[13]. In this study, barium sulfate, an eco-friendly material harmless to the human body, was selected as the material. Barium sulfate has a density of 4.5 g/cm$^3$, which is lower than tungsten, which is widely used as an eco-friendly shielding material, but is stable in the manufacture of shielding cream due to its water insoluble property[14]. The density of the shielding cream means the mass dissolved in the solution per unit volume, but it was calculated as a mass percentage (wt%) at the same thickness based on the amount injected due to the nature of barium sulfate[15]. The particle size of barium sulfate was 4 μm or less, so nanoparticles were not used so that it could be easily removed after use, and purity was 99.0% or higher. The wt% did not exceed a maximum of 30 wt% based on the accessibility of the skin, and three types of hand creams, 10, 20, and 30 wt%, which were the density levels, were prepared. An aqueous organic carrier, which is a raw material of hand cream, contains lubricants, humectants, surfactants such as glycerin, and emulsifiers such as glyceryl sterate. When coated on the skin, it is manufactured in the form of functional cosmetics to satisfy the same texture as the existing hand cream.

The mixing method of barium sulfate was mixed at a temperature of 70 °C. for 8 minutes at a speed of 3000 rpm with a Homo mixer (T.Kprimix, 2010, Japan). At this time, a method in which air bubbles were removed was added and a method in which air was mixed in one direction without removing air bubbles was compared. Air bubbles were artificially removed through a vacuum deaerator (HYUP SHIM, Vacuum, deaerator, low noise type). Bubble removal is a process that proceeds with equipment, but there are bubbles generated during the mixing process, and there are bubbles generated by the reaction between materials. In this study, a double removal method using a device and chemical additives was applied.

As for the comparative method, enlarged pictures were analyzed using an optical microscope (Olympus optical microscope, BX53F2, Japan). In order to evaluate the final shielding performance, the thickness of the shielding cream according to wt% was constantly tested. In order to fix the thickness constant, Fig. As in 1, a 2mm Polycarbonate (PC) plate was prepared and the shielding cream was fixed at 1mm. Based on lead, which is the absolute value of shielding performance, it was comparatively evaluated with a 0.1mm plate. Currently, the minimum standard for manufacturing shielding suits in Korea is lead equivalent of 0.25mm, but this product verifies the radiation reduction effect as a functional cosmetic material. The lead equivalent was compared with 1/10 of the thickness of the shielding cream. The geometrical structure with the radiation generator was configured as shown in Fig. 2[16]. The diagnostic X-ray used in the experiment (MOBIX-1000, Listem, 2010) was tested. In order to change the X-ray used in this experiment into effective energy, which is a single energy, the half-layer measurement calculated the slope from the attenuation coefficient law ($I = I_0 e^{-\mu x}$), After obtaining the value of the linear absorption coefficient μ from this slope, it could be calculated from the half value layer = 0.693/μ[17]. For the effective energy calculation, Hubbell's mass absorption coefficient table was used to calculate the effective energy having the same value as the half-value layer corresponding to the single energy from the half-value layer obtained above[18]. The calculation of the shielding rate of the shielding cream was (1-W/W0) × 100[19]. At this time, W is the dose measured when there is a shielding cream between the X-ray tube and the dosemeter. W0 was calculated as the irradiation dose value measured when there was no shielding cream between the X-ray tube and the dosemeter, and the shielding rate was calculated using the average value of 5 measurements.

For the radiation detection dosimeter, an ion chamber ionization chamber (Radical 9015 with 6 cc ion chamber, Radcal Co, 2017, Correction. 2020) was used.

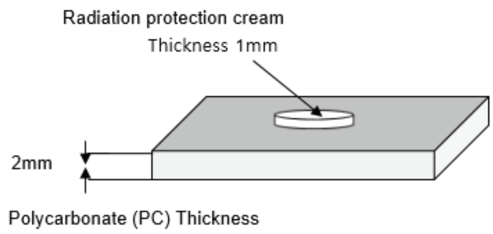


Fig. 1. Thickness control plate of protective cream to evaluate shielding performance.

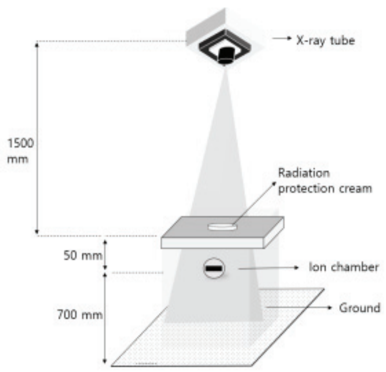


Fig. 2. X-ray shielding performance evaluation method.

## III. RESULT

Fig. 3 shows the appearance picture of the shielding cream using barium sulfate. Samples were prepared according to the mass content of barium sulfate, which is the same shielding material, using a fixed PC plate having a thickness of 1 mm. There was no difference in the appearance of the samples. However, the higher the content of barium sulfate, the more vivid the color and the less organic carrier is added, which may look a little rough, It is difficult to distinguish visually.

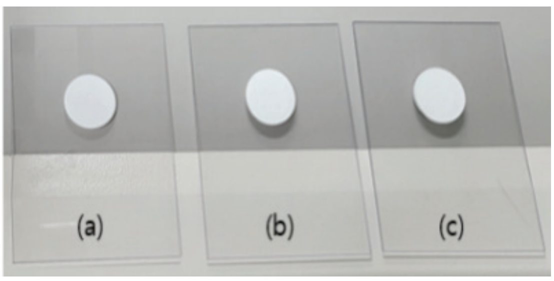


Fig. 3. Manufactured barium sulfate shielding cream. ((a) 10 wt%, (b) 20 wt%, (c) 30 wt%)

Fig. 4 is the particle distribution state of the process before and after removing air in the mixing process through small deaeration. In Fig. 4-(a), air distribution in various states can be observed, and the area marked with a red circle can be explained as a place where bubbles gather. In the case of Fig. 4-(b), the bubble state was well organized, but The bonding of the organism itself is high, so the area where the concentration rises, such as the blue circle, is easily generated, so the shielding performance can be improved. It is somewhat difficult to control the density in the state where air bubbles are removed. This should be adjusted in thickness during the coating process.

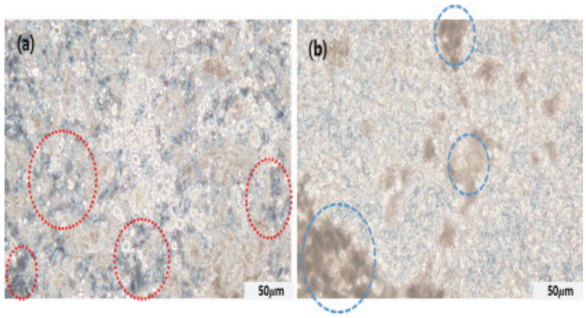


Fig. 4. Comparison of particle distribution before and after bubble removal (×40) ; (a) Before bubble removal (b) After bubble removal, the red circle indicates the bubble formation area, and the blue circle indicates the state in which barium sulfate is aggregated.

Fig. 5 shows the distribution of particles according to the mixture of barium sulfate and organisms. Comparing Fig. 5-(a) with (b) and (c), a difference in the distribution of barium sulfate appears in the optical microscope magnification picture. Depending on the concentration of barium sulfate, it can be seen that the form of distribution in the organism of the cream appears differently.

However, when coated on the back of the hand, as shown in Fig. 6, the texture may feel different as the wt% is higher. The shielding cream coated on the back of the hand has no difference other than the difference in texture, but there is an inconvenience that it takes a little longer to coat the skin due to the texture. Up to 20 wt%, you can feel the texture close to general hand cream, but when it is 30wt% or more, it is very dry and peeling from the skin may occur.

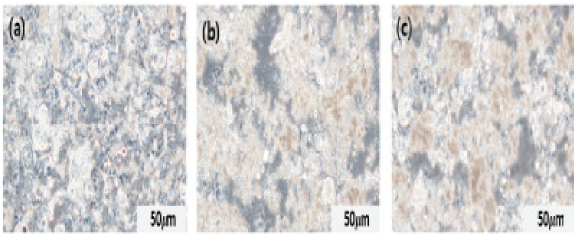


Fig. 5. Barium sulfate particle distribution state (×40). ((a) 10 wt%, (b) 20 wt%, (c) 30 wt%)

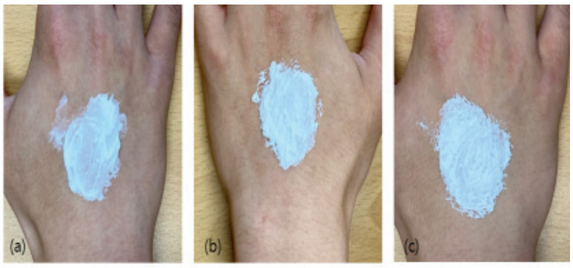


Fig. 6. State of coating the back of the hand with shielding cream. ((a) 10 wt%, (b) 20 wt%, (c) 30 wt%)

In the most important shielding performance, there was a difference according to the wt% of barium sulfate. As shown in Table 1, the smaller the content of the shielding material, the greater the difference in shielding performance. When the content of barium sulfate was low at 10wt%, it showed a lower protective effect in the higher energy region than when it was 30wt%. Compared to the standard lead 0.1mm plate, the shielding rate shows a difference of 59 % at 28.7 keV and 37 % at 61.9 keV. Although there is a 10-fold difference in the thickness of the shielding cream and the lead plate, it was found that there is a significant difference in the shielding rate. Therefore, it can be understood as a functional shielding cream rather than the term shielding. In addition, it is expected that a considerable thickness is required to enhance the performance of the shielding cream. As shown in Table 2 where the bubble removal process of the shielding cream was added, there was no difference in the low effective energy area, but there was a difference in the high energy area. Therefore, both 20wt% and 30wt% were found to have an effect on the shielding performance of air bubbles generated during the manufacturing process of the shielding cream.

Table 1. Radiation X-ray shielding rate of shielding cream

| | 28.7 keV | 36.1 keV | 53.2 keV | 61.9 keV |
|---|---|---|---|---|
| 10 wt% | 18.58 | 14.52 | 9.84 | 8.21 |
| 20 wt% | 23.51 | 21.45 | 18.24 | 16.12 |
| 30 wt% | 35.24 | 32.21 | 30.19 | 27.34 |
| 0.1 mmPb | 94.33 | 83.53 | 72.78 | 63.97 |

Table. 2 Radiation X-ray shielding rate of shielding cream (20 wt%, 30 wt%) before and after bubble removal

| | 28.7 keV | | 36.1 keV | | 53.2 keV | | 61.9 keV | |
|---|---|---|---|---|---|---|---|---|
| | 20wt% | 30wt% | 20wt% | 30wt% | 20wt% | 30wt% | 20wt% | 30wt% |
| Before air bubble removal (%) | 22.42 | 32.12 | 20.27 | 28.24 | 17.69 | 22.12 | 15.59 | 16.45 |
| After removing the bubbles (%) | 23.04 | 32.21 | 22.15 | 30.19 | 17.73 | 27.34 | 15.92 | 24.25 |

# IV. DISCUSSION

Examinations using X-rays at medical institutions include angiography and fluoroscopy, This leads to a significant increase in exposure dose to patients and operators by combining fluoroscopy and imaging. In general, medical staff dose is correlated with patient dose, so when the patient dose increases, the medical staff dose tends to increase as well[20]. Recently, as the awareness of radiation exposure of patients and operators has increased, various methods and studies are being actively conducted to reduce unnecessary exposure. The operator is also protected by wearing a lead gown, lead glasses, and a thyroid shield, and there are limitations due to restrictions on activity[21].

In particular, in the case of the hand, it is difficult to use a direct shielding tool because sensory movements must be considered. Therefore, since a very thin surgical glove less than 1 mm is used, protection against direct lines is not well achieved.

Therefore, the shielding cream presented in this study can be coated on the back of the hand to protect the skin from radiation. Although it is a low dose, continuous exposure to radiation can cause various complications such as cancer and genetic modification. Internationally, there are many efforts to manage radiation exposure by establishing dose limits[22]. The International Commission on Radiation Protection, ICRP 60, recommends that an individual's radiation exposure dose for occupational radiation exposure be kept below 50 mSv per year and 100 mSv for 5 years. In particular, it is thought to be effective in protecting the skin, such as the hands[23]. Although these radiation protection products are produced and sold in the United States and Japan, they are mainly used to obtain radiation reduction effects in normal tissues during aerospace and cancer treatment, but a coating thickness of 2 mm or more is recommended. Therefore, the core of the commercialization technology of the shielding cream is the technology of lowering the coating thickness and the dispersion of the shielding material. Since this problem has not been solved yet, technology to increase the thickness is being grafted[24].

In this study, it can be suggested as a limitation of the study by presenting the shielding effect of a single material using barium sulfate, In the future, it is necessary to study the density improvement of the shielding cream through the improvement of the composite material and manufacturing process. The key process technology for manufacturing shielding cream is the dispersion of shielding materials, and the effect was verified by adding a bubble removal method among the dispersion methods.

In this experiment, the density between particles was improved by applying the bubble removal method in the manufacturing process using a deaerator, It has been shown to affect the radiation defense in the shielding cream. If the density of the shielding cream is increased, the viscosity is improved and the adhesion of the skin is lowered, but there is a problem, This can be partially overcome with oil additives in the future, and high-density shielding cream has been found to be a very important technical factor. Masking creams and gels are functional cosmetic preparations. Therefore, rather than recognizing it as an existing shielding tool, it is produced and sold in anticipation of radiation reduction effect. Therefore, in order to faithfully play the role of functional cosmetics in the future, various studies are needed through technology to increase skin adhesion and technology to reduce the gap between particles.

For commercialization of the shielding cream, it is necessary to increase the accessibility of use, and the soft material coated on the skin and the treatment process that can be easily removed by water after use are also very important. In addition, it is thought that it can be used with various functional skin preparations in consideration of aging of the skin and removal of active oxygen[25]. Through this study, it will be necessary to develop products that can prevent continuous low-dose exposure. Therefore, it is thought that it is necessary to develop various tools that can provide radiation protection at all times in the future, such as shielding cream. In the case of an interventional procedure in a medical institution, the hands of the operator are indirectly exposed by placing the hands in the radiation exposure space, If you do not wear lead gloves, you may be exposed to scattered radiation for a long time. Although exposed skin is less sensitive to radiation than the eyeball, gonads, and thyroid gland, active protection against exposure is required[26]. In this case, the shielding cream can be used, can be easily selected and used by the user, and can be easily removed after use, so it can be used as a product that can be protected at all times. It is expected to make a significant contribution to reducing exposure in medical institutions in the future.

# V. CONCLUSION

A shielding cream that can protect the skin from low-dose radiation such as scattered rays generated during examination and treatment in medical institutions can be manufactured using barium sulfate. In order to evaluate the shielding performance compared to protective clothing for low-dose radiation shielding, a protective cream with easy body contact and increased accessibility was studied. The shielding effect is different depending on the shielding material and content before and after the removal of air bubbles. The higher the content of the shielding material, the better the shielding effect when bubbles are When barium sulfate 10wt% and 30wt% were compared, the difference was 16.7 % at 28.7 keV and 19.13 % at 61.9 keV. In addition, it can be said that there is a functional radiation protection effect because it shows a big difference from the lead equivalent 0.1 mmPb plate removed.

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# X-ray 저선량 피폭방지를 위한 기능성 차폐크림의 방어 효과 검증

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## 요 약

의료기관의 방사선 업무 종사자의 경우 환자 보호와 정확한 시술을 위해 방사선 노출이 이루어져 저선량 피폭의 문제점을 안고 있다. 저선량 방사선 피폭은 주로 Apron 영역 이외에 신체 부분에서 발생되며, 가장 많은 곳이 손 등 피부이다. 특히, 의료인의 손은 시술 중 감각과 미세한 동작을 필요로 하기에 방사선 노출영역에서는 무방비 상태로 피폭의 위험성을 안고 있다. 납장갑 등 차폐체로 문제를 해결할 수 있지만, 이는 시술 중 손의 활동성을 제안하여 사용상의 어려움이 있다. 이러한 문제점을 해결하고자 기능성 방사선 보호효과를 얻을 수 있는 차폐크림을 개발하여 납당량 0.1 mmPb와 차폐성능을 비교하였다. 차폐크림 제조과정에서 크림의 밀도를 높이기 위해 기공을 줄이는 탈포과정을 추가하여 차폐성능을 개선하였다. 따라서 황산바륨을 주 재료로 사용한 차폐크림은 납 plate보다 차폐율이 낮은 실효에너지 영역에서는 59%, 높은 실효에너지에서는 37% 정도의 차이는 보여 기능성 방사선 방어효과가 있는 것으로 나타났다. 따라서 피부에 직접 사용할 수 있는 장점으로 상시 방어효과와 수술용 장갑 착용전에 사용이 가능한 것으로 사료된다.

중심단어: 방사선, 황산바륨, 방사선 피폭, 차폐크림, X-ray

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