University of Al-Mustaqbal
College of Science
Department of Medical Physics

Biomaterials

Stage : fourth

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Biomaterials in Radiation Therapy

BY

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Introduction

Biomaterials play a fundamental role in the development and application of modern radiation therapy techniques. They are widely used to improve the accuracy of dose delivery and to minimize damage to surrounding healthy tissues. The success of radiation therapy depends on achieving a precise balance between delivering an effective dose to destroy cancer cells and protecting normal tissues. This requires the use of materials with carefully selected physical and chemical properties.

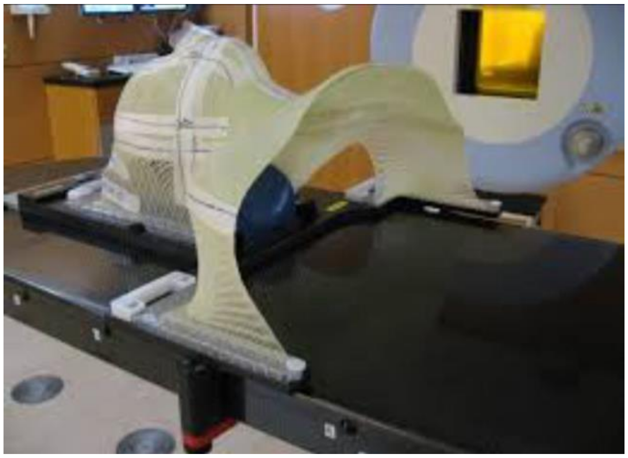
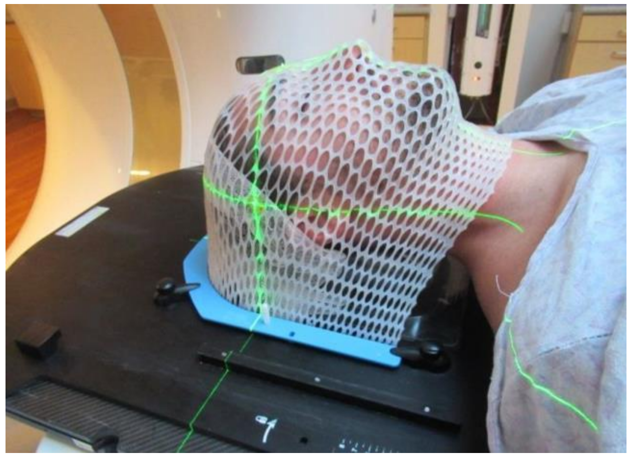
According to materials science principles, the selection of biomaterials depends on factors such as density, atomic number, mechanical properties, biocompatibility, and their interaction with radiation. Therefore, biomaterials are essential components in various aspects of radiation therapy, including patient immobilization, dose modification, tissue simulation, and radiation protection.

1.1 Immobilization Devices

Immobilization devices are essential components in radiation therapy, as they ensure that the patient maintains the same position throughout all treatment sessions. The accuracy of radiation beam delivery is highly dependent on patient stability; even slight movements can lead to misalignment of the radiation beam, reducing treatment effectiveness and increasing the risk of irradiating healthy tissues.

These devices are made from biomaterials that possess suitable mechanical properties, such as sufficient rigidity to prevent movement and enough flexibility to ensure patient comfort. One of the most commonly used materials is thermoplastic, which can be softened by heating and then molded to conform precisely to the patient's body. Once cooled, it hardens and maintains its shape, allowing for reproducible positioning in every treatment session. This is especially important in head and neck cancer treatments, where custom-made masks are widely used.

From a physical standpoint, these materials must be radiolucent, meaning they do not significantly absorb or interfere with the radiation beam. Additionally, they must exhibit high dimensional stability to prevent deformation over time. These characteristics make immobilization devices crucial for achieving precision and consistency in radiation therapy.

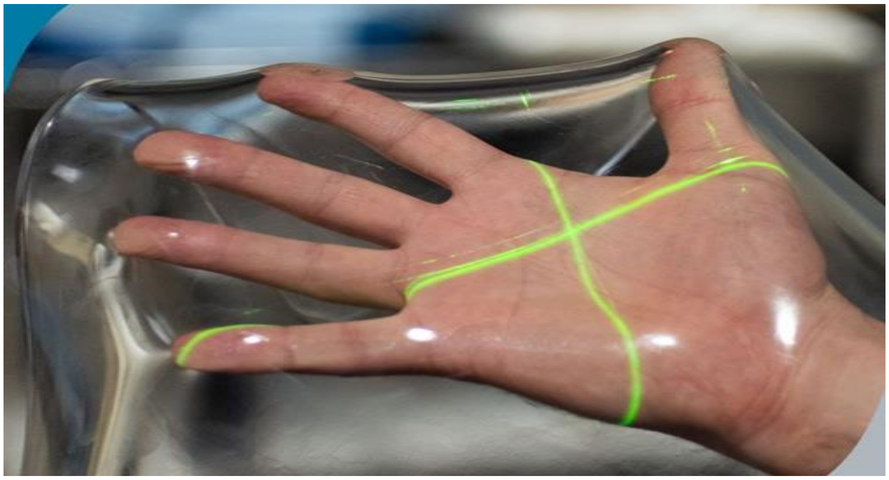



1.2 Bolus Materials

Bolus materials are used in radiation therapy to modify the dose distribution, particularly in cases where tumors are located near the surface of the skin. In photon beam therapy, the maximum radiation dose does not occur at the skin surface but at a certain depth within the tissue due to the build-up effect. While this effect can help spare the skin in some cases, it becomes problematic when treating superficial tumors.

To overcome this issue, bolus materials are placed directly on the skin surface. These materials act as an additional tissue-equivalent layer, effectively shifting the point of maximum dose toward the surface. This ensures that superficial tumors receive the intended therapeutic dose.

Bolus materials are typically made from substances that mimic the properties of soft tissue, such as having a density close to that of water and a similar effective atomic number. Common examples include gels, silicone, and paraffin wax. These materials are flexible and can conform closely to the body surface, minimizing air gaps that could otherwise affect dose distribution. Proper use of bolus materials significantly enhances the effectiveness of radiation therapy for superficial lesions.

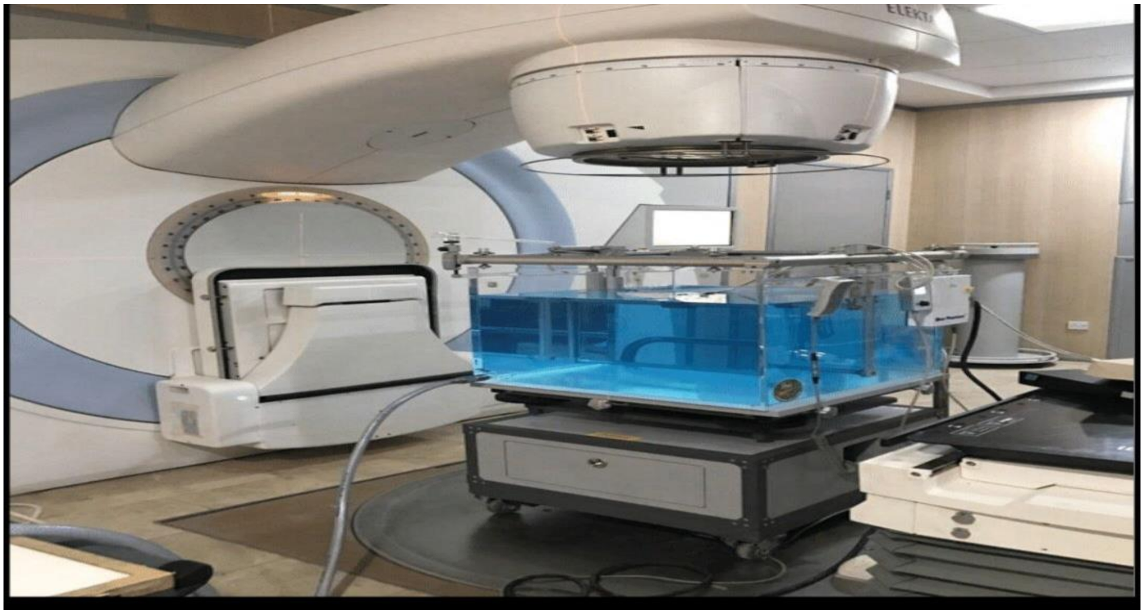


1.3 Phantom Materials

Phantom materials are essential tools in medical physics, used to simulate human tissue properties during measurements and equipment calibration. A phantom is a physical model that replaces the human body in experimental procedures, allowing for accurate dose measurements and equipment testing without exposing patients to radiation.

Water phantoms are considered the gold standard because water closely resembles soft tissue in terms of radiation absorption and scattering properties. However, using water can sometimes be impractical, so solid phantoms made from materials such as polymethyl methacrylate (PMMA) and polystyrene are also widely used. These materials offer ease of handling and greater mechanical stability.

From a materials science perspective, phantom materials must replicate key physical properties of human tissues, including density and attenuation coefficients. They should also be chemically stable and resistant to radiation-induced changes. Phantoms play a critical role in calibrating radiation therapy machines, verifying dose calculations, and ensuring that treatment plans are accurate and safe before being applied to patients.



1.4 Radiation Shielding Biomaterials

Radiation shielding biomaterials are used to reduce unnecessary exposure to radiation for both patients and healthcare professionals. These materials function by absorbing or attenuating radiation, thereby reducing its intensity. Their effectiveness depends largely on their physical properties, particularly density and atomic number.

Lead is one of the most commonly used shielding materials due to its high density and high atomic number, which make it highly effective in absorbing X-rays and gamma rays. Tungsten is also used in certain applications because of its excellent physical properties, including high density and thermal resistance. In addition, concrete is widely used in the construction of shielding walls in radiation therapy facilities.

In recent years, advanced materials such as polymer composites reinforced with high atomic number particles have been developed. These materials aim to provide effective radiation protection while being lighter and more flexible than traditional shielding materials like lead. The efficiency of radiation shielding depends on several factors, including material thickness, density, and the type and energy of the radiation.