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RESEARCH ARTICLE

# Generation of HPMC-derived Placebo Hydrogel Component Matrix System for Possible Pharmaceutical 3D Printing Applications

Gantala Sarva Sai Nikhilesh*

National Institute of Pharmaceutical Education and Research, Guwahati, Assam, India
Andhra Pradesh Med Tech Zone, Visakhapatnam, Andhra Pradesh, India

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**ABSTRACT**

Integration of 3D bioprinting technology in the design and fabrication of pharmaceutical dosage form has the potential to overcome the limitations and expand the range of drugs that can be delivered through different routes. In recent years, the field of bioprinting has emerged as a revolutionary technology with the potential to transform various aspects of the healthcare and pharmaceutical industries. Among its wide-ranging applications, one of the most promising areas is the development of transdermal drug delivery systems using 3D bioprinting techniques. This innovative approach holds significant promise in enhancing drug delivery efficiency, improving patient compliance, and revolutionizing personalized medicine. 3D bioprinting technology offers exciting prospects for the development of transdermal patches specifically designed for wound healing applications. With further advancements and research, these innovative patches have the potential to revolutionize the field of wound care and improve patient outcomes.

**Keywords:** HPMC, Hydrogel, Matrix, Pharmaceuticals.

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## INTRODUCTION

3D bioprinting is a cutting-edge technology that enables the precise fabrication of complex three-dimensional structures[1-3] using bioinks, which are bioactive materials containing living cells. By utilizing computer-aided design (CAD) models,[4-7] bioprinters can deposit multiple layers of bioink with high precision and resolution, mimicking the native architecture and functionality of various tissues and organs. This unique capability opens up new avenues for drug delivery applications, including the development of transdermal patches.[8-11] Additionally, the precise control over the geometry and internal structure provided by 3D bioprinting allows for the customization of transdermal patches to suit individual patient needs.[12-15] Tailoring the patch design to match the patient's anatomy can improve the adherence of the patch to the skin, enhance drug permeation, and increase overall patient comfort.[16-19] Furthermore, the incorporation of patient-specific cells or tissues in the bioink formulation enables the development of personalized transdermal patches, optimizing drug delivery for individual patients based on their unique biological characteristics. Moreover, 3D bioprinting offers the potential for multi-layered transdermal patches with spatially controlled drug release profiles. By precisely depositing different bioinks containing varying concentrations of drugs or encapsulating drug-loaded particles within the printed structures, it is possible to achieve localized and controlled release of multiple drugs from a single patch. This capability is particularly advantageous in cases where combination therapy or sequential release of multiple drugs is required.[19-21]

The use of 3D bioprinting technology has been explored for the development of transdermal patches with applications in wound healing. 3D bioprinting is a cutting-edge technology that enables the precise deposition of bioinks composed of living cells and bioactive materials to create three-dimensional structures. In the context of transdermal patches for wound healing, this technology allows for the fabrication of patches that can deliver therapeutic substances directly to the wound site. Traditional transdermal patches are primarily designed for systemic drug delivery, but 3D bioprinting offers the

*Author for Correspondence: nikhilesh.gantala@gmail.com

possibility to tailor the patches specifically for wound healing applications. Furthermore, 3D bioprinting technology enables the customization of patch properties such as mechanical strength, porosity, and degradation rates. This flexibility allows for the optimization of the patches to match specific wound characteristics and promote better healing outcomes.[22]

## MATERIALS AND METHODS

The following materials were used to prepare the hydrogel: 5.0 gms of hydroxypropyl methylcellulose (HPMC), 3.0 mL of glycerol, and 50 mL of distilled water. The detailed procedure for the preparation of the hydrogel is outlined below.[3]

At first, 5 gm of HPMC powder was accurately measured using a digital weighing scale. The precision in weighing ensured the reproducibility of the hydrogel formulation.The measured quantity of HPMC powder was gradually added to 50 mL of distilled water in a clean and sterile container. The HPMC powder was added slowly while continuously stirring the mixture to prevent the formation of lumps. Once all the HPMC powder was added to the water, the mixture was stirred vigorously using a magnetic or mechanical stirrer. The stirring process was carried out at a moderate speed to ensure the uniform dispersion of HPMC throughout the solution. This step was crucial to prevent the formation of clumps or aggregates in the hydrogel. After achieving a homogeneous HPMC dispersion, 3 mL of glycerol was added to the mixture. Glycerol is commonly used as a plasticizer in hydrogel formulations as it enhances the flexibility and elasticity of the gel. The addition of glycerol further contributed to the improved mechanical properties of the hydrogel. Following the addition of glycerol, the mixture was stirred again for a sufficient amount of time to ensure the proper incorporation of the glycerol into the HPMC solution. This step facilitated the uniform distribution of glycerol within the hydrogel, resulting in enhanced gel properties. The prepared hydrogel mixture was allowed to rest undisturbed at room temperature for a specific period. During this time, the HPMC molecules interacted and formed a gel network through physical or chemical cross-linking. The gelation time varied depending on the specific formulation and environmental conditions. After the gelation process was complete, the hydrogel was visually inspected for any irregularities or defects. The gel was evaluated for its clarity, consistency, and absence of air bubbles or foreign particles. The prepared hydrogel using HPMC needs to be further 3D printed & investigated to obtain desirable characteristics such as good mechanical strength, endurance, and flexibility, etc.

The developed hydrogel can be utilized in various biomedical applications, including drug delivery, wound healing, tissue engineering, and controlled release systems. It is important to note that the described method serves as a general guideline for preparing a hydrogel using HPMC, Glycerol, and distilled water. The specific proportions of the components and the gelation time may vary depending on the desired properties and applications of the hydrogel. Therefore, further optimization and characterization studies are recommended to fine-tune the formulation parameters and ensure the suitability of the hydrogel for the intended purpose.

## RESULTS AND DISCUSSION

The development of such HPMC-derived hydrogels for pharmaceutical applications involves a thorough validation process to ensure its quality, performance, and suitability for use.[1-22] Several techniques will be employed to validate the properties and characteristics of the developed 3D printed prototype in the form of film, including SEM, DSC, Raman spectroscopy, FTIR, Micro CT, and UTM. Each of these techniques provides valuable insights into different aspects of the transdermal film as discussed below.

Scanning electron microscopy (SEM) is a powerful tool for visualizing the surface morphology and microstructure of the transdermal patch. It allows for examining the patch's topography, including the distribution of active ingredients, the presence of defects or impurities, and the interaction between the patch and the skin. SEM analysis provides crucial information on the transdermal patch's structural integrity, uniformity, and surface characteristics.

Differential scanning calorimetry (DSC) is used to analyze the thermal behavior of the transdermal patch. This technique measures the changes in heat flow associated with phase transitions, such as melting or crystallization. DSC analysis can reveal important information about the patch's thermal stability, drug-polymer interactions, and the presence of any physical or chemical changes that may occur during storage or application.

Raman spectroscopy is employed to study the transdermal patch's chemical composition and molecular structure. It can identify and quantify the active pharmaceutical ingredients (APIs) and other components present in the patch, ensuring the consistency and accuracy of drug loading. Raman analysis also helps in detecting any chemical interactions or degradation of the patch components, which could impact its efficacy and stability.

Fourier transform infrared spectroscopy (FTIR) is another technique used to examine the transdermal patch's chemical composition and structural properties. It provides information on the functional groups present in the patch's materials, facilitating the identification of polymers, adhesives, and other excipients used in the formulation. FTIR analysis helps verify the presence of desired components and detect any changes or impurities that may have occurred during manufacturing.

Micro CT (Computed Tomography) is a non-destructive imaging technique that enables the evaluation of the internal structure and distribution of the components within the transdermal patch. It provides valuable information on the uniformity of drug distribution, the presence of air pockets, or any defects that may impact the patch's performance. Micro CT imaging helps in optimizing the formulation and manufacturing processes, leading to improved quality and efficacy of the transdermal patch.

Universal testing machine (UTM) is used to assess the mechanical properties of the transdermal patch, including tensile strength, elongation at break, and adhesive strength. UTM analysis ensures that the patch has appropriate flexibility, elasticity, and adhesion to the skin, which are crucial for its successful application and comfort.

In summary, the validation of a film for pharmaceutical applications involves a comprehensive assessment of its physical, chemical, and mechanical properties. Techniques such as SEM, DSC, Raman spectroscopy, FTIR, Micro CT, and UTM provide critical insights into the patch's morphology, thermal behavior, chemical composition, internal structure, and mechanical performance. These validation methods ensure the transdermal patch's quality, efficacy, and safety, making it suitable for its intended pharmaceutical application.[22]

## CONCLUSION

In conclusion, the combination of 3D bioprinting and hydrogel preparation techniques has opened up new possibilities for the development of transdermal patches with enhanced functionalities and tailored properties. The utilization of 3D bioprinting allows for the precise fabrication of complex structures, while hydrogel preparation techniques enable the incorporation of living cells and the controlled release of therapeutic agents. The material properties of the transdermal patch, such as mechanical strength, flexibility, and adhesion, play a crucial role in its performance and efficacy. The hydrogel formulation, which includes materials like Hydroxypropyl Methylcellulose (HPMC), Glycerol, and distilled water, provides favorable characteristics such as biocompatibility, high water content, and controlled drug release capabilities.

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