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To Assess and Evaluate the Characterisation of Gelatin as A Material of Choice for Membrane Adhesive

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ABSTRACT

The current study aims to develop a novel tissue adhesive glue incorporating synthetic and semisynthetic material. The tissue glue is fabricated by incorporating bisphenol A-glycidyl methacrylate (Bis-GMA), gelatin methacrylate and methacrylic acid. The tissue adhesive was then tested for compressive strength, swelling behaviour and compatibility. The fabricated tissue adhesive exhibited compressive strength of 16.14 MPa and swelling behavior 3.69% at 3 hours. The biocompatibility of the material was 85.3% when treated against dental pulp stem cells. We conclude that gelatin-based hydrogels can be used as an alternative to conventional tissue adhesives.

Keywords: *Tissue adhesive, Cyanoacrylate adhesive, Bisphenol A-glycidyl methacrylate (Bis-GMA), gelatin.*

1. INTRODUCTION

Each year, millions of surgical patients depend on wound closure and healing. Traditional methods like staples and sutures have a number of drawbacks, including the requirement for a comparatively lengthy application period, the potential for additional tissue damage and inflammatory reactions, and their inability to effectively halt bodily fluid or gas in bigger wounds.(Lopes et al. 2025)Comparable benefits of tissue adhesives include ease of use, reduced time, less discomfort, and no removal required. Two examples of commercial adhesives are fibrin sealants and cyanoacrylates. Nevertheless, the limited adhesive strength of fibrin sealants and the toxicity of cyanoacrylate breakdown byproducts restrict their respective uses. High tissue adhesive strength and biocompatibility are desired in order to create the perfect tissue adhesive.(Yuan et al. 2025)

One of the most significant treatment approaches in regenerative medicine is tissue engineering. The primary goal of these new technologies is to create biomaterial-based replacements that can regenerate, mend, or heal damaged or sick tissues and organs. The restricted capacity of human tissues and organs to regenerate is what these creations aim to unleash.In this article, we highlight the advantageous inherent qualities of gelatin for the creation of cutting-edge tissue engineering systems.The hydrolysis of collagen produces the natural protein known as gelatin. In order to adapt the properties of the formulations and get around the drawbacks of this polymeric material, we provide here a state of the art in gelatin-based composites.(Alshangiti et al. 2023a).

Presently accessible biomedical adhesives are primarily designed to fulfill a single purpose, which is to give the healed tissue mechanical support. There are many multifunctional bioadhesives described in the literature that aim to enhance the functionality of current bioadhesives and increase their uses in medicine.According to their design, these adhesives fall into one of two categories: passive or active.(Ji et al. 2025) The intrinsic structural designs and compositions of passive multifunctional bioadhesives enable them to perform additional tasks without the need for extra external stimuli. These adhesives show new capabilities like self-healing capabilities, antibacterial qualities, cellular ingrowth promotion, and reshaping capabilities.

In contrast, active multifunctional bioadhesives react to environmental changes (such as pH, temperature, voltage, light, and concentration of biomolecules) by changing the adhesive in a way that releases encapsulated medications or activates or deactivates the bioadhesive for interfacial attachment.

In biomedical applications, membrane adhesives are essential, especially in tissue engineering and wound healing. The perfect adhesive should have suitable mechanical qualities, biocompatibility, and high adherence. Gelatin, which comes from collagen, is a good option because it has these qualities.(Forooshani et al. 2025) The characteristics, improvement techniques, and possible applications of gelatin as a membrane adhesive are examined in this article.Gelatin, a protein derived from the partial hydrolysis of collagen, has been widely investigated as a membrane adhesive due to its biocompatibility, biodegradability, low immunogenicity, and cost-effectiveness. Its adhesive properties can be enhanced through various crosslinking and modification techniques, enabling its application in biomedical, pharmaceutical, and industrial fields.

2. MATERIALS AND METHODS

SYNTHESIS OF GELATIN METHACRYLATE (GelMA)

GelMA was synthesized through direct reaction of gelatin with methacrylic anhydride. It was synthesized by modification of the traditional method proposed by Van Den Bulcke et al. 10% of gelatin solution was prepared in deionized water at 50 ºC and the pH was adjusted to 8 by using 5N NaOH. 9.3 ml of methacrylic anhydride was added to the gelatin solution and stirred overnight at 50 ºC. The pH was periodically adjusted to 8 using 5N NaOH. The product was lyophilized and stored at 4 ºC for further use.

FABRICATION OF TISSUE ADHESIVE MATERIAL

The adhesive material was fabricated by mixing 50 wt% Bis-GMA to GelMA and methacrylic acid of ratio 3:2. 1% Hyaluronic acid was added as filler material and the solution was stirred to form a homogenous solution. 100 µl of 0.5% Irgacure 2959 was added as a photoinitiator. The solution was exposed to UV radiation (365 nm) for 10 mins. The material was stored at room temperature for further analysis.

ATTENUATED TOTAL REFLECTANCE FOURIER TRANSFORM INFRARED SPECTROSCOPY (ATR-FTIR)

Attenuated total reflectance fourier transform infrared spectroscopy (ATR-FTIR) is a powerful technique to determine any possible chemical interaction ATR-FTIR spectroscopic analysis was performed using Bruker ATR infrared spectrometer (model). The functionalities of the Bis-GMA and GelMA were confirmed by the FTIR spectrum.

MECHANICAL TESTING

The strength for all the specimens were tested by applying a unidirectional force at a displacement of 2 mm/min (UTM, Instron, UK). The samples were centrally placed on the sample plate and then subjected to a maximum load until it breaks, to calculate the stress at failure

SWELLING RATIO (%) OF THE FABRICATED MATERIAL.

The swelling behavior of the adhesive material was studied by immersing 10mg of the material in 500 µl of artificial saliva. After 1 hr, the material was removed from the artificial saliva, dabbed to remove excess solution, weighed and placed back into the solution. The similar process was performed after 3 hr. The swelling ratio (%) was calculated using the following equation.

Swelling ratio (SR) = $((W_w - W_0)/W_0) \times 100\%$

W_0 and W_w are the initial dry weight and the wet weight, respectively.

DENTAL PULP STEM CELLS (HDPSC) CELL CULTURE

After obtaining informed consent and ethical approval from SIMATS ethics committee, the Dental Pulp stem cells were isolated from molars. The cells were cultured in DMEM-F12 / 10% FBS / 1% Penicillin-streptomycin. After two passages, the cells were used for cell viability and compatibility assays.

BIOCOMPATIBILITY ANALYSIS

1 mg/ml of sample was prepared and UV treated. 1000 cells per well were seeded in 48 well plates and treated with DMEM-F12 /1% Penicillin-streptomycin media. The prepared sample was placed onto the media. After 24hrs of culture, 10uL/100mL of MTT reagent (5 mg/mL stock) was added to cultured cells and then incubated for 4 h to allow the formation of the formazan dye at 37°C. The medium is exchanged to DMSO (200 µL) and stands for 10min. The reaction product was transferred to a 96 well ELISA plate and A590 was measured with ELISA plate reader.

STATISTICAL ANALYSIS

All values are expressed as the mean + standard error of the mean (SEM) of at least three independent experiments. A one-way ANOVA (analysis of variance) was used to test for significant differences, and multiple comparisons were performed using Scheffe’s method. Statistical significance was set at $p<0.05$.

3. RESULTS

Characterization of synthesized GelMA Formation of GelMA is evidenced by the appearance of C=C at 1636 cm^{-1}, C=O at 1626 cm^{-1}, C-H at 2359 cm^{-1}, O-H at 3360 cm^{-1},. This proves the presence of gelatin methacrylation.(Rupashri et al. 2024)

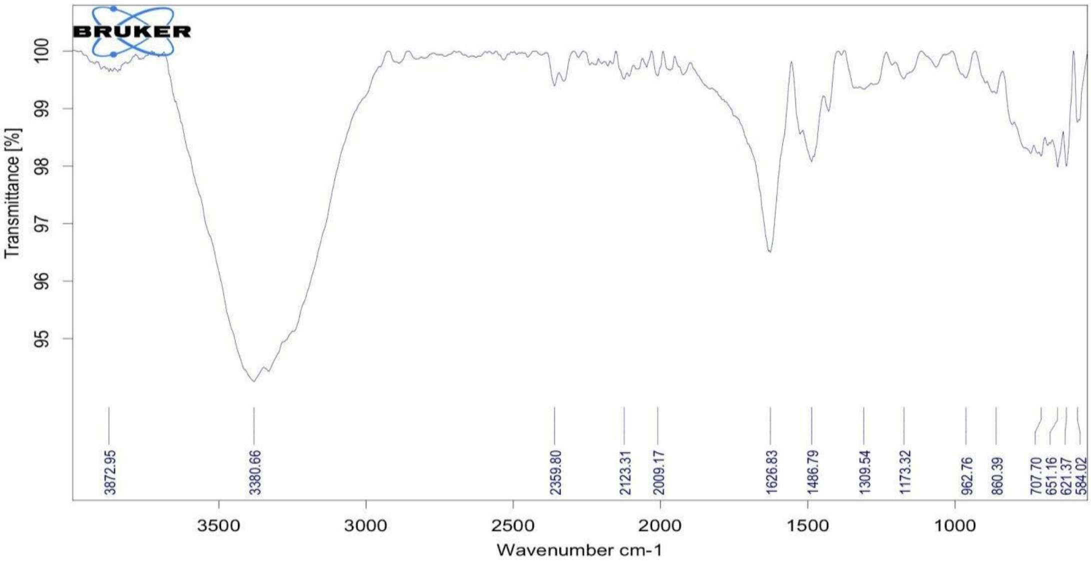


Figure 1 : IR Spectrum of GELMA

Compressive strength of the fabricated material The fabricated material, with a tensile strength of 16.14 MPa, offers a competitive alternative to cyanoacrylate glue's strength of 23.1 MPa. While slightly lower in strength, it may still provide suitable performance for specific applications.

TABLE 1: Tensile strength of fabricated Bone Adhesive Material

SAMPLE	MAXIMUM FORCE [N]	TENSILE STRESS AT TENSILE STRENGTH
BISGMA+GEL+MA+MA	0.37	16.14

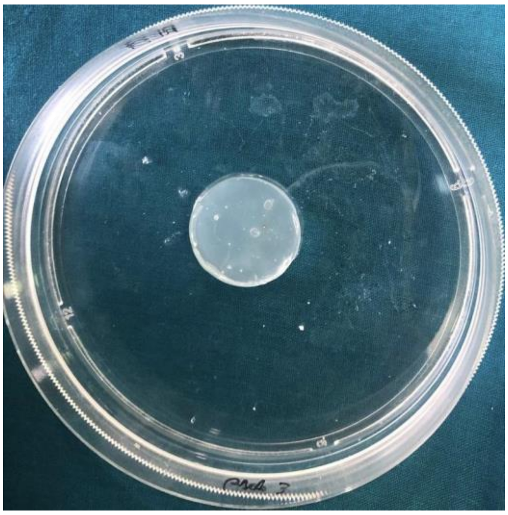
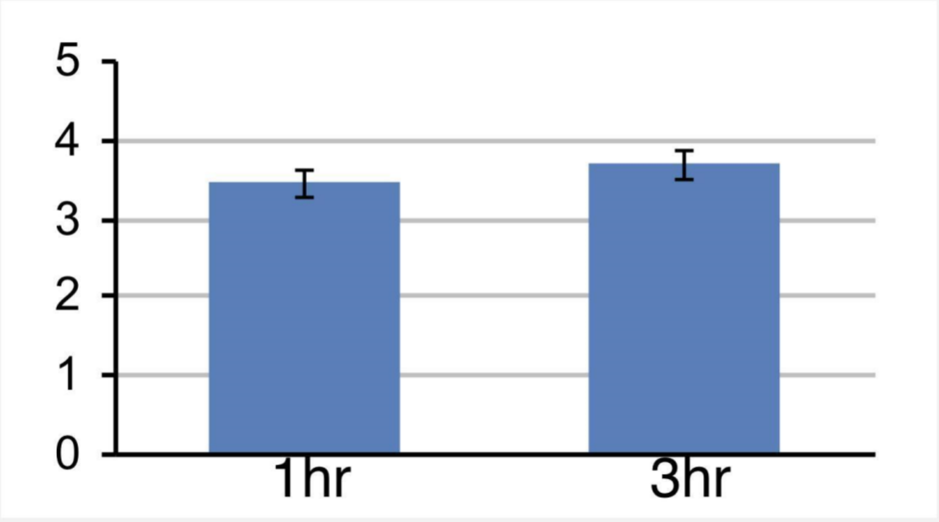


Figure 2 : Fabrication of Tissue adhesive

Swelling behaviour

The material's swelling behavior affects the body's fluid absorption as well as the movement of cells, nutrients, and metabolites. As a result of the material swelling in the fluid, the scaffold's internal surface area is maximized and the pore size and overall porosity rise.(Bilgili et al. 2025) It facilitates the ingrowth of cells within the material. The mechanical characteristics of the material would be adversely affected, though, if the swelling was greater.

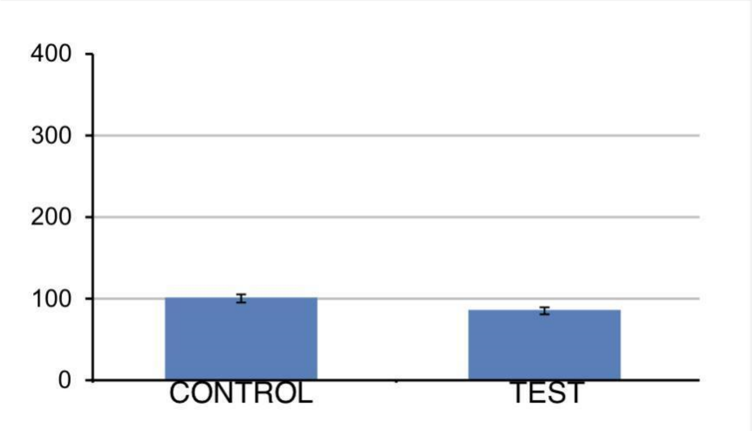


Swelling behaviour of fabricated material

The fabricated material had swelling behavior of 3.4615385 and it increased to 3.6923077 at 3 hours.

Bio - compatibility Analysis -

The produced hydrogel's compatibility with oral keratinocytes was investigated using the MTT assay. Comparing the cell viability of the MTT assay to that of the untreated group, it revealed above 85%.



Biocompatibility of fabricated material against dental pulp stem cells

4. DISCUSSION

Gelatin, a hydrolyzed form of collagen, boasts a rich history in biomedical applications, primarily due to its biocompatibility, which ensures a harmonious interaction with biological systems without eliciting adverse immune responses. (Ahamed et al. 2021)This unique property positions gelatin as an ideal candidate for membrane adhesion, particularly in scenarios demanding compatibility with living tissues. (Ramezani et al. 2025)

Delving into its adhesive mechanisms, gelatin's molecular structure exhibits an array of functional groups that facilitate interactions with various substrates. However, to harness its full adhesive potential and address specific application challenges, researchers have embarked on sophisticated modification strategies. (Habiburrohman et al. 2025)Cross-linking remains a cornerstone in this realm, with methods ranging from physical cross-linking through temperature modulation to chemical cross-linking utilizing agents like glutaraldehyde. Such cross-linking mechanisms induce structural modifications, enhancing gelatin's tensile strength, flexibility, and adhesive durability.

Moreover, recognizing the need for tailored adhesive properties, the amalgamation of gelatin with other polymers has garnered attention. For instance, blending gelatin with chitosan—a polysaccharide derived from crustacean shells—creates composite materials synergizing the adhesive prowess of both constituents. (Wang et al. 2025)This synergy manifests in improved mechanical properties, adhesion strength, and enhanced biodegradability, augmenting its suitability for intricate medical interventions.

In tandem with physical modifications, chemical derivatization techniques have been instrumental in modulating gelatin's adhesive attributes.Introducing functional groups through acylation, methacrylation, or grafting processes endows gelatin with customizable properties, such as pH responsiveness or enhanced cross-linking capabilities, catering to nuanced medical application demands.(Surendran et al. 2023)

Transitioning to practical applications, the versatility of modified gelatin adhesives permeates various medical domains. In tissue engineering, these adhesives facilitate scaffold-tissue integration, ensuring optimal cell migration, proliferation, and differentiation—a testament to gelatin's biocompatibility and adhesive synergy.(Mehta et al. 2023) In surgical arenas, its utility transcends mere adhesive functions; gelatin-based sealants serve as hemostatic agents, tissue reinforcements, and barrier materials, mitigating post-operative complications and fostering expedited healing(HariniRamesh et al. 2025). Furthermore, the advent of drug delivery systems harnesses gelatin's adhesive attributes to encapsulate therapeutic agents, ensuring targeted delivery, sustained release, and enhanced therapeutic efficacy. (Alshangiti et al. 2023b; Lou and Chen 2023; Afewerki et al. 2019)

In summation, the multifaceted realm of gelatin-based membrane adhesives, fortified through intricate modifications and innovative applications, epitomizes the confluence of biocompatibility, adhesive ingenuity, and biomedical prowess, heralding transformative advancements in therapeutic interventions and patient care paradigms.

5. CONCLUSION

Gelatin shows great potential as a membrane adhesive due to its natural ability to adhere to tissues, biocompatibility, and biodegradability. Its gel-forming properties help create a stable interface, supporting wound healing and tissue regeneration. By modifying its structure or combining it with other materials, its strength and durability can be improved to better match clinical needs. While its biological compatibility makes it a promising choice, further research is needed to refine its formulation and ensure long-term effectiveness in real-world applications.We conclude that gelatin-based hydrogels can be used as an alternative to conventional tissue adhesives.

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