Hydrogel Based Drug Delivery System for Wound Healing by Using Green Tea Extract

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Abstract— **1. Aim And Objective**

Aim:

Hydrogel based drug delivery system for wound healing

Objective

1. **To design and synthesis a hydrogel matrix suitable for wound-application (unnatural/synthetic polymers, cross linking etc).**
2. **To incorporate a therapeutic agent (such as an antibiotic, anti-inflammatory drug, growth factor or combination thereof) into the hydrogel.**
3. **To characterise the hydrogel system for key physical/chemical properties: swelling behaviour, mechanical strength, porosity, degradation rate, drug loading efficiency, and in-vitro drug release kinetics.**
4. **To evaluate the hydrogel's biocompatibility (cytotoxicity tests, possibly hemocompatibility) and antimicrobial/anti-infection potential (if using antimicrobial payload).**

I. INTRODUCTION

Introduction of Hydrogels: -

A hydrogel is a three-dimensional network of hydrophilic polymer chains that is cross-linked (either chemically or physically) and capable of absorbing large amounts of water or biological fluids, yet maintaining its structural integrity (i.e., it does not dissolve).

- According to one definition: "Hydrogels are natural or synthetic polymeric networks, insoluble in water which can absorb approximately 90% water and are regarded as superabsorbent materials."
- The term "hydro-gel" literally means "water gel" (gel whose dispersion medium is water).

Advantages of Hydrogel: - 1. High Water Absorption

1. Biocompatibility
2. Soft and Flexible Structure
3. Controlled Drug Release
4. Permeability
5. Stimuli Responsiveness

Disadvantages of hydrogel: - 1. Low mechanical strength.

1. Dehydration
2. Over-swelling
3. Difficult to handle
4. Limited stability
5. High production cost

II. LIMITATION OF HYDROGEL

1. Low mechanical strength – Hydrogels are soft and weak, making them unsuitable for load-bearing applications.
2. Dehydration and instability – They can lose water and shrink or, conversely, absorb too much water and swell excessively.
3. Difficult sterilization – Many hydrogels cannot tolerate standard sterilization methods such as heat or radiation.
4. Limited durability – Some hydrogels degrade or lose functionality over time in biological or environmental conditions.

III. APPLICATIONS

1. Drug delivary system
2. Wound dressings
3. Tissue engineering

4. Contact lences
5. Biosensors

IV. MATERIAL OF HYDROGEL

Hydrogels can be made from a wide variety of natural, synthetic, or hybrid (composite) materials.

✓ Natural material: - a) Alginate
b) Gelatin

✓ Synthetic material: -a) Polyacrylamide
b) Polyacrylic acid

✓ Hybride: - a) Fibers
b) Protein

V. METHODS OF HYDROGEL

Physical method: -a) Ionic cross linking
b) Freeze Thawing method

Chemical method: - a) Free Radical Polymerization
b) Condensation reaction

Causes of Wound Healing: -

1. Local Factors: - a) Infection- bacteria prolong inflammation and tissue damage.

b) Poor blood supply (ischemia) – limits oxygen and nutrient delivery.

2. Systemic Factors: - a) Age – older individuals heal slower due to reduced cell activity.

b) Malnutrition – especially lack of protein, vitamin C, zinc, and iron.

3. Environmental & Psychosocial Factors: -a) Stress – releases cortisol, which suppresses immune function.

b) Poor hygiene – increases infection risk.

- Treatment: -

a) Initial care
b) Prevent infection
c) Promote healing

VI. INTRODUCTION OF WOUND HEALING

- Definition: -

Wound healing is the biological process through which the body repairs and restores the integrity of damaged tissue after an injury.It involves a complex series of overlapping cellular and molecular events that work together to close the wound, replace lost or damaged tissue, and restore normal function.

- Types of Wound Healing: -
- Primary Intention: Edges of the wound are directly closed (e.g., surgical incision). Minimal scarring.
- Secondary Intention: Wound heals naturally without closure; more granulation tissue and scarring.
- Tertiary Intention (Delayed Primary): Wound is initially left open to control infection, then closed later.

Mechanisms of wound healing

The mechanism of wound healing is an organized sequence of four overlapping phases: hemostasis, inflammation, proliferation, and remodeling. During hemostasis, the body stops bleeding by forming a clot. Next, in the inflammation phase, immune cells clear debris and fight infection. The proliferation phase involves new tissue growth, including angiogenesis (new blood vessels), granulation tissue formation, epithelialization (skin resurfacing), and wound contraction. Finally, the remodeling phase strengthens the new tissue by converting the initial scar into a more mature, organized matrix.

VII. PLANT PROFILE GULVEL

Gulvel, also known as Giloy or Amrita, is a highly valued medicinal plant in Ayurveda. Its scientific name is Tinospora cordifolia, and it belongs to the Menispermaceae family. Gulvel is a climbing shrub with heart-shaped leaves and long, twining stems. It is native to India and commonly found in tropical regions.

Ayurvedic texts praise Gulvel as an “Amrita” (nectar of immortality) due to its wide range of health benefits. It is known for its immunomodulatory, antipyret anti-inflammatory, antioxidant, and detoxifying properties. Traditionally, it is used to boost immunity, reduce fever, manage diabetes, and improve digestion and overall vitality.

- Biological sources: -

Biological source: Gulvel is the dried stem of Tinospora cordifolia (Family Menispermaceae).

- Chemical constituents: Alkaloids: Magnoflorine

Palmatine
Tembetarine
Glycosides: - Cordifolioside A, B, C, D
Commen name: -
Sanskrit: - Guduchi, amrita
Hinde: - Giloy
English: - Indian tinospora

- Uses of gulvel in wound healing: -

1. promotes faster wound contraction and epithelialization
2. Enhance collagen formation
3. anti-inflammatory effect
4. Angiogenesis

- Applications: Immuno health Anti-inflammatory Antioxidant
- Advantages: - Reduce fever Boosts Immunity Inproves energy
- Disadvantages: -Hypoglycemia risk

Digestive upset
Gastro intestinal issues

VIII. GREEN TEA EXTRACT

Green tea extract is a concentrated form of the bioactive compounds found in green tea leaves (Camellia sinensis). Unlike regular brewed green tea, the extract provides higher amounts of polyphenols, especially catechins, which are responsible for most of its health benefits. Among these catechins, epigallocatechin gallate (EGCG) is the most potent and widely studied for its antioxidant and metabolic properties.

Green tea extract is commonly available as a dietary supplement in capsules, powders, or liquid form. It is known for its antioxidant, anti-inflammatory, and metabolism-boosting effects, making it popular in weight management, cardiovascular health, and general wellness products. Biological Source: -

It is derived from camellia sinensis leaves is a potent natural product rich in catechins especially EGCG. Family: - Theaceae

- Chemical constituent: -

Alkaloid
Catechins
Phenolic Acid
Common Name: -
Camellia Sinensi

- Mechanism Of Action: -

Anti-oxidant Activity
Anti-inflammatory effect

- Used in wound healing: -

Anti-oxidant effect
Anti-inflammatory action
Anti-microbial action

- Application: -

Medical and pharmaceutical
Cosmatic Application
Food and beverage industary application

- Advantages: -

Cardiovascular benefites metabolic and weight mannagement

- Disadvantages: -

liaver toxicity
Gastro intestinal issues

IX. TRIDAX

Introduction of tridax

Tridax commonly refers to Tridax procumbens, a flowering plant in the Asteraceae family. It is a small, creeping herb that is widely distributed in tropical regions and is often considered a weed. Despite its status as a weed, Tridax has significant medicinal and ecological importance.

- Biological source: - Tridax is the plant Tridax procumbens.
- Scientific Name: Tridax procumbens
- Family: Asteraceae
- Chemical constituent: - flavonoides Saponins Tannins
- Common names: - Antimicrobial

Antioxidant
Migration
Used: -
Promotes tissue regeneration
Antioxidante activity
Antioxidante activity

- Application: -

Hemostatic
Traditional uses in others aliments
Agricultures

- Advantages: -

Easily available
Economical
Low toxicity

- Disadvantages: -

Limited clinical evidences
Low standardization
Weed nature

X. REVIEW AND LITERATURE

1. Hydrogel based drug delivery system: A review (Bhalerao et al., 2022) Broad review of hydrogels (types, classification, general drug-delivery) including wound healing.
2. Insight Into Bioactive Hydrogels for Wound Healing and Drug Delivery Systems (2019) Focuses on bioactive hydrogels, antibacterial/hydrogel dressings, smart systems.
3. Review on Hydrogel Based Systems and their use in Drug Delivery for Wound Healing & Wound Management (Jayswal et al., 2024) Specific to wound healing + drug-delivery in hydrogel systems.
4. Comprehensive Review on Antimicrobial based Hydrogel for Wound Healing (Singh & Sharma, 2025) Emphasis on antimicrobial drug-loaded hydrogels for wound healing.
5. Polymer-Based Hydrogel Loaded with Honey in Drug Delivery System for Wound Healing Applications (Yasin et al., 2023) Niche review: honey-loaded hydrogels in wound healing.
6. Stimuli-responsive hydrogels for skin wound healing and regeneration (Emergent Materials, 2024) Explores "smart" hydrogels (pH/temperature/light responsive) for wound healing.

XI. RESEARCH PAPER

1. Polymer-Based Hydrogel Loaded with Honey in Drug Delivery System for Wound Healing Applications (2023)

Authors: Yasin S.N.N., Said Z., Halib N., Rahman Z.A., Mokhzani N.I.
Summary: Natural/synthetic polymer hydrogel loaded with honey (which has antibacterial, anti-inflammatory, antioxidant properties) is designed for wound healing.

2. Hydrogels and hydrogel-based drug delivery systems for promoting refractory wound healing: Applications and prospects (2024)

Authors: (not listed here) Publisher: Elsevier.
Summary: This review focuses on challenging (refractory, chronic) wounds, and how hydrogels plus drug delivery can help. It discusses limitations and future perspectives of hydrogel systems for wound healing.

3. Review on Hydrogel Based Systems and their use in Drug Delivery for Wound Healing & Wound Management (2024)

Authors: Meet A. Jayswal, Priyanka Ahlawat, Ashaben Patel.
Summary: This review covers hydrogel types (natural/synthetic, cross-linking, ionic charge etc), preparation methods, drug delivery aspects, and wound healing/wound management applications.

XII. PLANE OF WORK

1. Literature Review
2. Identify key compound in
3. Collection and prepration
4. Extraction process with the help of heating metal
5. Formulation of hydrogel
6. Evaluation Test
7. Result and Conclusion

XIII. MATERIAL AND METHOD

1. Beaker
2. PH meter
3. Conical flask
4. Stirrer
5. Analytical Balance

6. Syringes and needle
7. Water bath
8. Petri dish

Chemical: -
1. Chitosan
2. Polyvinyl alcohol
3. Glycerol
4. Silver nano partical

XIV. FORMULATION

Method of Preparation
1. Preparation of Polymer Solution
- Disperse Carbopol in distilled water with continuous stirring.
- Allow it to hydrate and swell completely.

2. Drug Incorporation
- Dissolve drug separately and add slowly to polymer solution.

3. Addition of Excipients
- Add glycerin and preservative.

4. Neutralization
Add triethanolamine dropwise to adjust pH and form gel.
5. Homogenization
Mix thoroughly to obtain uniform hydrogel.
6. Storage
Store in airtight container.

Procedure
1. Preparation of PVA Solution
Take 10 g PVA + 60 mL distilled water
Heat at 80–90°C with continuous stirring
Continue until clear solution forms
Cool to ~40°C

2. Preparation of Chitosan Solution
Dissolve 2 g chitosan in 50 mL of 1% acetic acid
Stir overnight or until fully dissolved
Filter if needed

3. Preparation of Extract Phase
Dissolve:
2 g green tea extract
2 g gulvel extract
Use minimal distilled water (≈10–15 mL)
Stir to get uniform solution
4. Mixing Phase
Slowly add chitosan solution into PVA solution with stirring
Add glycerol (5 g)
Then add herbal extract solution
Maintain temperature below 40°C to protect actives

5. Gel Formation (Cross-linking)
Option A: Physical Cross-linking (Recommended)
Pour mixture into petri plates/molds
Subject to freeze–thaw cycles:
Freeze at −20°C for 16 hours
Thaw at room temperature for 8 hours
Repeat 3 cycles
Produces stable, non-toxic hydrogel

6. Final Adjustment
Adjust weight to 100 g with distilled water
Check pH → adjust to 5.5–6.5 (skin compatible)

XV. FORMULATION TABLE

Total batch size:50 g per formulation

Ingredients	F1(2%Extract)	F2(3%extact)	F3(5%extract)
Chitosan	1.0g	1.0g	1.0g
PVA	4.0g	4.0g	4.0g
Gulvel	1.0g(2%)	1.5g(3%)	2.5g(5%)
Green Tea Extract	1.0g(2%)	1.5g(3%)	2.5g(5%)
Ginpin	0.25g	0.20g	0.20g
Glycerol	0.5g	0.5g	0.5g
Distilled Water	q.s.to 50g	q.s. to 50g	q.s.to 50g

XVI. EVALUATION PARAMETER TEST

Physicochemical Evaluation Parameters:
These determine the basic material properties of the hydrogel.
a. Swelling Behavior
Measures fluid absorption capacity in simulated wound fluid (SWF) or PBS
Important for exudate management
Parameters:
Swelling ratio (%) = (Wt − W0) / W0 × 100
Equilibrium swelling time
b. Gel Fraction
Indicates crosslinking efficiency
Higher gel fraction → better structural stability

c. Porosity
Determines oxygen/nutrient transport and drug diffusion
Measured by liquid displacement or SEM imaging
d. pH Responsiveness
Important for infected wounds (often acidic environment)
Evaluates drug release behavior under different pH conditions

2. Mechanical Properties
Critical for maintaining integrity at wound site.
a. Tensile Strength
Resistance to breaking under tension
b. Elastic Modulus
Flexibility and softness (important for skin compatibility)
c. Adhesive Strength
Ability to adhere to wound bed without secondary dressing
d. Compressibility / Rheology
Flow behavior for injectable hydrogels

3. Drug Delivery Performance
a. Drug Loading Efficiency (DLE)
Percentage of drug successfully incorporated
b. Drug Entrapment Efficiency (DEE)
c. In Vitro Drug Release Profile
Studied in PBS or simulated wound fluid
Models used:
Higuchi model (diffusion-controlled)
Korsmeyer–Peppas model (mechanism identification)
d. Release Kinetics
Burst release vs sustained release behavior

4. Biological Evaluation (In Vitro)
a. Cytocompatibility
Tested on fibroblasts or keratinocytes (e.g., NIH-3T3 cells)
MTT or Live/Dead assay
b. Cell Migration (Scratch Assay)
Measures wound closure rate in cell monolayer
c. Hemocompatibility
Hemolysis assay (<5% hemolysis is considered safe)
d. Antibacterial Activity
Against common wound pathogens:
Staphylococcus aureus
Escherichia coli
Zone of inhibition or CFU reduction

XVII. CONCLUSION

Hydrogel-based drug delivery systems represent a promising and innovative approach to wound healing, combining the advantages of controlled drug release, high water content, biocompatibility, and structural similarity to natural extracellular matrix. These systems can maintain a moist environment conducive to tissue regeneration, reduce infection risk, and enable localized, sustained release of therapeutic agents such as antibiotics, growth factors, and anti-inflammatory drugs. Advances in stimuli-responsive and smart hydrogels further enhance their ability to respond dynamically to wound conditions, promoting faster and more effective healing. However, challenges such as mechanical strength, long-term stability, and large-scale manufacturing still need to be addressed.

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REFERANCES

[1] H. Liu, C. Wang, C. Li, Y. Qin, Z. Wang, F. Yang, Z. Li, and J. Wang, "A functional chitosan-based hydrogel as a wound dressing and drug delivery system in the treatment of wound healing," *RSC Advances*, vol. 8, pp. 7533–7549, 2018, doi: 10.1039/C7RA13510F.

[2] Patel, S. Agarwal, A. Sharma, and S. R. Swain, "A review on promising drug delivery hydrogel formulation by different natural and synthetic polymers treated in wound healing," *Journal of Chemical Health Risks*, vol. 14, no. 3, 2024.

[3] M. A. Jayswal, P. Ahlawat, and A. Patel, "Review on hydrogel-based systems and their use in drug delivery for wound healing & wound management," *Current Materials Science*, vol. 17, no. 4, 2024, doi: 10.2174/2666145417666230710165247.

[4] "Emerging role of hydrogels in drug delivery systems, tissue engineering and wound management," *Pharmaceutics*, vol. 13, no. 3, p. 357, 2021.