Ind. J. Pharm. Edu. Res., 2026; 60(2s):s853-s863.
https://www.ijper.org

Review Article

Therapeutic Potential of Nanosilver Encapsulated Polysaccharide in Wound Healing

Aniket Hajra, Moumita Chowdhury*, Prosun Ganguly, Swarnakamal Bag

Department of Pharmaceutical Sciences, Guru Nanak Institute of Pharmaceutical Science and Technology, 157/F Nilgunj Road, Panihati, Kolkata, West Bengal, INDIA.

ABSTRACT

Chronic wounds create a major threat for an individual, which, if neglected, can cause severe infection in the form of sepsis. Therefore, early clinical diagnosis is very crucial to prevent further complications. Since conventional treatments are often inadequate and may lead to scar, innovative wound healing strategies are in greater demand. Recently, silver nanoparticles, due to their wide antimicrobial activity, greater surface area, and functionalization property, have garnered attention in wound healing. Apart from that, natural polysaccharides, due to their biodegradable, biocompatible, flexible properties and inherent antimicrobial and antioxidant properties, are gaining popularity in addressing the needs of wound healing. Despite their widespread use, silver nanoparticles and natural polysaccharides face certain stability issues and other formulation-related challenges. This paper outlines the mechanism and applications of silver nanoparticles and polysaccharides in wound healing and their limitations. The review thoroughly inspects the recent research to explore the strategies adapted to overcome the limitations of silver nanoparticles and advocates the use of the additive effect of polysaccharides and silver nanoparticles in formulation. Silver Nanoparticles are being conjugated with natural polysaccharides termed as Nanocomposites, which lower their cytotoxic potential and show additive effects as the polysaccharide itself possesses wound healing capacity. The paper focuses on Nano Silver-Polysaccharide conjugation, which provides better results in wound recovery and antimicrobial potency. Therefore, the present review focuses on the conjugation of silver nanoparticles and polysaccharides for an advanced and effective strategy for wound healing and emphasizes future research work in this arena.

Keywords: Nanocomposite, Polysaccharide, Silver Nanoparticles, Wound Healing.

Correspondence:
Dr. Moumita Chowdhury
Assistant Professor, Department of Pharmaceutical Sciences, Guru Nanak Institute of Pharmaceutical Science and Technology, 157/F Nilgunj Road, Panihati, Kolkata-700114, West Bengal, INDIA.
Email: moumita.chowdhury@gnipst.ac.in
ORCID: 0000-0003-0472-8122

Received: 02-12-2025;
Revised: 29-01-2026;
Accepted: 27-02-2026.

INTRODUCTION

The wound requires immediate attention to decrease infection effectively and hasten the recovery process to regain the integrity of the tissues. The wound causes inflammation manifested by the release of mediators like Leukocytes and Cytokines. This inflammation is characterized by arterial vasodilation and an increase in small vessel permeability, which further causes exudation of fluid and swelling of the affected area.[1] Thus, the healing of wounds is a very complex and lengthy process. Although our body's defensive mechanism can combat and cure wounds, it is ineffective in cases of chronic wounds, leading to infection, cellulitis, or sepsis. Therefore, the use of an effective healing agent is imperative in chronic wounds.

DOI: 10.5530/ijper.20262151

The antibacterial agent, Silver, is known for its wide-spectrum antimicrobial, anti-inflammatory, and antioxidant effects. Although marketed formulations, Silver Sulfadiazine, Silver Nitrate are available, silver nanoparticles have sparked attention due to their exceptional antimicrobial spectrum, anti-inflammatory, and faster regenerative properties, healing chronic wounds. They have greater surface area, a high surface-to-volume ratio, flexibility for conjugation, target-specific surface properties, and are more potent than bulk silver.[2] Silver Nanoparticles (AgNPs) destroy microbial cells by oxidative stress by generating Reactive Oxygen Species (ROS). They block proinflammatory mediators, Tissue Necrosis Factor-α, interleukin-6 and increase anti-inflammatory mediators like Interleukin-10, thereby decreasing chronic inflammation states.[2]

However, AgNPs lose their antimicrobial property in the presence of high bacterial load. It shows cytotoxicity when administered at high concentrations or during long-term usage.[3] Therefore, silver nanoparticles can be coated to enhance their stability. Natural, unutilized polysaccharides are now widely exploited for their biocompatible, biodegradable, and immunocompatible nature. They facilitate cell proliferation, angiogenesis, and tissue repair at the wound site, promoting faster recovery. Several natural polysaccharides inhibit microbial growth at the wound site but require a long healing period. Therefore, AgNPs can be encapsulated within natural polysaccharides for their additive antimicrobial property and minimize their limitation to get a safe, potent wound healing agent. Moreover, the polysaccharide coating can also impart a sustained release of AgNPs from it. Nguyen *et al*., have capped green-synthesized AgNPs with pectin and chitosan to develop biofilm for wound healing to enhance bioavailability and antimicrobial properties.[4] Similar studies were conducted where, polymer integrated AgNPs showed improved stability, antimicrobial potency, and effective wound healing property.[5] Therefore, polysaccharides having antimicrobial activity can be utilized to encapsulate AgNPs to minimize the cytotoxicity of silver-based formulations and synergize the efficacy of wound healing.

The current review focuses on the advancements of nanosilver-based formulations and nanosilver polysaccharide composites. It highlights the polysaccharides with wound healing property, and compares the antimicrobial properties of silver nanocomposites to explore the novel concept of encapsulating AgNPs within natural polysaccharides.

METHODOLOGY

The peer-reviewed literature data from multiple databases, including Science Direct, PubMed, Google Scholar, and Web of Science, for the last fifteen years were collected. The search was based on the keywords "Silver Nanoparticles", “Wound Healing”, and "Natural Polysaccharides”. Out of 250 articles, 127 articles were considered based on their citation score, scientific quality, and relevance. All the articles were thoroughly analyzed.

MECHANISMS OF NANO SILVER FORMULATIONS IN WOUND HEALING

Silver Nanoparticles promote wound healing through cell proliferation, facilitating tissue regeneration, imparting anti-inflammatory and antimicrobial property.[6] Silver stimulates keratinocytes and promotes differentiation, maturation and migration of cells. It helps in the expression of α-Smooth Muscle Actin, converting fibroblasts to myofibroblasts and quickens the healing process. AgNPs exhibit antibacterial activity primarily due to their surface properties as illustrated in Figure 1. Silver ions being cationic, adhere to the cell wall and cytoplasmic membrane of bacteria, and easily permeate through the membranes causing rupture and leakage of the cellular materials. Increased expression of growth factors by AgNPs leads to enhanced tissue regeneration, collagen matrix, re-epithelialization, and, faster wound closure. AgNPs lower the level of proinflammatory cytokines, and raises anti-inflammatory cytokines, facilitating angiogenesis and tissue repair.[6]

LIMITATIONS OF SILVER NANOPARTICLES

Cytotoxicity

Silver Nanoparticles have carcinogenic effects and can permeate through the Blood-Brain Barrier (BBB) causing toxicity at a higher concentration. Noga *et al*., revealed that AgNPs induce cytotoxicity and abnormal cell morphology in the Human Hepatoma Cell Line above the concentration of 1 μg/mL.[7] A study on Alveolar Macrophage AgNPs with an average size of 15 nm destroyed the mitochondrial integrity and its activity. Another study on Lung Cell lines, shows that smaller nanoparticles (10 nm) showed more toxicity than larger particles.[3]

Stability Issues

Poorly capped and unstable AgNPs excessively release silver ions, imparting high toxicity. They may degrade due to chemical oxidation, temperature, and light conditions, losing their therapeutic potential. AgNPs are prone to aggregation, leading to altered size and impaired therapeutic potential. Thus, controlling the aggregation, ensuring particle stability, and delivering AgNPs at a low dose is a challenge posed to effectively balance the wound healing potential and cytotoxic risk of AgNPs.[6] Therefore, the green synthesized nanoparticles with lower toxicity, their therapeutic applications and synthesis is emphasized in Table 1.

POLYSACCHARIDE AND ITS MECHANISM IN WOUND HEALING

Polysaccharides exert wound healing properties through antibacterial, antioxidant, and anti-inflammatory activities, promoting cell proliferation. Natural polysaccharides like chitosan and polysaccharides from olive leaves show extensive bactericidal activities by inhibiting biofilm formation, altering their permeability, causing leakage of cellular materials.[22] Polysaccharides inhibit RNA Synthesis by binding to DNA molecules and inhibiting Phospholipid Pathway to interrupt cell functions.[23] Chitosan has hemostatic properties for wound healing, Sodium Alginate absorbs exudates and maintain hydration. Hyaluronic Acid helps in tissue regeneration and re-epithelialization by enhancing cell migration and angiogenesis.[24]

Natural polysaccharides are easily available, biodegradable, biocompatible, and flexible, which makes them a suitable candidate for conjugation. A summary of such polysaccharide-based formulations is represented in Table 2. Polysaccharides are generally used to control the release of drugs, acting as carriers and providing stability to formulations; therefore, researchers are utilizing natural polysaccharides to entrap silver nanoparticles to get the best therapeutic outcome. Though natural polysaccharides possess wound healing and antibacterial properties, they face some potential limitations, like low solubility, stability and poor mechanical properties.[22] Integration of the polysaccharides with silver nanoparticles will strengthen their wound healing potential and minimize their limitations.

NANOCOMPOSITE FORMULATIONS FOR WOUND HEALING

Silver nanoparticle encapsulated in a polysaccharide matrix can be an effective wound healing agent as shown in Figure 2 and the nanocomposites can be formulated into different dosage forms as depicted in Figure 3.

Transdermal Patch

A Transdermal Patch loaded with Gallocatechin and AgNP showed extensive wound healing by decreasing Malondialdehyde content and increasing antioxidant activity.[33] Ahsan *et al*., by impregnating green synthesized AgNP from *Brassica oleracea* with PVA-based hydrogel showed extensive wound healing during 20 days of study.[34]

Hydrogel Dressings

A hydrogel dressings of Sodium Alginate, Gelatin, *Dactyloctenium aegypticum* plant extract-mediated green synthesized AgNPs showed significant wound closure with accelerated wound healing in 9 days.[35] Pooja *et al*., formulated hydrogel from *Premna integrifolia* L. roots mediated AgNPs with extensive wound healing activity against *S. aureus*-induced wounds.[36] A glass hydrogel coated with Hyaluronic Acid-Pluronic F-127 AgNPs conjugate increased the expression of Cyclin-D1, β-Catenin, enhancing wound healing.[37] A dual network hydrogel of polyethylene glycol diacrylate and catechol-modified hyaluronic acid with silver-doped mesoporous silica nanoparticles showed high antibacterial activity accompanied by angiogenic capability and cytocompatibility.[38]

Nanocomposite Films

Gelatin-neem-silver-nanocomposite films from *Praecitrullus fistulosus*, showed extensive regeneration of tissues.[39] Benkhira *et al*., formulated amidated pectin, gelatin, tannic acid-based silver nanocomposite films, showing extensive antibacterial activity.[40] A chitosan-AgNP nanotubes showed extensive wound healing potency with enhanced antimicrobial effect and fibroblast cell compatibility.[41] Elabbasy *et al*., formulated a Carboxymethyl Cellulose-polyvinyl-based nanocomposite film with AgNPs for wound healing.[42] Ozelin *et al*., prepared bacterial cellulose-AgNP-based Nanocomposite films, with 97% wound contraction and inflammation.[43] A PVA-based silver nanocomposite films offer a greater cell multiplication.[44] Mohammadi *et al*., formulated castor oil-polyurethane silver nanocomposite with increased antimicrobial activity.[45]

Nanofiber

An Ethyl Hydroxy Ethyl Cellulose-PVA-based silver nanofiber found effective against burns and heals without scar formation.[46] A chitosan-PVA-AgNP films regenerates and heals the wound quickly.[47] Sariipek *et al*., formulated chitosan nanofibrous scaffolds with curcumin-reduced AgNPs, with extensive antibacterial and wound healing potency.[48] Balakrishnan *et al*., fabricated riboflavin-PVA-β-Cyclodextrin Nanofibrous Scaffolds with AgNP exhibiting greater wound healing and skin regeneration potency.[49] Nematollahi *et al*., prepared Polyhexamethylene biguanide AgNP-Chitosan-Thiourea nanofibers exhibiting extensive burn wound healing activity.[50]

Several FDA approved nanocomposites available are Acticoat™, Tegaderm™, SilvaSorb, and AQUACEL Ag. The recent research on wound healing potential of Silver nanocomposites are discussed in Table 3 and nanocomposite of metallic nanoparticles like Zinc oxide, gold, and copper, showing efficient wound healing activity, are mentioned in Table 4.

Table 1: Applications of AgNPs-Based Formulations in Wound Healing.

Sl. No.	Formulation	Polysaccharide Source	Application	References
1	AgNP	*Cotyledon orbiculata, Hybanthus enneaspermus, Achyranthes aspera, Cinnamomum verum, Cyanobacterium Synechocystis.*	Antibacterial, anti-inflammatory activity, fibroblasts differentiation, accelerates keratinocyte migration, collagen synthesis.	8-11
2	AgNP Hydrogel	Halofuginone, Levan, *Woodfordia fruticosa*, *Saccharomyces boulardii, Ocimum sanctum.*	Promotes skin fibroblast healing, stops proliferation of microorganisms, potentiates anti-inflammatory activities.	12-15
3	AgNP Nanofiber	Collagen, Casein, *Mimosa pudica.*	Increases re-epithelialization, Fibroblast cell proliferation, excellent exudate uptake, Inhibits microbial growth.	16-18
5	AgNP Ointment	*Phytophthora infestans.*	Higher wound healing rate.	19
6	AgNPs- cotton fabrics	*Curcuma longa, Scutellaria barbata.*	Extensive wound-healing properties.	20-21

Table 2: Polysaccharide based formulations in Wound Healing.

Sl. No.	Formulation	Polysaccharide Used	Therapeutic Outcome	References
1	Hydrogel	Sodium Alginate, Gelatin, carboxymethyl chitosan, Dextran, bacterial cellulose.	ROS scavenging activity, reduces inflammation, induces diabetic wound healing activity, Improves cell proliferation, skin migration.	25,26
2	Nanofibrous Matrix	Collagen, Hyaluronic Acid, Chitosan, *Cleome droserifolia, Allium sativum* extract.	Effective wound recovery with Scarless skin regeneration, enhances neovascularization and collagen deposition.	27,28
3	Nanocomposite	Halloysite powder, chitosan oligosaccharides.	Better skin re-epithelization.	29
4	Proteins	Fish collagen.	Efficient in wound contraction and quick wound healing.	30
5	Membranes	*Gluconacetobacter xylinum* cellulose, *Acetobacter xylinum,* chitosan.	Wound healing and faster re-epithelization collagen deposition.	31,32

Table 3: Silver Nanocomposites in Wound Healing.

Sl No.	Silver Nanocomposite	Polysaccharide source	Therapeutic outcome	References
1	Nanocomposite	*Moringa oleifera,* chitosan, Bacterial Cellulose, *Sanghuangporus sanghuang,* Carbon Composites, Filter Paper.	Rapid wound contraction, internal tissue growth, Fibroblast Cell Proliferation.	51-53
2	Nanocomposite Film	Chitosan, Alginate, Bacterial Cellulose, Carboxymethyl chitin.	Ruptures microbial biofilm, Enhances skin healing, collagen deposition, angiogenesis, higher antibacterial and wound-healing potency.	54,55
3	Nanofibrous scaffolds	Chitosan, Cellulose Acetate, Bacterial Cellulose.	Extensive wound healing, Increases Fibroblast proliferation, wound contraction, reduces inflammation.	56, 57
4	Nano Hydrogel	Galacto-xyloglucan, Bamboo Cellulose, Chitosan, Alginate.	Increased Wound Healing by improving the level of growth factors, better wound healing properties.	58,59
5	Gold AgNPs	Carbohydrate.	Scar-free regeneration of infected wounds.	60
6	AgNPs sponge	Egg White, Konjac glucomannan.	Accelerates fibroblast proliferation and re-epithelialization.	61

EVALUATION OF WOUND HEALING ACTIVITIES

Antimicrobial Activity

Silver nanocomposite inhibits microbial growth and shows potent bactericidal activity. The antimicrobial efficacy of *Lepidium draba* synthesized AgNP against *Escherichia coli, Klebsiella pneumoniae, Enterococcus faecalis* showed Minimum Inhibitory Concentration (MIC) of 62.5 μg/mL, reflecting highest growth inhibitory effect and antibacterial potency.[79] Wypij *et al*., studied the antimicrobial activity of Actinobacterial strain SF 23 synthesized AgNP, against *E. coli, K. pneumoniae*, and *P. aeruginosa*.[80] Another AgNP prepared from *Rheum ribes* have lethal effect of 55.35%, 48.96%, 83.23%, and 66.85% against *S. aureus*, MRSA, *B. subtilis*, and *E. coli*, respectively, advocating a wide antimicrobial spectrum.[81]

Anti-Inflammatory Activity

Chi *et al*., formulated AgNPs from *Azadirachta indica*, showing anti-inflammatory activity of 69.77%.[82]

Antioxidant Activity

In Acute Wounds, ROS acts as a signaling molecule for the hemostasis, inflammation, but in chronic wounds, ROS is overproduced and inhibits cell proliferation and migration. A nanocomposite of Chitosan-AgNP revealed antioxidant potential against DPPH and Hydrogen Peroxide, at 100 μg/mL concentration.[83] Arya *et al*., formulated AgNP from *Cassia accidental* L. seed extract showing highest DPPH free radical scavenging activity as IC_{50} value (345 μg/mL), showing potent antioxidant activity.[84]

Table 4: Applications of other Metallic Nanoparticles in Wound Healing.

Sl. No.	Formulation	Polymer Source	Application	References
1	Gold Nanoparticles	Collagen, Chitosan, Snail Slime, Hyaluronic Acid, *Alteromonas macleodii.*	Cutaneous wound healing, Enhances epithelialization, wound contraction, Prevents oxidative damage, promotes collagen synthesis, cell differentiation, growth factor levels.	62-64
2	Zinc Oxide Nanoparticles	*Elettaria cardamomum*, Silymarin, Alginate, Chitosan, *Aspergillus niger, Barleria gibsoni*, Acacia, Starch, Tragacanth.	Faster epithelialization, cell growth, collagen deposition, anti-inflammatory effects, rapid vascularization, Extensive chronic/ acute wound healing, bactericidal potency.	65-68
3.	Zinc-Magnesium Oxide Nanoparticles	Silk Fibroin, *Aspergillus terreus.*	Promotes cell proliferation, Accelerates wound healing.	69,70
4.	Potamine Nanoparticle	Hyaluronan Oligosaccharides.	Increases angiogenesis and Vascular Endothelial Growth Factor.	71
5	Copper oxide Nanoparticle	Sodium Alginate, *Ficus religiosa*, Starch, *Calotropis gigantea.*	Significant Diabetic Wound Healing Activity with increased antibacterial and antioxidant effects.	72,73
6	Titanium Dioxide Nanoparticle-Biofilm.	Gellan Gum.	Promotes cell proliferation, cell migration, and faster excision wound healing, Absorbs large amount of wound exudates.	74
7	Copper-Zinc Oxide Nanocomposite	Calotropis gigantea.	Potentiates wound healing.	75
8	Silver-Zinc Oxide nanocomposite	Chitosan.	Promotes re-epithelialization and collagen deposition.	76
9	Silver-Magnesium Nanocomposite	*Aloe vera*, Xanthan Gum.	Efficient in wound closing.	77
10	Magnesium Oxide Nanoparticle	Dillenia indica.	Represents an essential tissue regrowth scaffold.	78

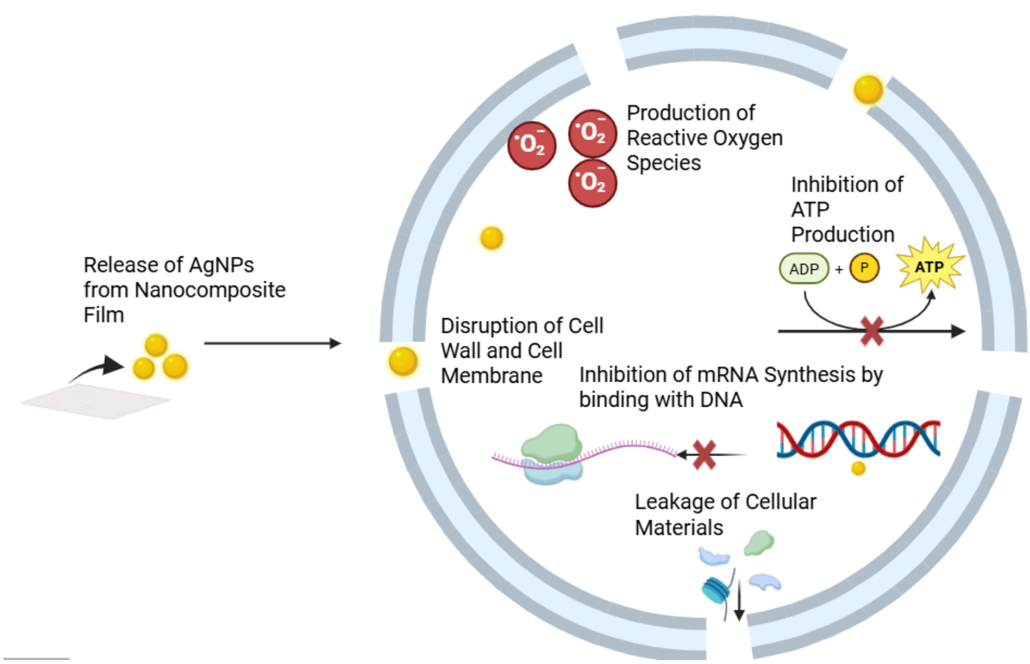

Figure 1: Bactericidal Mechanism of Silver Nanoparticles.

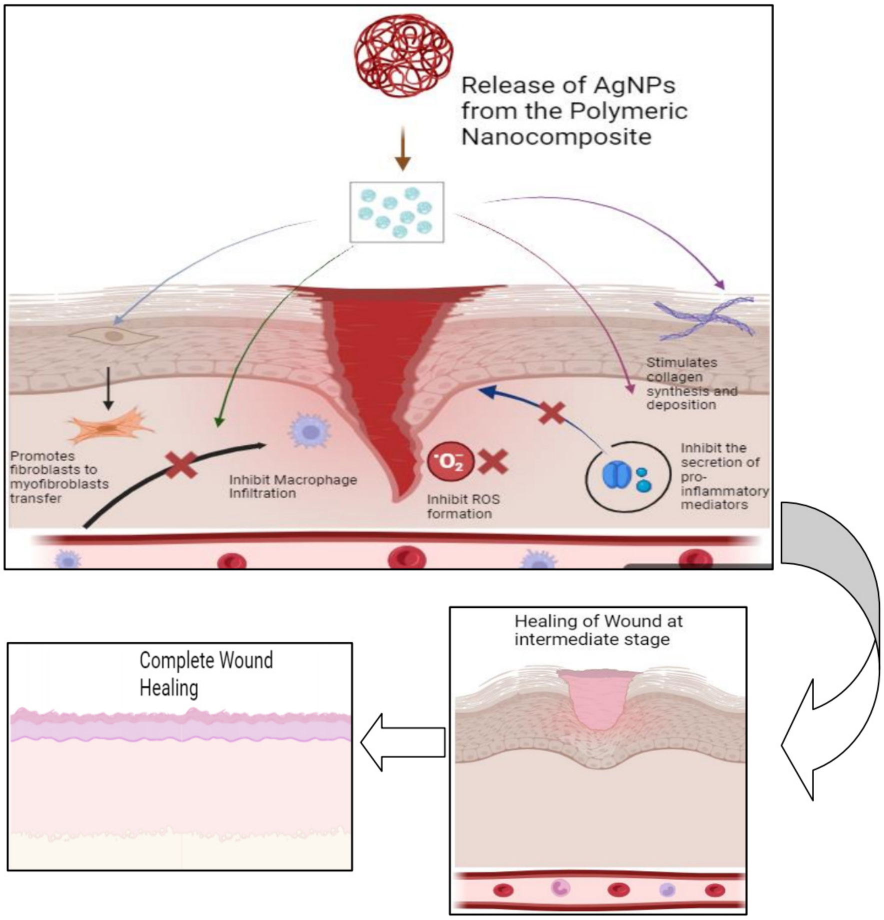

Figure 2: Mechanisms of Nano Silver embedded Polysaccharide in Wound Healing.

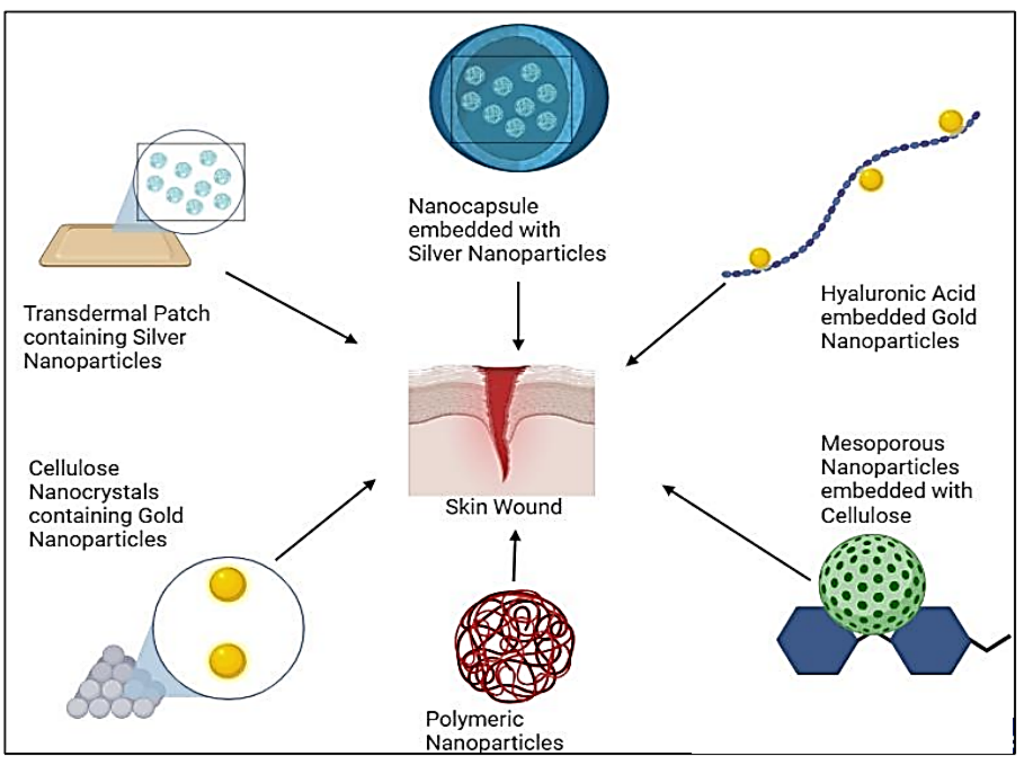

Figure 3: Nanoparticle embedded Polysaccharide Formulations in Wound Healing.

Table 5: Comparitive study of Antimicrobial potential of Silver nanocomposite on *S. aureus*.

Sl. No.	Formulation	Polysaccharide source	Dose of Silver	Zone of Inhibition (Nanocomposite)	Zone of Inhibition (Control)	References
1.	AgNPs-Membrane	Chitosan, gelatin	150 µg/mL AgNP	25.5 mm	0 mm	5
2.	AgNPs	Moringa oleifera	30 µg/mL AgNP	14 mm	0 mm	51
3.	Nanocomposite Film	Quaternized Chitosan	0.5% (w/w) AgNPs	14.2 mm	13.7 mm	54
4.	Nanocomposite	Bacterial Cellulose	2 mM Silver Nitrate	22.33 mm	0 mm	55
5.	Nanofiber	Bacterial Cellulose	-	3.46 mm	0 mm	56
6.	Nanosilver Films	Chitosan	0.01 mg Silver oxide	37 mm	Control- 0 mm	57
7.	AgNPs Hydrogel	Galacto-xyloglucan	0.55% AgNPs	7.5 mm	0 mm	59
8.	AgNPs	Cymbopogon citratus	100 µL AgNPs (1mg/mL)	15.00 mm (Flower Extract mediated AgNPs)	7.00 mm (Flower Extract)	87
9.	AgNPs	Hypnea pannosa	100 µL AgNPs (4000 µg/mL)	21 mm	0 mm	88
10.	AgNPs	Neem and Turmeric	100 µL AgNPs	20 mm	33 mm (Positive Control)	89

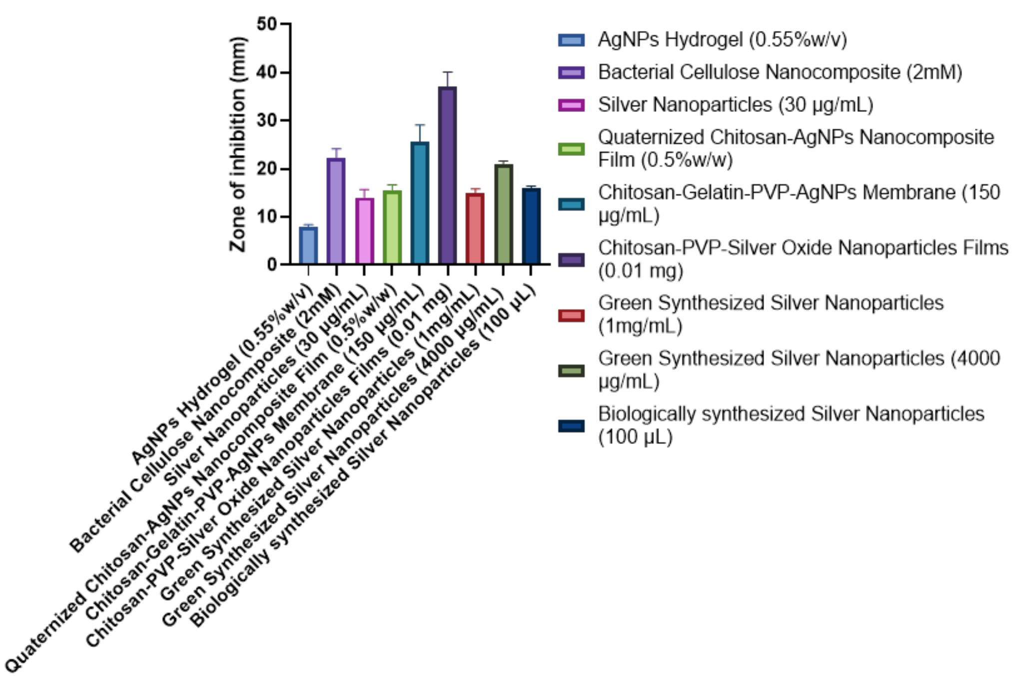

Figure 4: Comparative analysis of Antimicrobial Activities of Silver Nanocomposites on *S.aureus*.

Analgesic Activity

Silver nanoparticles reduce the release of proinflammatory cytokines and inhibit the infiltration of leukocytes and specific peripheral nerve receptors, responsible for pain signaling.

Hemostatic Activity

Polymers like chitosan, cellulose, and alginate, as well as nanoparticles like silver and silica, have hemostatic activity by platelet activation, aggregation, thrombin formation, and promote the release of coagulation factors. A Chitosan-Cellulose sponge, formulated showed rapid blood clotting in 34 sec, much faster than traditional gauze and gelatin sponge.[85] Jiang *et al*., fabricated a AgNP-chitin sponge with blood-absorbing ratio, 2.4-fold and 2.7-fold higher than the normal chitin sponge and marketed polyvinyl formal sponge, respectively.[86]

ANTIMICROBIAL ANALYSIS OF SILVER NANOCOMPOSITES ON *S. AUREUS*

Figure 4 represents a comparison of silver nanoparticle-based formulations and their antimicrobial activity (Zone of inhibition) on *S. aureus,* as per the data represented in Table 5. The comparative analysis from the research work done evolved that AgNP-chitosan conjugate at its highest concentration is having highest antimicrobial activity when compared to AgNPs at their highest concentrations, thus advocating greater antimicrobial potential of AgNP-polysaccharide conjugate.

CONCLUSION

The study discussed the exceptional wound healing potential of silver nanoparticles and natural polysaccharides along with its potential challenges related to toxicity and stability. Therefore, the review throws light on the remedial measures that can be adopted to meet the challenge of exploring more potent and safer silver nanoparticles-polysaccharide formulations with improved stability. The study identified the effectiveness of Nano Silver-Polysaccharide Conjugates in treating chronic wounds over Nano Silver or Polysaccharide alone. Nano Silver encapsulated formulations regenerate the tissue faster, subsequently faster wound closure. They show broader antimicrobial spectrum, preventing sepsis and promoting efficient wound healing. Thus, the current review emphasizes on utilization of natural polysaccharides to explore their antimicrobial, immunocompatible, and tissue regeneration properties. Apart from that, the limitations of AgNPs emphasize the need to be encapsulated to reduce its toxicity and improve stability and antimicrobial potency of the formulation. Therefore, the review offers an additive approach of silver nanocomposite, which may serve as an effective alternative to currently available marketed formulations and pave the way for future research encompassing the exploration of the potential of unutilized natural polysaccharides in chronic wound healing cases.

ACKNOWLEDGEMENT

The authors would like to shower sincere thanks to Guru Nanak Institute of Pharmaceutical Science and Technology for providing support to complete the work.

ABBREVIATIONS

AgNPs: Silver Nanoparticle; **PVA:** Poly(vinyl) Alcohol; **MIC:** Minimum Inhibitory Concentration; **MRSA:** Methicillin Resistant *Staphylococcus aureus*; **ROS:** Reactive Oxygen Species; **IC$_{50}$:** Inhibitory Concentration 50; **PDA:** Polydopamine.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTION BY AUTHOR

Hajra A has conceptualized and drafted the Manuscript, Chowdhury M has reviewed and edited the manuscript. Ganguly P and Bag S have studied literature and collected data.

SUMMARY

The review focuses on the emerging scopes of polysaccharides in encapsulating silver nanoparticle and their additive therapeutic efficacy in wound healing. The review starts with the mechanism of silver nanoparticles in wound healing. It discusses the applications of silver nanoparticles as well as their limitations. The use of polysaccharides in encapsulating silver nanoparticles to prevent the limitations of silver nanoparticles, the formation of nanocomposites, their applications, and the evaluation of wound healing activity are discussed and compared. The article discusses the recent studies of silver nanoparticle-encapsulated polysaccharide formulation and shows their therapeutic effectiveness in wound healing.

REFERENCES

1. Verma R, Gupta PP, Satapathy T, Roy A. A review of wound healing activity on different wound models. Journal of Applied Pharmaceutical Research. 2019;7(1):01-7. doi: 10.18231/2348-0335.2018.0013.
2. Chinnasamy G, Chandrasekharan S, Koh WT, Bhatnagar S. Synthesis, Characterization, Antibacterial and Wound Healing Efficacy of Silver Nanoparticles from *Azadirachta indica*. Frontiers in Microbiology. 2021; 12. DOI:10.3389/fmicb.2021.611560
3. Sánchez-Gálvez J, Martínez-Isasi S, Gómez-Salgado J, Rumbo-Prieto JM, Sobrido-Prieto M, Sánchez-Hernández M, García-Martínez M, Fernández-García D. Cytotoxicity and concentration of silver ions released from dressings in the treatment of infected wounds: a systematic review. Frontiers in Public Health. 2024; 12.DOI:10.3389/fpubh.2024.1331753Top of Form
4. Nguyen TT, Tran NT, Le TQ. Passion fruit peel pectin/chitosan based antibacterial films incorporated with biosynthesized silver nanoparticles for wound healing application. Alexandria Engineering Journal. 2023;69:419-30. doi: 10.1016/j.aej.2023.01.066.
5. El-Aassar MR, Ibrahim OM, Fouda MM, Fakhry H, Ajarem J, Maodaa SN, *et al.* Wound dressing of chitosan-based-crosslinked gelatin/polyvinyl pyrrolidone embedded silver nanoparticles, for targeting multidrug resistance microbes. Carbohydrate polymers. 2021;255:117484. doi: 10.1016/j.carbpol.2020.117484.

6. Singh M, Thakur V, Kumar V, Raj M, Gupta S, Devi N, Upadhyay SK, Macho M, Banerjee A, Ewe D, Saurav K. Silver Nanoparticles and Its Mechanistic Insight for Chronic Wound Healing: Review on Recent Progress. Molecules. 2022;27(17):5587. doi: 10.3390/molecules27175587.
7. Noga M, Milan J, Frydrych A, Jurowski K. Toxicological aspects, safety assessment, and green toxicology of silver nanoparticles (AgNPs)- critical review: state of the art. International Journal of Molecular Sciences. 2023;24(6):5133. doi: 10.3390/ijms24065133.
8. Tyavambiza C, Elbagory AM, Madiehe AM, Meyer M, Meyer S. The antimicrobial and anti-inflammatory effects of silver nanoparticles synthesised from Cotyledon orbiculata aqueous extract. Nanomaterials. 2021;11(5):1343. doi: 10.3390/nano11051343.
9. Cheng L, Zhang S, Zhang Q, Gao W, Mu S, Wang B. Wound healing potential of silver nanoparticles from *Hybanthus enneaspermus* on rats. Heliyon. 2024;10(17). doi: 10.1016/j.heliyon.2024.e36118.
10. Shidramshettar SL, Vijapur LS, Shalavadi M, Desai AR, Gudigennavar AS, Srinivas Y. Microwave assisted biosynthesis of silver nanoparticles from *Achyranthes aspera* for burn wound healing activity. Inorganic Chemistry Communications. 2024;159:111691. doi: 10.1016/j.inoche.2023.111691.
11. Younis NS, Mohamed ME, El Semary NA. Green synthesis of silver nanoparticles by the *Cyanobacteria synechocystis* sp.: Characterization, antimicrobial and diabetic wound-healing actions. Marine Drugs. 2022;20(1):56. doi: 10.3390/md20010056.
12. Zuo RN, Gong JH, Gao XG, Huang JH, Zhang JR, Jiang SX, *et al.* Using halofuginone–silver thermosensitive nanohydrogels with antibacterial and anti-inflammatory properties for healing wounds infected with *Staphylococcus aureus*. Life Sciences. 2024;339:122414. doi: 10.1016/j.lfs.2024.122414.
13. Kubavat J, Sarvaiya J, Tyagi T, Banerjee S, Aggarwal P. Development of Levan capped silver nanoparticles based product and its effect on wound healing. Burns Open. 2023;7(1):8-21. doi: 10.1016/j.burnso.2022.12.002.
14. Maheshwari S. Synergistic effects of *Woodfordia fruticosa* silver nanoparticles accelerating wound healing in Swiss mice *iv vivo*. Intelligent Pharmacy. 2024;2(1):17-27. doi: 10.1016/j.ipha.2023.09.005.
15. Sood R, Chopra DS. Optimization of reaction conditions to fabricate *Ocimum sanctum* synthesized silver nanoparticles and its application to nano-gel systems for burn wounds. Materials Science and Engineering: C. 2018;92:575-89. doi: 10.1016/j.msec.2018.06.070.
16. Rath G, Hussain T, Chauhan G, Garg T, Goyal AK. Collagen nanofiber containing silver nanoparticles for improved wound-healing applications. Journal of drug targeting. 2016;24(6):520-9. doi: 10.3109/1061186X.2015.1095922.
17. Selvaraj S, Thangam R, Fathima NN. Electrospinning of casein nanofibers with silver nanoparticles for potential biomedical applications. International journal of biological macromolecules. 2018;120:1674-81. doi: 10.1016/j.ijbiomac.2018.09.177.
18. Patil S, George T, Mahadik K. Green synthesized nanosilver loaded silk fibroin gel for enhanced wound healing. Journal of Drug Delivery Science and Technology. 2015;30:30-6. doi: 10.1016/j.jddst.2015.09.001.
19. Thirumurugan G, Veni VS, Ramachandran S, Seshagiri Rao JV, Dhanaraju MD. Superior wound healing effect of topically delivered silver nanoparticle formulation using eco-friendly potato plant pathogenic fungus: synthesis and characterization. Journal of biomedical nanotechnology. 2011;7(5):659-66. doi: 10.1166/jbn.2011.1336.
20. Maghimaa M, Alharbi SA. Green synthesis of silver nanoparticles from *Curcuma longa* L. and coating on the cotton fabrics for antimicrobial applications and wound healing activity. Journal of Photochemistry and Photobiology B: Biology. 2020;204:111806. doi: 10.1016/j.jphotobiol.2020.111806.
21. Veeraraghavan VP, Periadurai ND, Karunakaran T, Hussain S, Surapaneni KM, Jiao X. Green synthesis of silver nanoparticles from aqueous extract of *Scutellaria barbata* and coating on the cotton fabric for antimicrobial applications and wound healing activity in fibroblast cells (L929). Saudi journal of biological sciences. 2021;28(7):3633-40. doi: 10.1016/j.sjbs.2021.05.007.
22. Hu H, Xu FJ, Rational design and latest advances of polysaccharide-based hydrogels for wound healing. *Biomater. Sci*., 2020;8:2084-101 Doi:10.1039/D0BM00055H
23. Wang Z, Sun Q, Zhang H, Wang J, Fu Q, Qiao H, *et al.* Insight into antibacterial mechanism of polysaccharides: a review. Lwt. 2021;150:111929. doi: 10.1016/j.lwt.2021.111929.
24. Liu M, Jin J, Zhong X, Liu L, Tang C, Cai L. Polysaccharide hydrogels for skin wound healing. Heliyon. 2024;10(15). doi: 10.1016/j.heliyon.2024.e35014.
25. Hu Y, Zhang Z, Li Y, Ding X, Li D, Shen C, *et al.* Dual-crosslinked amorphous polysaccharide hydrogels based on chitosan/alginate for wound healing applications. Macromolecular rapid communications. 2018;39(20):1800069. doi: 10.1002/marc.201800069.
26. Lin SP, Kung HN, Tsai YS, Tseng TN, Hsu KD, Cheng KC. Novel dextran modified bacterial cellulose hydrogel accelerating cutaneous wound healing. Cellulose. 2017;24:4927-37. doi: 10.1007/s10570-017-1448-x.
27. Vigani B, Rossi S, Sandri G, Bonferoni MC, Caramella CM, Ferrari F. Hyaluronic acid and chitosan-based nanosystems: A new dressing generation for wound care. Expert opinion on drug delivery. 2019;16(7):715-40. doi: 10.1080/17425247.2019.1634051.
28. Sarhan WA, Azzazy HM, El-Sherbiny IM. Honey/chitosan nanofiber wound dressing enriched with Allium sativum and Cleome droserifolia: enhanced antimicrobial and wound healing activity. ACS applied materials & interfaces. 2016;8(10):6379-90. doi: 10.1021/acsami.6b00739.
29. Sandri G, Aguzzi C, Rossi S, Bonferoni MC, Bruni G, Boselli C, *et al.* Halloysite and chitosan oligosaccharide nanocomposite for wound healing. Acta biomaterialia. 2017;57:216-24. doi: 10.1016/j.actbio.2017.05.032.
30. Shalaby M, Agwa M, Saeed H, Khedr SM, Morsy O, El-Demellawy MA. Fish scale collagen preparation, characterization and its application in wound healing. Journal of Polymers and the Environment. 2020: 166-78. doi: 10.1007/s10924-019-01594-w.
31. Qiu Y, Qiu L, Cui J, Wei Q. Bacterial cellulose and bacterial cellulose-vaccarin membranes for wound healing. Materials Science and Engineering: C. 2016;59:303-9. doi: 10.1016/j.msec.2015.10.016.
32. Lin WC, Lien CC, Yeh HJ, Yu CM, Hsu SH. Bacterial cellulose and bacterial cellulose–chitosan membranes for wound dressing applications. Carbohydrate polymers. 2013;94(1):603-11. doi: 10.1016/j.carbpol.2013.01.076.
33. Vendidandala NR, Yin TP, Nelli G, Pasupuleti VR, Nyamathulla S, Mokhtar SI. Gallocatechinsilver nanoparticle impregnated cotton gauze patches enhance wound healing in diabetic rats by suppressing oxidative stress and inflammation via modulating the Nrf2/HO-1 and TLR4/NF-κB pathways. Life sciences. 2021;286:120019. doi: 10.1016/j.lfs.2021.120019.
34. Ahsan A, Farooq MA. Therapeutic potential of green synthesized silver nanoparticles loaded PVA hydrogel patches for wound healing. Journal of Drug Delivery Science and Technology. 2019;54:101308. doi: 10.1016/j.jddst.2019.101308.
35. Zain M, Nayab S, Rashid Z, Aleem A, Raza H, Yousif MD. Biosynthesis and *iv vivo* wound healing abilities of *Dactyloctenium aegyptium*-mediated silver nanoparticles used as hydrogel dressing. Process Biochemistry. 2024;147:31-8. doi: 10.1016/j.procbio.2024.08.011.
36. Verma P, Dixit J, Singh C, Singh AN, Singh A, Tiwari KN, *et al.* Preparation of hydrogel from the hydroalcoholic root extract of *Premna integrifolia* L. and its mediated green synthesis of silver nanoparticles for wound healing efficacy. Materials Today Communications. 2024;41:110228. doi: 10.1016/j.mtcomm.2024.110228.
37. Fayaz R, Farahpour MR, Tabatabaei ZG. The effects of bioactive glass hydrogel coated with hyaluronic acid-Pluronic F-127 conjugates containing silver nanoparticles for accelerating of infected wounds healing. International Journal of Pharmaceutics. 2024;664:124448. doi: 10.1016/j.ijpharm.2024.124448
38. Huang L, Li W, Guo M, Huang Z, Chen Y, Dong X, *et al.* Silver doped-silica nanoparticles reinforced poly (ethylene glycol) diacrylate/hyaluronic acid hydrogel dressings for synergistically accelerating bacterial-infected wound healing. Carbohydrate Polymers. 2023;304:120450. doi: 10.1016/j.carbpol.2022.120450
39. Sheokand B, Pathak SR, Srivastava CM, Kumar A, Bahadur I, Vats M. Green silver nanoparticles functionalised gelatin nanocomposite film for wound healing: Construction and characterization. Journal of Molecular Liquids. 2022;368:120561. doi: 10.1016/j.molliq.2022.120561.
40. Benkhira I, Zermane F, Cheknane B, Trache D, Brosse N, Paolone A, *et al.* Preparation and characterization of amidated pectin-gelatin-oxidized tannic acid hydrogel films supplemented with *in situ* reduced silver nanoparticles for wound-dressing applications. International Journal of Biological Macromolecules. 2024;277:134158. doi: 10.1016/j.ijbiomac.2024.134158.
41. Hernández-Rangel A, Silva-Bermudez P, Almaguer-Flores A, García VI, Esparza R, Luna-Bárcenas G, *et al.* Development and characterization of three-dimensional antibacterial nanocomposite sponges of chitosan, silver nanoparticles and halloysite nanotubes. RSC advances. 2024;14(34):24910-27. doi: 10.1039/D4RA04274C.
42. Elabbasy MT, Algahtani FD, Othman MS, Ahmad K, Maysara S, Al-Najjar MA, *et al.* Laser deposited ultra-thin silver nanoparticles on CMC-PVA blend film as sheet for wound dressings. Materials Chemistry and Physics. 2024;318:129246. doi: 10.1016/j.matchemphys.2024.129246.
43. Ozelin SD, Esperandim TR, Dias FG, de Freitas Pereira L, Garcia CB, de Souza TO, *et al.* Nanocomposite based on bacterial cellulose and silver nanoparticles improve wound healing without exhibiting toxic effect. Journal of Pharmaceutical Sciences. 2024;113(8):2383-93. doi: 10.1016/j.xphs.2024.04.010.
44. Warale D, Shabeena M, Prabhu A, Kouser S, Manasa DJ, Nagaraja GK. Sustainable organosolv-lignin coated nanosilver-halloysites reinforced poly (vinyl alcohol) nanocomposites for wound healing application. International Journal of Biological Macromolecules. 2024;257:128628. doi: 10.1016/j.ijbiomac.2023.128628.
45. Mohammadi A, Kerdabadi ZG, Najafabadi SA, Pourali A, Nejaddehbashi F, Azarbarz N, *et al.* A high-efficient antibacterial and biocompatible polyurethane film with Ag@rGO nanostructures prepared by microwave-assisted method: Physicochemical and dermal wound healing evaluation. Heliyon. 2023;9(11). doi: 10.1016/j.heliyon.2023.e21783.
46. Wali A, Gorain M, Kundu G, Badiger M. Silver nanoparticles in electrospun ethyl hydroxy ethyl cellulose-PVA Nanofiber: Synthesis, characterization and wound dressing applications. Carbohydrate Polymer Technologies and Applications. 2024;7:100477. doi: 10.1016/j.carpta.2024.100477.
47. Kota S, Anantha R, RAO GOVADA VA, Dumpala P. Chitosan/PVA Films and Silver Nanoparticle Impregnated Nanofibrous Dressings for Evaluation of their Wound Healing Efficacy in Wistar Albino Rat Model. Journal of Polymer Materials. 2023; 40. doi: 10.32381/JPM.2023.40.3-4.10
48. Sarıipek FB. Biopolymeric nanofibrous scaffolds of poly (3-hydroxybuthyrate)/chitosan loaded with biogenic silver nanoparticle synthesized using curcumin and

their antibacterial activities. International Journal of Biological Macromolecules. 2024;256:128330. doi: 10.1016/j.ijbiomac.2023.128330.

49. Balakrishnan SB, Thambusamy S. Preparation of silver nanoparticles and riboflavin embedded electrospun polymer nanofibrous scaffolds for *iv vivo* wound dressing application. Process Biochemistry. 2020;88:148-58. doi: 10.1016/j.procbio.2019.09.033.
50. Nematollahi S, Maghsoudian S, Motasadizadeh H, Nouri Z, Azad K, Fatahi Y, *et al.* Polyhexamethylene biguanidine coated silver nanoparticles embedded into chitosan thiourea/PVA nanofibers as wound healing mats: *In vitro* and *iv vivo* studies. Carbohydrate Polymers. 2025;347:122704. doi: 10.1016/j.carbpol.2024.122704.
51. Mehwish HM, Liu G, Rajoka MS, Cai H, Zhong J, Song X, *et al.* Therapeutic potential of *Moringa oleifera* seed polysaccharide embedded silver nanoparticles in wound healing. International Journal of Biological Macromolecules. 2021;184:144-58. doi: 10.1016/j.ijbiomac.2021.05.202.
52. Ran L, Zou Y, Cheng J, Lu F. Silver nanoparticles *in situ* synthesized by polysaccharides from *Sanghuangporus sanghuang* and composites with chitosan to prepare scaffolds for the regeneration of infected full-thickness skin defects. International journal of biological macromolecules. 2019;125:392-403. doi: 10.1016/j.ijbiomac.2018.12.052.
53. Kim MH, Cho D, Kwon OH, Park WH. Thermal fabrication and characterization of Ag nanoparticle-activated carbon composites for functional wound-dressing additives. Journal of Alloys and Compounds. 2018;735:2670-4. doi: 10.1016/j.jallcom.2017.11.347.
54. Rahimi M, Ahmadi R, Kafil HS, Shafiei-Irannejad V. A novel bioactive quaternized chitosan and its silver-containing nanocomposites as a potent antimicrobial wound dressing: Structural and biological properties. Materials Science and Engineering: C. 2019;101:360-9. doi: 10.1016/j.msec.2019.03.092
55. Jiji S, Udhayakumar S, Maharajan K, Rose C, Muralidharan C, Kadirvelu K. Bacterial cellulose matrix with *in situ* impregnation of silver nanoparticles via catecholic redox chemistry for third degree burn wound healing. Carbohydrate Polymers. 2020;245:116573. doi: 10.1016/j.carbpol.2020.116573.
56. Wu J, Zheng Y, Wen X, Lin Q, Chen X, Wu Z. Silver nanoparticle/bacterial cellulose gel membranes for antibacterial wound dressing: investigation *in vitro* and *iv vivo*. Biomedical materials. 2014;9(3):035005. doi: 10.1088/1748-6041/9/3/035005.
57. Archana D, Singh BK, Dutta J, Dutta PK. Chitosan-PVP-nano silver oxide wound dressing: *in vitro* and *iv vivo* evaluation. International journal of biological macromolecules. 2015;73:49-57. doi: 10.1016/j.ijbiomac.2014.10.055.
58. Sandri G, Miele D, Faccendini A, Bonferoni MC, Rossi S, Grisoli P, *et al.* Chitosan/glycosaminoglycan scaffolds: the role of silver nanoparticles to control microbial infections in wound healing. Polymers. 2019;11(7):1207. doi: 10.3390/polym11071207.
59. Preethi GU, Unnikrishnan BS, Sreekutty J, Archana MG, Anupama MS, Shiji R, *et al.* Semi-interpenetrating nanosilver doped polysaccharide hydrogel scaffolds for cutaneous wound healing. International Journal of Biological Macromolecules. 2020;142:712-23. doi: 10.1016/j.ijbiomac.2019.10.012.
60. Kumar S, Majhi RK, Singh A, Mishra M, Tiwari A, Chawla S, *et al.* Carbohydrate-coated gold–silver nanoparticles for efficient elimination of multidrug resistant bacteria and *iv vivo* wound healing. ACS applied materials & interfaces. 2019;11(46):42998-3017. doi: 10.1021/acsami.9b17086.
61. Chen H, Lan G, Ran L, Xiao Y, Yu K, Lu B, *et al.* A novel wound dressing based on a Konjac glucomannan/silver nanoparticle composite sponge effectively kills bacteria and accelerates wound healing. Carbohydrate polymers. 2018;183:70-80. doi: 10.1016/j.carbpol.2017.11.029.
62. Hashem AH, Shehabeldine AM, Ali OM, Salem SS. Synthesis of chitosan-based gold nanoparticles: Antimicrobial and wound-healing activities. Polymers. 2022;14(11):2293. doi: 10.3390/polym14112293.
63. Gubitosa J, Rizzi V, Fini P, Laurenzana A, Fibbi G, Veiga-Villauriz C, *et al.* Biomolecules from snail mucus (*Helix aspersa*) conjugated gold nanoparticles, exhibiting potential wound healing and anti-inflammatory activity. Soft Matter. 2020;16(48):10876-88. doi: 10.1039/D0SM01638A.
64. Poomrattanangoon S, Pissuwan D. Gold nanoparticles coated with collagen-I and their wound healing activity in human skin fibroblast cells. Heliyon. 2024;10(13). doi: 10.1016/j.heliyon.2024.e33302.
65. Valadi M, Doostan M, Khoshnevisan K, Doostan M, Maleki H. Enhanced healing of burn wounds by multifunctional alginate-chitosan hydrogel enclosing silymarin and zinc oxide nanoparticles. Burns. 2024;50(8):2029-44. doi: 10.1016/j.burns.2024.07.021.
66. Rasha E, Alkhulaifi MM, AlOthman M, Khalid I, Doaa E, Alaa K, *et al.* Effects of zinc oxide nanoparticles synthesized using *Aspergillus niger* on carbapenem-resistant klebsiella pneumonia *in vitro* and *iv vivo*. Frontiers in Cellular and Infection Microbiology. 2021;11:748739. doi: 10.3389/fcimb.2021.748739.
67. Shao F, Yang A, Yu DM, Wang J, Gong X, Tian HX. Bio-synthesis of Barleria gibsoni leaf extract mediated zinc oxide nanoparticles and their formulation gel for wound therapy in nursing care of infants and children. Journal of Photochemistry and Photobiology B: Biology. 2018;189:267-73. doi: 10.1016/j.jphotobiol.2018.10.014.
68. Irfan M, Munir H, Ismail H. Characterization and fabrication of zinc oxide nanoparticles by gum Acacia modesta through green chemistry and impregnation on surgical sutures to boost up the wound healing process. International Journal of Biological Macromolecules. 2022;204:466-75. doi: 10.1016/j.ijbiomac.2022.01.080.
69. Radulescu DM, Andronescu E, Vasile OR, Ficai A, Vasile BS. Silk fibroin-based scaffolds for wound healing applications with metal oxide nanoparticles. Journal of Drug Delivery Science and Technology. 2024: 105689. doi: 10.1016/j.jddst.2024.105689.
70. Mousa SA, El-Sayed ES, Mohamed SS, Abo El-Seoud MA, Elmehlawy AA, Abdou DA. Novel mycosynthesis of Co 3 O 4, CuO, Fe 3 O 4, NiO, and ZnO nanoparticles by the endophytic *Aspergillus terreus* and evaluation of their antioxidant and antimicrobial activities. Applied Microbiology and Biotechnology. 2021;105:741-53. doi: 10.1007/s00253-020-11046-4.
71. Wang T, Zheng Y, Shi Y, Zhao L. pH-responsive calcium alginate hydrogel laden with protamine nanoparticles and hyaluronan oligosaccharide promotes diabetic wound healing by enhancing angiogenesis and antibacterial activity. Drug delivery and translational research. 2019;9:227-39. doi: 10.1007/s13346-018-00609-8.
72. Li S, Wang X, Chen J, Guo J, Yuan M, Wan G, *et al.* Calcium ion cross-linked sodium alginate hydrogels containing deferoxamine and copper nanoparticles for diabetic wound healing. International Journal of Biological Macromolecules. 2022;202:657-70. doi: 10.1016/j.ijbiomac.2022.01.080.
73. Abdollahi Z, Zare EN, Salimi F, Goudarzi I, Tay FR, Makvandi P. Bioactive carboxymethyl starch-based hydrogels decorated with CuO nanoparticles: Antioxidant and antimicrobial properties and accelerated wound healing *iv vivo*. International journal of molecular sciences. 2021;22(5):2531. doi: 10.3390/ijms22052531.
74. Ahmed A, Niazi MB, Jahan Z, Ahmad T, Hussain A, Pervaiz E, *et al. In vitro* and *in vivo* study of superabsorbent PVA/Starch/g-C3N4/Ag@ TiO2 NPs hydrogel membranes for wound dressing. European Polymer Journal. 2020;130:109650. doi: 10.1016/j.eurpolymj.2020.109650.
75. Govindasamy GA, Mydin RB, Harun NH, Sreekantan S. Bactericidal potential of dual-ionic honeycomb-like ZnO-CuO nanocomposites from Calotropis gigantea against prominent pathogen associated with skin and surgical wound infections:. Materials Science for Energy Technologies. 2021;4:383-90. doi: 10.1016/j.mset.2021.08.013.
76. Lu Z, Gao J, He Q, Wu J, Liang D, Yang H, *et al.* Enhanced antibacterial and wound healing activities of microporous chitosan-Ag/ZnO composite dressing. Carbohydrate polymers. 2017;156:460-9. doi: 10.1016/j.carbpol.2016.09.051.
77. Saravanakumar K, Sathiyaseelan A, Zhang X, Choi M, Wang MH. Bimetallic (Ag and MgO) nanoparticles, Aloe vera extracts loaded xanthan gum nanocomposite for enhanced antibacterial and *in vitro* wound healing activity. International Journal of Biological Macromolecules. 2023;242:124813. doi: 10.1016/j.ijbiomac.2023.124813.
78. Bal T. Fabrication and evaluation of *Dillenia indica*-carrageenan blend hybrid superporous hydrogel reinforced with green synthesized MgO nanoparticles as an effective wound dressing material. International Journal of Biological Macromolecules. 2024;265:130835. doi: 10.1016/j.ijbiomac.2024.130835.
79. Hajizadeh M, Sarayan MS, Taleghani A, Shafaei E, Sahebkar A, Eghbali S, *et al.* Evaluation of antimicrobial and antioxidant effects of silver nanoparticles synthesized with leaves of *Lepidium draba* L. Journal of Radiation Research and Applied Sciences. 2024;17(3):101004. doi: 10.1016/j.jrras.2024.101004.
80. Wypij M, Jędrzejewski T, Trzcińska-Wencel J, Ostrowski M, Rai M, Golińska P. Green synthesized silver nanoparticles: antibacterial and anticancer activities, biocompatibility, and analyses of surface-attached proteins. Frontiers in microbiology. 2021;12:632505. doi: 10.3389/fmicb.2021.632505.
81. Aygün A, Gülbağça F, Nas MS, Alma MH, Çalımlı MH, Ustaoglu B, *et al.* Biological synthesis of silver nanoparticles using *Rheum ribes* and evaluation of their anticarcinogenic and antimicrobial potential: A novel approach in phytonanotechnology. Journal of pharmaceutical and biomedical analysis. 2020;179:113012. doi: 10.1016/j.jpba.2019.113012.
82. Chi NT, Narayanan M, Chinnathambi A, Govindasamy C, Subramani B, Brindhadevi K, *et al.* Fabrication, characterization, anti-inflammatory, and anti-diabetic activity of silver nanoparticles synthesized from *Azadirachta indica* kernel aqueous extract. Environmental research. 2022;208:112684. doi: 10.1016/j.envres.2022.112684.
83. Meydan I, Aygun A, Tiri RN, Gur T, Kocak Y, Seckin H, *et al.* Chitosan/PVA-supported silver nanoparticles for azo dyes removal: fabrication, characterization, and assessment of antioxidant activity. Environmental Science: Advances. 2024;3(1):28-35. doi: 10.1039/D3VA00224A.
84. Arya A, Tyagi PK, Bhatnagar S, Bachheti RK, Bachheti A, Ghorbanpour M. Biosynthesis and assessment of antibacterial and antioxidant activities of silver nanoparticles utilizing *Cassia occidentalis* L. seed. Scientific Reports. 2024;14(1):7243. doi: 10.1038/s41598-024-57823-3.
85. Fan X, Li Y, Li N, Wan G, Ali MA, Tang K. Rapid hemostatic chitosan/cellulose composite sponge by alkali/urea method for massive haemorrhage. International Journal of Biological Macromolecules. 2020;164:2769-78. doi: 10.1016/j.ijbiomac.2020.07.312.
86. Jiang Q, Luo B, Wu Z, Gu B, Xu C, Li X, *et al.* Corn stalk/AgNPs modified chitin composite hemostatic sponge with high absorbency, rapid shape recovery and promoting wound healing ability. Chemical Engineering Journal. 2021;421:129815. doi: 10.1016/j.cej.2021.129815.
87. Ramasamy M, Karuppiah P, Ranganathan H, Djearamane S, Muthukrishnan E, Kayarohanam S, *et al.* Nanomedicine potential of *Cymbopogon citratus* Linn.–Biogenic

synthesized silver nanoparticles: A study on antimicrobial and anticancer efficacy. Journal of King Saud University-Science. 2024;36(11):103533. doi: 10.1016/j.jksus.2024.103533.

88. Bashar MA, Attia EM, Mekky AE, Selim TA, Shaban WM, El-Tabakh MA, *et al*. Exploring the multifaceted bioactivities of silver nanoparticles synthesized from red algae Hypnea pannosa: Antimicrobial, antibiofilm, and insecticidal potentials. Electronic Journal of Biotechnology. 2025. doi: 10.1016/j.ejbt.2024.12.001.

89. Singh RK, Nallaswamy D, Rajeshkumar S, Varghese SS. Green synthesis of silver nanoparticles using neem and turmeric extract and its antimicrobial activity of plant mediated silver nanoparticles. Journal of Oral Biology and Craniofacial Research. 2025;15(2):395-401. doi:

Cite this article: Hajra A, Chowdhury M, Ganguly P, Bag S. Therapeutic Potential of Nanosilver Encapsulated Polysaccharide in Wound Healing. Indian J of Pharmaceutical Education and Research. 2026;60(2s):s853-s863.