Therapeutic Potential of Snakehead Fish (*Channa striata*) Skin Collagen Hydrogel in Third Degree Burn Wound Healing: A Systematic Review

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ABSTRACT

Third-degree burn wounds represent a major clinical challenge because of extensive tissue damage, delayed healing, and a high risk of infection and scarring. Snakehead fish (*Channa striata*) skin collagen has emerged as a promising biomaterial for advanced wound dressings owing to its biocompatibility and regenerative properties. This systematic review evaluated the therapeutic potential of *Channa striata* skin collagen hydrogels for third-degree burn wound healing. A comprehensive literature search was conducted in PubMed, ScienceDirect, and Google Scholar following PRISMA guidelines to identify eligible studies published between 2015 and 2026. Of 40 records identified, five studies met the inclusion criteria. The evidence showed that fish collagen-based hydrogels promoted wound healing by enhancing cell adhesion, collagen deposition, angiogenesis, re-epithelialisation, and wound closure while maintaining a moist wound environment and reducing inflammation. Advanced formulations incorporating thermosensitive hydrogels or nanoemulsion delivery systems further improved antibacterial activity and therapeutic performance in preclinical models. Nevertheless, evidence specific to *Channa striata* skin collagen hydrogels for third-degree burn wounds remains limited, with most available studies focusing on general fish collagen, bone-derived collagen, or less severe burn models. Overall, *Channa striata* skin collagen hydrogels represent a promising biomaterial for advanced burn wound management because of their favourable regenerative properties. Further well-designed preclinical studies and clinical trials are needed to optimise formulations and establish their efficacy and safety for clinical application.

Keywords: Biomaterial, *Channa striata*, collagen, hydrogel, third-degree burn

INTRODUCTION

Burn injuries constitute a major global health concern, leading to significant morbidity and mortality annually (Mer et al., 2023; Torres-Bautista et al., 2025). Third-degree burns, characterised by full-thickness skin destruction, present particularly complex challenges for effective wound management (Yoon et al., 2020). These extensive injuries necessitate advanced therapeutic strategies to facilitate rapid healing, minimise scarring, prevent infection, and restore tissue function (Fani et al., 2024; Singh & Rede, 2024). Traditional wound dressings often exhibit limitations in providing an optimal environment for severe burn recovery, frequently failing to address infection control, exudate management, and active tissue regeneration concurrently (Fani et al., 2024; Gounden & Singh, 2024; Kaur et al., 2022).

Collagen, as the most abundant protein in mammalian extracellular matrix, is vital for maintaining tissue integrity and orchestrating various stages of wound healing (Emam, 2025; Singh & Rede, 2024). Its biocompatibility, biodegradability, and capacity to promote cellular adhesion, proliferation, and differentiation render it an attractive biomaterial for regenerative medicine (Furtado et al., 2022; Negrescu & Cimpean, 2025) . While mammalian-derived collagen has been extensively used, concerns regarding disease transmission, immunogenicity, and ethical considerations have driven research towards alternative sources (Furtado et al., 2022; Gallo et al., 2022). Fish-derived collagen has emerged as a promising substitute, offering advantages such as reduced pathogen transmission risk, lower immunogenicity, and greater availability from aquaculture by-products (Furtado et al., 2022; Gallo et al., 2022; Mer et al., 2023).

Among various fish species, the snakehead fish (*Channa striata*) has garnered particular interest due to its traditional recognition for medicinal properties, including wound healing Collagen extracted from its skin exhibits favourable characteristics for biomedical applications (Wulandari et al., 2015). When formulated into hydrogels, these biomaterials provide a moist wound environment, absorb exudates, and can act as delivery systems for therapeutic agents, thereby creating an optimal milieu for complex wound repair (Gounden & Singh, 2024; Negrescu & Cimpean, 2025). The combination of snakehead fish skin collagen with advanced hydrogel technology, particularly thermosensitive and nanoemulsion-loaded systems, represents an innovative strategy for managing third-degree burn wounds.

This systematic review focuses on the therapeutic potential of snakehead fish (*Channa striata*) skin collagen hydrogels as advanced wound dressings for third-degree burn healing. While fish collagen research is expanding, studies specifically on *Channa striata* skin collagen remain relatively limited (Cai, 2024). A notable gap exists in the comprehensive evaluation of its effectiveness, particularly in the context of severe burn models. Furthermore, hydrogel formulations utilising this specific collagen source are not yet extensively explored. This review aims to systematically synthesise current evidence regarding the characteristics, properties, and efficacy of *Channa striata* skin collagen hydrogels, with a specific emphasis on their application in third-degree burn wound healing. The objectives include characterising the source and extraction methods of *Channa striata* skin collagen, detailing the properties of hydrogels relevant to wound dressing, elucidating burn wound healing mechanisms, assessing the effectiveness of fish collagen-based hydrogels in preclinical and, if available, clinical settings for third-degree burns, and comparing their performance with conventional dressings. Moreover, this review identifies existing research gaps and outlines future opportunities for the development and clinical translation of this biomaterial.

METHODS

- **Database Searching Strategy:**
  A systematic search was conducted across three electronic databases: PubMed, ScienceDirect, and Google Scholar. The search was limited to articles published between 2015 and 2026. The search strategy employed a combination of keywords and Medical Subject Headings (MeSH) terms, utilising Boolean operators ("AND", "OR") to capture relevant literature. The primary search string was constructed as follows:
  ("*Channa striata*" OR "snakehead fish") AND (collagen OR "fish skin collagen") AND (hydrogel OR "thermosensitive hydrogel") AND ("burn wound" OR "third degree burn" OR "burn healing")
  Further complementary searches were performed using terms such as "collagen biomaterial" and "nanoemulsion loaded hydrogel" in conjunction with species-specific and wound type terms to ensure comprehensive coverage.

- **Inclusion and Exclusion Criteria:**
  Studies were considered eligible for inclusion if they investigated collagen derived from the skin of *Channa striata* (snakehead fish) and focused on hydrogel formulations containing this collagen for burn wound healing applications, particularly third degree burns or severe burn models. Eligible articles included original research studies, systematic reviews, and meta analyses published in English between 2015 and 2026 with full text availability.

  Studies were excluded if they primarily examined collagen derived from other fish species or mammalian sources without direct comparison to *Channa striata* skin collagen. Articles investigating collagen in non hydrogel forms, such as scaffolds, films, or sponges, were also excluded unless the findings were directly relevant to hydrogel properties. In addition, studies focusing on non burn wounds or less severe burn injuries without relevance to third degree burns were not included. Conference abstracts, editorials, opinion articles, and book chapters lacking original research data were excluded, as were publications outside the specified time range or those not written in English.

- **Data Extraction:**
  Data extraction was performed independently by two reviewers using a pre-defined data extraction form. The extracted information included study characteristics (author, year, country, study design), details of the collagen source (species, tissue, extraction method), hydrogel composition and properties (type, thermosensitivity, loaded agents), burn model specifics (animal model, burn degree, method), outcome measures (wound closure rate, re-epithelialization, inflammation markers, angiogenesis, collagen deposition, mechanical properties), and key findings related to therapeutic efficacy and safety. Any discrepancies during data extraction were resolved through discussion between the reviewers or consultation with a third reviewer. Extracted data were then systematically organised to facilitate synthesis and analysis within the review.

RESULTS AND DISCUSSION

A total of five studies fulfilled the eligibility criteria for inclusion in this review. As presented in Table 1, the extracted evidence includes experimental studies evaluating collagen derived from *Channa striata* skin, bone, or skin by-products, with variations in formulation, burn wound models, and outcome measures.

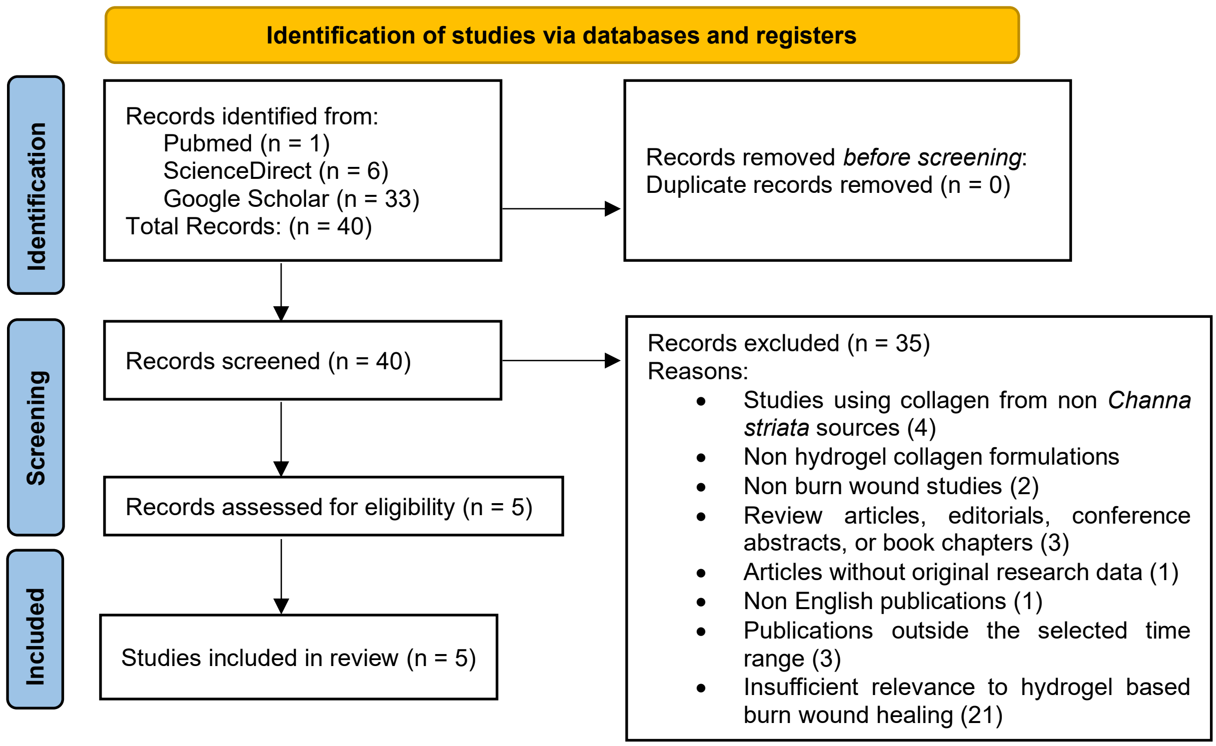

Figure 1. PRISMA 2020 flow diagram illustrating the study selection process for this systematic review. A total of 40 records were identified through database searching (PubMed, n = 1; ScienceDirect, n = 6; Google Scholar, n = 33). Following title and abstract screening, 35 records were excluded based on the predefined eligibility criteria. Five studies met the inclusion criteria and were included in the qualitative synthesis.

Table 1. Data Extraction

No.	Author (Year)	Study Design	Source of Collagen	Formulation/ Material	Wound Model	Outcomes Evaluated	Main Findings
1	Wulandari et al. (2015)	Experimental laboratory study	*Channa striata* skin	Collagen extract	No wound model	Collagen characterization and extraction efficiency	Alkaline pretreatment and acetic acid hydrolysis successfully produced collagen with stable triple helix structure
2	Hasri et al. (2020)	Experimental in vivo study	*Channa striata* bone collagen	Collagen cream	Burn wound model in rats	Wound diameter reduction, healing rate	Collagen cream accelerated burn wound healing compared with control groups
3	Febriyani et al. (2024)	Experimental animal study	*Channa striata* skin collagen	Collagen extract	Second degree burn model in mice	Wound closure and healing effectiveness	Collagen extract at 20% concentration showed the best burn wound healing effect
4	Tarannum et al., 2025	Experimental laboratory and in vivo study	*Channa striata* waste skin collagen peptide	Extracted collagen peptide	Partial thickness burn wound model in mice	Wound closure	Ch/PVA5-CP2 hydrogel showed the highest swelling ratio (619%), strong antibacterial and anti inflammatory activity, and promising burn wound healing effects compared with silver sulfadiazine control
5	Truong et al. (2021)	Experimental laboratory study	*Channa striata* skin by products	Acid soluble collagen	No wound model	Extraction yield, thermal stability, SDS PAGE, FTIR	Snakehead fish skin collagen demonstrated good thermal stability and biomaterial potential

This systematic review evaluated the current evidence regarding the application of *Channa striata*-derived collagen for burn wound healing, with particular emphasis on its potential as a biomaterial for hydrogel-based wound dressings. Although only five studies fulfilled the inclusion criteria, the collective findings consistently demonstrated that *Channa striata* collagen possesses favourable physicochemical characteristics and regenerative properties that support its application in tissue repair (Febriyani et al., 2024; Hasri et al., 2020; Tarannum et al., 2025; Truong et al., 2021; Wulandari et al., 2015). Importantly, the included studies represent successive stages of biomaterial development, beginning with collagen extraction and physicochemical characterisation and progressing towards evaluation of collagen-based formulations in experimental burn models. Together, these findings suggest that the therapeutic performance of *Channa striata* collagen depends on both its intrinsic biological properties and the optimisation of extraction methods and formulation strategies.

Among the five included studies, two primarily investigated collagen extraction and physicochemical characterisation (Truong et al., 2021; Wulandari et al., 2015), whereas three evaluated its therapeutic application in experimental burn wound models (Febriyani et al., 2024; Hasri et al., 2020; Tarannum et al., 2025).

Rather than representing separate lines of investigation, these studies complement one another by demonstrating that the favourable structural characteristics of *Channa striata* collagen underpin its regenerative effects during wound healing.

A major finding of this review is that fish-processing by-products, particularly skin, scales, and bone, represent valuable and sustainable sources of type I collagen for biomedical applications. Wulandari et al. (2015) demonstrated that optimisation of alkaline pretreatment followed by acetic acid extraction produced collagen with high protein purity while preserving its native triple-helical structure. Preservation of this molecular structure is critical because the biological activity, biodegradability, and mechanical stability of collagen depend largely on maintaining the integrity of the triple helix. Furthermore, the extracted collagen contained abundant glycine and proline residues, amino acids that stabilise collagen fibrils and contribute to extracellular matrix organisation during tissue regeneration (Wulandari et al., 2015).

Similarly, Truong et al. (2021) isolated acid-soluble type I collagen from *Channa striata* skin and mixed skin-scale by-products and reported favourable physicochemical characteristics suitable for biomedical applications. Although collagen extracted from skin alone produced a higher extraction yield, collagen isolated from the combined skin and scale fraction exhibited greater imino acid content and improved thermal stability. Because imino acids, particularly proline and hydroxyproline, stabilise hydrogen bonding within collagen molecules, increased imino acid content enhances resistance to thermal denaturation and improves scaffold stability under physiological conditions (Truong et al., 2021). These findings demonstrate that collagen quality is influenced not only by fish species but also by tissue source and extraction methodology.

The extraction studies also demonstrate the importance of protocol optimisation during biomaterial development. Previous investigations have shown that alkaline pretreatment effectively removes non-collagenous proteins and pigments, whereas acid or pepsin extraction preserves the native collagen structure while improving extraction efficiency and biological activity (Ge et al., 2020; Uchida et al., 2025). Consequently, differences in collagen yield, thermal stability, and biological performance observed among the included studies are likely attributable, at least in part, to methodological variation. Standardisation of extraction procedures would therefore improve reproducibility and facilitate comparison among future studies.

The favourable physicochemical characteristics reported by Wulandari et al. (2015) and Truong et al. (2021) also support previous evidence identifying marine-derived collagen as an attractive alternative to mammalian collagen. Compared with bovine or porcine collagen, fish collagen exhibits lower immunogenicity, presents minimal risk of zoonotic disease transmission, and avoids ethical and religious concerns associated with mammalian sources (Furtado et al., 2022; Gallo et al., 2022). Furthermore, utilisation of fish-processing by-products supports sustainable biomaterial production by converting industrial waste into high-value biomedical products. Therefore, *Channa striata* collagen represents both a biologically and environmentally attractive candidate for regenerative medicine (Febriyani et al., 2024; Hasri et al., 2020; Tarannum et al., 2025; Truong et al., 2021; Wulandari et al., 2015).

The physicochemical characteristics identified in the extraction studies provide the mechanistic basis for the therapeutic outcomes observed in experimental burn models. Stable collagen structure, favourable amino acid composition, and adequate thermal stability enable collagen scaffolds to maintain structural integrity within the wound environment while supporting fibroblast attachment, keratinocyte migration, angiogenesis, and extracellular matrix remodelling (Chen et al., 2021; Negrescu & Cimpean, 2025). Consequently, the extraction studies should not be viewed solely as biomaterial characterisation but as evidence explaining why *Channa striata* collagen demonstrates favourable regenerative performance following topical application.

Despite differences in collagen source, formulation, burn severity, and experimental design, all three intervention studies consistently demonstrated that topical administration of *Channa striata* collagen accelerated burn wound healing compared with untreated controls (Febriyani et al., 2024; Hasri et al., 2020; Tarannum et al., 2025). Nevertheless, comparison among these studies indicates that therapeutic efficacy depends not only on collagen concentration but also on biomaterial formulation and physicochemical characteristics. Hasri et al. (2020) reported that a 3% bone collagen cream produced the greatest reduction in wound diameter, whereas Febriyani et al. (2024) observed maximal wound healing with a 20% skin collagen formulation. Rather than representing conflicting findings, these differences are likely explained by variation in collagen source, extraction procedures, formulation composition, burn induction methods, and release behaviour. Bone-derived collagen differs from skin-derived collagen in molecular organisation and matrix composition, while creams and crude collagen extracts exhibit different release kinetics, tissue retention, and penetration profiles. Therefore, optimisation of formulation appears to be equally important as optimisation of collagen concentration (Febriyani et al., 2024; Hasri et al., 2020; Tarannum et al., 2025; Truong et al., 2021; Wulandari et al., 2015).

The regenerative effects observed across the included studies are biologically plausible considering the established role of collagen within the extracellular matrix. Collagen functions as a temporary scaffold that supports fibroblast proliferation, keratinocyte migration, angiogenesis, and matrix remodelling while regulating cellular signalling during tissue repair (Cai et al., 2024; Chen et al., 2021; Negrescu & Cimpean, 2025). Furthermore, collagen degradation products generate bioactive peptides capable of stimulating chemotaxis, fibroblast activation, and growth factor production, thereby promoting granulation tissue formation and re-epithelialisation. The consistent improvement in wound healing observed in the included studies therefore agrees with the established biological functions of collagen and supports its role as an active regulator of tissue regeneration rather than merely a structural biomaterial.

CONCLUSION

This systematic review demonstrates that *Channa striata*-derived collagen is a promising marine biomaterial for burn wound management because of its favourable physicochemical properties, biocompatibility, and regenerative potential. The available evidence indicates that *Channa striata* collagen promotes wound healing by supporting extracellular matrix remodelling, tissue regeneration, and wound closure, while hydrogel formulations provide additional advantages through moisture retention and enhanced antibacterial and anti-inflammatory activities.

However, the current evidence remains limited by the small number of available studies, methodological heterogeneity, and the predominance of preclinical investigations. Only one included study evaluated a *Channa striata* collagen hydrogel, and no study specifically investigated third-degree burn wounds or human clinical populations. Therefore, evidence supporting the application of *Channa striata* collagen hydrogels for full-thickness burn management remains insufficient.

Future studies should focus on standardising collagen extraction methods, optimising hydrogel formulations, and conducting rigorous preclinical and clinical evaluations in third-degree burn models. Overall, the current evidence supports the continued development of *Channa striata*-derived collagen as a promising biomaterial for advanced burn wound dressings while highlighting the need for further research before clinical implementation.

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