



## A novel method for accelerating surgical wound healing in rabbits by collagen extraction from carp (*Cyprinus carpio*) fish skin

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### Abstract

Recycling biological aquatic environment waste products is considered a source of biomaterials and a challenge in biomedicine. This study aims to investigate the functional group of collagens extracted from fish skin and to evaluate its activity in accelerating wound healing based on a statistical descriptive histogram of the mean wound area, contraction, and healing rate, along with a semi-qualitative gross assessment. This includes histological evaluations of both healing criteria (inflammatory cells, collagen deposition, maturation of granulation tissue, angiogenesis, and re-epithelization) and the expression of protein genes related to collagen III, vascular endothelial growth factor, and keratin-14. Collagen was chemically extracted from carp fish skin and applied three times daily to induce wounds in the paralumbar region of rabbits. The extracted collagen was characterized by low viscosity, transparency, and a watery consistency; the functional groups of collagens were detected using Fourier Transform Infrared Spectroscopy. Semi-qualitative analysis revealed improved gross inflammatory features, a statistically significant reduction in wound area, and a high contraction rate in the treated group. The descriptive histogram indicated a highly significant healing rate of 0.59 in the treated group. The healing criteria showed mild infiltration of inflammatory cells and maturation of granulation tissue. Histochemical analysis demonstrated thick, parallel collagen bundles over seven days in the CoIII-treated group, with these pathophysiological events combined with intense immunohistochemistry staining of collagen III, vascular endothelial growth factors, and keratin-14 expression at the wound biopsy. This study concludes that collagen extracted from carp skin can be an innovative therapeutic substance in regenerative medicine, accelerating wound healing.

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### Introduction

The skin is the body's largest organ and the most vulnerable to damage, which leads to disruption and loss of its integrity, along with tissue breakdown resulting from acute or chronic wounds (1). Wound healing and tissue repair comprise complex physiological dynamic phases. The first phase, called hemostasis, is characterized by platelet activation and the release of growth factors, such as Transforming Growth Factors (TGFs), Vascular Endothelial Growth Factors (VEGF), and Fibroblast Growth Factors (FGFs). Secondly, the formation of the fibrin clot and the

migration of neutrophils from blood circulation to the injury site occurs under the influence of chemical mediators, which are key features of inflammation, the second phase. The proliferative phase, the third stage of wound healing, involves monocytes, with macrophages and lymphocytes playing important roles in secreting cytokines and interleukin-2, which recruit and aggregate fibroblasts (2,3). The fourth phase is represented by re-epithelialization, occurring through the proliferation and migration of keratinocytes and the release of several growth factors, such as EGF and TGF $\alpha$ . Additionally, angiogenic factors like Platelet-Derived Growth Factor (PDGF) and VEGF play a

role in angiogenesis, activated by the migration of endothelial cells and the formation of new blood vessels. A reduced number of inflammatory cells and increased collagen deposition are key features of the remodeling phase (4). Regenerative medicine has the potential to support specific goal-directed biomaterial therapies in both acute and chronic wound healing, playing a vital role as cell growth stimulators and in regenerative tissue repair, thereby accelerating wound healing (5). Although natural plants play an essential role in fish health performance (6), they may also represent a source of biomaterials, such as gel extracted from Aloe vera (7). Biomaterials originating from animal sources include platelet-rich fibrin, stem cells, and avian eggshells (8-10). Raffea and Allawi (11) reported the beneficial use of peritoneum in treating anastomosis in dogs. Another advanced biological approach for accelerating wound healing in rabbits involves the skin of carp fish (12). The skin of *Oreochromis niloticus* has been used to treat metacarpal wounds in (13) donkeys. Collagen is considered a novel, advanced base biomaterial for wound dressings due to its unique mechanical and physical properties, including high biodegradability and biocompatibility, low immunogenicity, non-toxicity, and a wide safety margin. It also reduces inflammation and serves as an effective stimulant for the secretion of growth factors, promoting cellular proliferation and adhesion (14-16). Collagen makes up 30% of animal body proteins, and there are 27 types of collagens. The first type is fibrous collagen, a component of connective tissues such as teeth and bones (17,18). Collagen is extracted from the skin of mammals, including bovine and porcine, but this can lead to certain diseases' transmission, posing a public health risk (19). Therefore, many studies have focused on finding alternative sources of natural collagen. Gaikwad and Kim (20) and Srikanya *et al.* (21) reported that the fish industry uses 25% of its products for human consumption. In comparison, 75% is considered waste by-products, including skin, bones, scales, viscera, and heads. Of this discarded fish processing, 30% can be utilized as a source of collagen (22). Collagen is extracted from various aquatic animals, such as sharks (blacktip and bamboo), and from the skin of *P. hypophthalmus*, *Gadus morhua*, and tilapia (23-26). Immunohistochemistry is a vital and significant technique in the pathophysiological dynamics of wound healing due to its ability to visualize *in situ* target tissue components involved in the different stages of wound healing through the use of antibodies labeled with specific markers that can be detected using various microscopy techniques (27).

Although common carp (*Cyprinus carpio*) is the most farmed fish in Iraq, the industry surrounding this species still lacks systematic and advanced processes for recycling its by-products, particularly collagen extraction. Therefore, this study focused on the extraction and examination of the functional groups of collagens from the skin of common carp, as well as evaluating the effective role of the extracted collagen in wound treatment through dermatological

mathematical methods, histological and histochemical analysis, and the assessment of collagen as a stimulator of growth factors using immunohistochemistry reactivity quantification.

## Materials and methods

### Ethical approval

The experiment was carried out on study animals with the approval of the Research Ethics Committee at the College of Veterinary Medicine, University of Mosul, UM.VET.2024.026.

### Fish samples

Live and visually healthy carp fish *Cyprinus carpio* (28-30), weighing 2.5kg and measuring 40cm in length, were transported in ice bags from local markets to the Poultry and Fish Diseases Laboratory at the College of Veterinary Medicine, University of Mosul. A concentration of 150 mg/L was used for general anesthesia in the fish.

### Skin preparation

Scales were removed from the fish's skin, starting from the dorsal shoulder region and the ventral side and moving toward the caudal region. A surgical blade was used to remove the skin from the top to the bottom from the pectoral to the lateral line of the body. It was then cut into small pieces of 0.5\*0.5 cm<sup>2</sup> in size and washed with distilled water; they were placed in polyethylene bags and stored at freezing temperature -18±2°C (31).

### Collagen extraction from fish skin

According to Nagai *et al.* (32), several steps involved in pre-collagen extraction include extracting proteins other than collagen by soaking pieces of skin in a 0.1M sodium hydroxide solution (NaOH) for 24 hours at a ratio of 1:30 (w/v). According to Hukmi and Sarbon (33), non-collagenous material was removed by washing the skin pieces with cold distilled water until reaching a neutral pH of 7. This step is followed by defatting the skins with 10% butanol alcohol for 24 hours while continuously stirring; during this time, the butanol solution is replaced every 8 hours. After that, the skins are washed with cold distilled water (34), followed by collagen extraction using 0.5 M acetic acid at a ratio of 1:10 (w/v) with continuous stirring for 24 hours, then subjected to cold temperature centrifugation (4°C at 10,000 x g for 30 minutes). The residues are redissolved with 0.5 M acetic acid for 12 hours, followed by re-centrifugation. The two supernatants are mixed, salted, and precipitated with 2.6 M NaCl in 0.05 M Tris-HCl at pH 7.5. The subsequent precipitates are redissolved in 0.1 M acetic acid and then dialyzed with a cutoff of 14 kDa against distilled water. The resultant gelatin is kept in a plastic tube and preserved in the refrigerator.

### Study design

White healthy male rabbits (New Zealand), aged 25-30 weeks with a mean weight of 2.500 kg, were used for this experiment. A total of ten rabbits were caged into two groups and maintained under air environmental conditions, with ad libitum access to water and standard pellet ration, along with equal hours of dark/light cycles.

### Pre-operative and surgical incision wound

Xylazine and Ketamine hydrochloride were administered intramuscularly at a dose of 5 and 50 mg/kg body weight, respectively, for general anesthesia. After the para lumbar region was clipped and cleaned, it was disinfected with 10% povidone-iodine. A complete layer of skin measuring 2\*2cm was surgically excised, leaving an opening. The first group remained untreated, while the second group (CoIII treated group) was treated with the application of collagen gel on the experimental wound three times daily.

### Semi-qualitative gross assessment

Semi-qualitative wound healing activity has been reported daily for an extended period after injury, depending on key inflammatory factors (redness, edematous swelling, formation of a white layer (fibrin deposition), thickening of the wound edges (re-epithelialization), and closure of the wound edges).

### Semi-quantitative mathematical assessment

Al-Anaaz *et al.* (12) and Ravishankar *et al.* (35) explain the formula for calculating wound healing activity as follows: Wound Area (WA)% =  $(WA^x/WA^0) * 100$ . Wound Contraction (WC)% =  $([WA^x * 100] / WA^0) - 100$ . Quantitative measure the wound healing rate, derived from the equation (36), as Healing rate =  $(WA^0 - WA^x) / \text{number of days}$ .

### Histopathological assessment

Based on daily follow-up and qualitative macroscopic evaluations of the wound, biopsies were taken from the wound areas (0.5-1 cm) of experimental animals at different time points after injury to evaluate the chain of pathological events related to wound healing. Biopsies were fixed in 10% formalin for routine tissue processing, stained with hematoxylin and eosin, and special staining (Mason Trichrome). Collagen deposition was assessed according to Santos *et al.* (37), as shown in table 1.

Table 1: Score analysis of the collagen catalog in progressive wound healing

Collagen catalog	Score
Orientation	4/ horizontal, 2/mixed, 1/vertical
Pattern	4/fascicle, 2/ mixed, 1/reticular
Amount of early collagen	4/absent, 3/minimal, 2/ modest, 1/intense
Quantity of mature collagen	4/ minimal, 2/modest, 1/intense

### Immunohistochemical analysis

Collagen III (CoIII), VEGF, and keratinocyte -14 were evaluated in the wound biopsy. Following dewaxing, the sample was rehydrated and washed with distilled water, then incubated overnight with primary antibodies, specifically a mouse monoclonal antibody at 4 °C. After washing the samples three times, they were incubated with goat anti-rabbit IgG for one hour, followed by incubation with streptavidin-biotin-horseradish peroxidase for another hour. The samples were washed three times, and 3,3'-diaminobenzidine (DAB) combined with hydrogen peroxide was used to visualize the reaction. Finally, the sections were counterstained with Mayer's hematoxylin (38,39).

### Statistical analysis

The two-way ANOVA was used to compare the data of both study groups at different times, with significance set at  $P \leq 0.05$ . The analysis was completed using the SPSS program (40).

### Results

#### Physical characterization and functional chemical groups of extracted collagens

Collagen extracted from the skin of common carp (*Cyprinus carpio*) fish has a translucent white color and a consistency ranging from watery to low viscosity (Figure 1A). The FTIR analysis of carp collagen extraction revealed numerous peaks in the FTIR chart. The band at  $3304 \text{ cm}^{-1}$  is attributed to N-H amine from aliphatic primary amines. In comparison, the band at  $3079 \text{ cm}^{-1}$  represents C-H aromatic (olefinic) groups. Additionally, peptide C-H is represented at the band  $2923 \text{ cm}^{-1}$ , and the bands at  $17433 \text{ cm}^{-1}$  and  $1452-1635 \text{ cm}^{-1}$  correspond to carbonyl amide and C=C aromatic, respectively (Figure 1B).

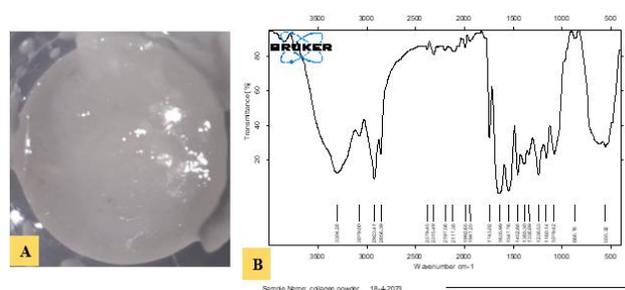


Figure 1: Image of collagen extraction from carp skin (A) and FTIR analysis of carp skin (B).

### Semi-qualitative assessment

Through daily monitoring of the inflammatory signs in the wound area, redness, swelling, and congestion were observed in the untreated group of rabbits on the second and third days following the operation, in contrast to the group treated with fish skin collagen extract, which showed faster

convergence of the wound edges and smaller size of the wound by the seventh day post-operative (PO) as shown in figure 2.

The semi-qualitative assessment (score-grade) results of wound area and healing features indicate that collagen extracted from carp skin plays a vital role in reducing the criteria for inflammatory reaction and improving the healing process. Redness and edema were observed at moderate and mild grades on days three and two in the untreated group, in contrast to mild grades on one day for both features in the

treated group. There was a clear difference using the collagen biomaterial in the deposition of the fibrin layer and the formation of scars on the second and third days, rated at degree (+++), with re-epithelialization and thickening of the wound edges on the fifth day, which occupied score (+++) and severe grade to a level that led to accelerated wound closure on the seventh day. The same pathological events were recorded visually in the untreated group but over longer periods, as clarified in table 2.

Table 2: Semi-qualitative assessment catalog of grossly inflammatory criteria of experimental surgical wound

Experimental groups	Inflammation criteria days POst operative (PO)					
	Redness	Swelling	Layer formation	Scare	Wound edges thickening	Wound closer
Untreated	++ 3 day	+++ 2 day	++ 3 day	+++ 7 day	++ 9 day	+++ 14 day
CoIII -treated	+ 1 day	+ 1 day	+++ 2 day	+++ 3 day	+++ 5 day	+++ 9 days

+++ sever, ++moderate, + mild

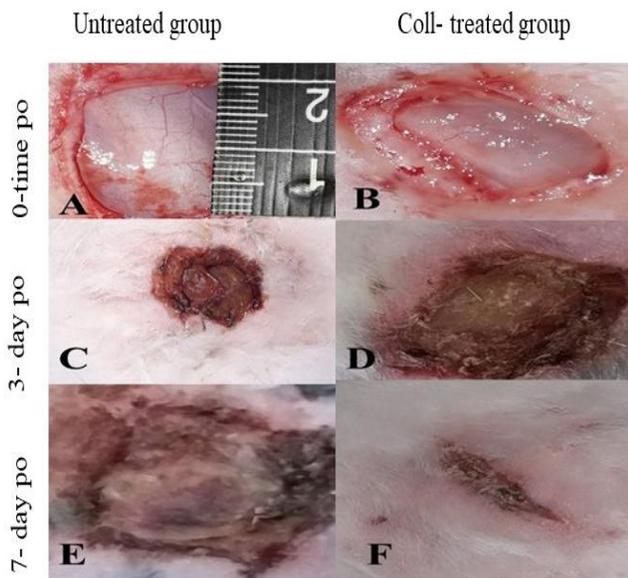


Figure 2: Photograph of the surgical incision wound in the para-lumbar region of male rabbits illustrates the differences in wound healing between the untreated and CoIII-treated groups at 3 and 7 days.

**Semi-quantities assessment**

The statistical analysis of the wound area revealed a reduction in both groups. Still, it was significantly greater in the CoIII-treated group at all time PO, except on the fourth and fifth days when there wasn't a significant difference between the two groups. The wound area was reduced to 0.37 and 0.23% in the treated group, in contrast to the untreated group, where the wound area remained high at 27.57 and 24.27% on the ninth- and tenth-days PO. Furthermore, the daily treatment group with collagen extracted from the skin of carp fish led to highly significant contraction, mainly from

the eighth to tenth days PO, reaching 91.67, 99, and 100%, respectively. In contrast, the untreated group saw wound contraction of 62.10, 72.43, and 75.73% (Figure 3A). The descriptive analysis of the wound healing rate and other mathematical and semi-quantitative methods revealed significant variation in both groups of the recent study. The healing rate is highly significant in the CoIII-treated group compared to the untreated group, with values of 0.59 and 0.34, respectively (Figure 3B).

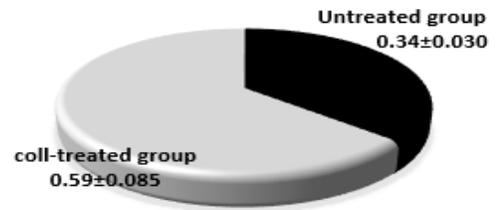
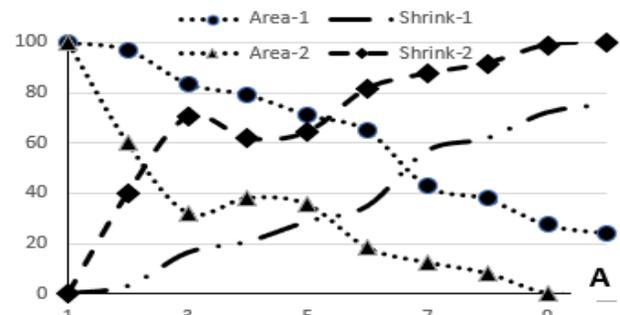


Figure 3: Descriptive histogram of percentage wound area and contraction (Area and Shrinkage-1 refers to the untreated group, while Area and Shrinkage-2 denotes the CoIII-treated group) (A), and wound healing rate (B) in untreated and CoIII-treated groups of rabbits.

### Histological analysis

Histological analysis of the biopsies taken from the wound area of both groups (untreated and treated with collagen) showed a series of pathophysiological events that play a role in the healing process. This was characterized by severe to moderate infiltration of inflammatory cells that continued for three days post-operatively in both the untreated and collagen-treated groups, respectively. Other lesions noted in the histological sections of the wound area in the untreated rabbits included deposition of thin thread collagen, a limited number of new blood vessels, mild proliferation of fibroblasts, and persistence of necrotic tissue (Figure 4-1). In contrast, the histological examination of the wound area in the CoIII-treated rabbits revealed thick collagen bundles, many newly formed capillaries, and severe proliferation of fibroblasts (Figure 4-2). The untreated group exhibited collagen deposition in a reticular pattern and moderate scores for the other two lesions (infiltration of cells and new capillary formation) (Figure 4-3). When collagen extracted from fish skin was applied to the wound area for five days post-operatively, microscopic examination showed improvements in the speed of wound healing, evidenced by maturation of granulation tissue as indicated by collagen deposition parallel to the wound, mild infiltration of mononuclear inflammatory cells, and intense formation of new capillaries (Figure 4-4).

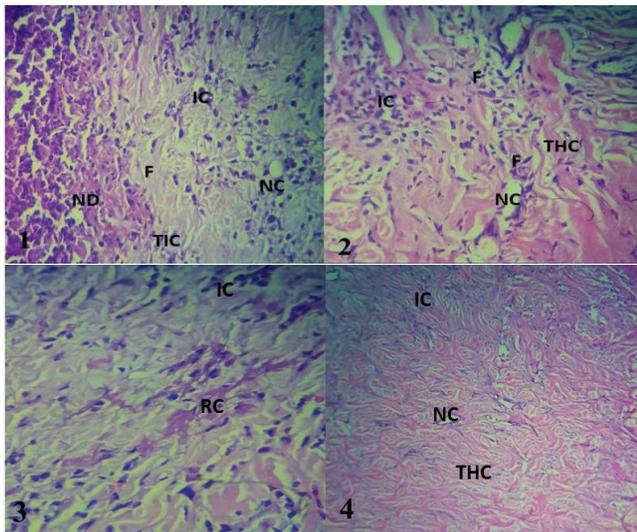


Figure 4: Histological image of the wound area in rabbits, both untreated and treated with collagen extracted from carp skin for three days post-operation (PO) shown in (1 and 2) at 400X magnification, while (3-400) reveals reticular collagen deposition and moderate infiltration of inflammatory cells. The (4-100X) image illustrates the maturation of granulation tissue in the CoIII-treated group on the fifth day PO. ND = necrotic dead tissue, IC = inflammatory cells, F = fibroblast, NC = newly formed capillary, TIC= thin collagen, THC = thick collagen, RC= reticular collagen. H&E.

Re-epithelialization is histologically characterized by hyperplasia of both the epithelial cells lining the dermis layer and the keratinocytes, which leads to a decrease in the distance of the wound area and a partial closure of the wound at nine- and seven days post-operative in the untreated and treated groups, respectively (Figure 5).

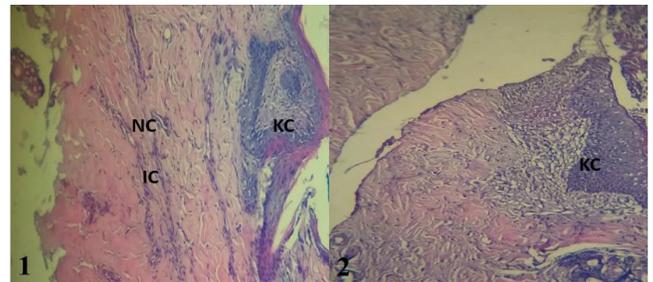


Figure 5: Histological image of the wound area of untreated (1) and treated (2) rabbits with collagen extracted from carp skin after nine- and seven-day PO, respectively. IC = infiltration of inflammatory cells, NC = newly formed capillaries, KC = keratinocytes, H&E, 100X.

Histochemical assessment of the wound area revealed criteria for healing in both study groups. Still, there was variability in the duration of time PO. The collagen orientation was scored as 2/mixed and 1/reticular in the untreated and treated groups, respectively, with minimal and modest amounts of collagen deposition in the untreated and treated groups at three days PO (Figure 6-1). On the fifth day post-operation, the microscopic examination determined a large amount of elastic fiber deposition with a score of 4/fascicle and horizontal, alongside an intense quantity of mature collagen in the CoIII-treated group (Figure 6-2). By the seventh day in the untreated group, this collagen appeared as a mature thick bundle, parallel to the wound area pattern at scores of nine and seven days in both groups, respectively (Figure 6-3). Complete wound healing was observed with the growth of primary hair follicles at ten and fourteen days in both CoIII-treated and untreated groups (Figure 6-4).

### Immunohistochemical (IHC) analysis

Collagen is one of the key factors in wound healing and provides a matrix for regenerative and healing processes. The IHC detected collagen-III as reticular fibers with moderate to strong immunohistochemical staining in the tissue of the scar in the untreated and treated groups, respectively, at seven days post-operative (Figures 7 A and B). Furthermore, recent studies show that the results of the untreated group revealed moderate expression of VEGF at seven days post-wound, while the IHC of the wound area in the CoIII-treated group showed intense immunoreactivity for VEGF expression in the endothelial cells of newly formed capillaries and granulation tissue (Figures 7 C and D).

Keratin-14 expression in this study was dependent on the efficacy of re-epithelization activity. Epidermal regeneration was assessed in the wound area of the treated group on day seven, evidenced by strong intensity in the immunohistochemistry staining of Keratin-14. IHC analysis also revealed mild positive expression in the untreated group (Figures 7 E and F).

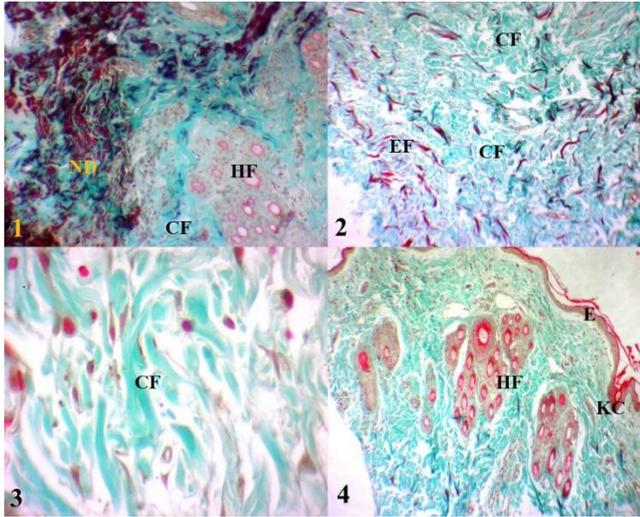


Figure 6: Histological image of the wound area of an untreated rabbit for three days (1), CoIII-treated rabbit for five days post-operation (PO) (2), (3) for seven days PO at 400X, and (4) for ten days PO at 100X, Masson Trichrome 100X. HF = hair follicles, CF = collagen fibers, E = epidermis layer, KC = keratinocyte centers.

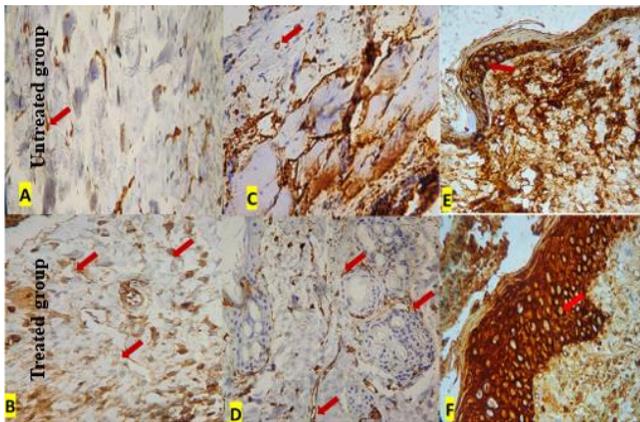


Figure 7: Grade analysis of immunohistochemical staining results of biopsies taken 7 days post-wounding in both untreated and treated groups: moderate to intense staining of CoIII (A and B) and VEGF (C and D) expression, respectively (E), mild keratinocyte -14 expression in the untreated group and intense expression in the treated group (F), 400X.

## Discussion

Biological aquatic waste, including fish, is a rich source of fish oil, enzymes, and collagen and a source of biofuel and renewable energy (41,42). Collagen is the main protein in fish skin components, so it is extracted from carp skin. This finding aligns with the results of (43), which reported that carp fish waste represents the primary and easily accessible source of collagen. The waste was shown to contain functional chemical groups identified by the infrared system, and these results were consistent with studies (44,45). The semi-quantitative results of a recent study revealed the improved effects of collagen dressings in reducing inflammation and significant results related to wound area and contraction, with healing rates of 0.59% and 0.34% in the treated and control groups, respectively. This indicates that collagen from carp skin is a promising bioactive material for accelerating and enhancing wound healing. This finding agrees with the results of AYAD *et al.* (46), who reported that collagen extracted from carp skin serves as an advanced dressing for tissue injury, demonstrating bioactivity and significant effects on wound healing and regeneration (47). Histological examination revealed well-defined wound healing and regeneration tissue in the treated group over a short post-operative period, characterized by moderate infiltration of inflammatory cells and granulation tissue formation with angiogenesis occurring between three to five days, along with re-epithelization by the ninth day. AYAD *et al.* (46) investigated the effects of collagen extraction from carp skin on wound healing in rabbits over 7 to 21 days. The natural compound and bio-dressing properties of collagen can modulate pro-inflammatory macrophages (M1) to anti-inflammatory macrophages (M2), promote angiogenesis, and reduce the duration of the inflammatory phase (48).

Additionally, collagen supports a moist environment, an important factor in healing injured tissue due to its unique three-dimensional structure that increases liquid absorption. Collagen is also the main protein in the extracellular matrix. Its porosity supports flexibility in cell proliferation, migration, and adhesion (49), evidenced by the proliferation of fibroblasts responsible for collagen production, clearly defined as thick bundle deposition by day nine, detected using Masson Trichrome.

Immunohistochemical analysis of wound area sections revealed positive effects of exogenous collagen gel on collagen deposition, vascular endothelial growth factor, and keratinocyte expression. Recent studies show that the intense staining of collagen III in the collagen-treated group suggests that exogenous collagen promotes and accelerates the synthesis and maturation of collagen, increases wound strength, and decreases scar tissue formation (50), Zhuo *et al.* (51) and Ge *et al.*, (52). have reported that extracting collagen from fish improves collagen formation at the wound site. Additionally, VEGF was involved in the wound biopsy sections from the immunohistochemically stained CoIII-

treated group, in contrast to the untreated group. This indicates that collagen -improved angiogenesis and provided a neovascularization bed to supply oxygen and nutrients for healing and tissue regeneration. These results agree with previous findings by Elbially *et al.* (53), who reported that collagen extraction from Nile Tilapia accelerated wound closure and upregulated VEGF expression. The proliferation and migration of keratinocytes (54), called epithelialization, represent the third phase of wound healing and play a crucial role in epidermal regeneration and wound closure. Thus, re-epithelialization was investigated in a recent study through the intense positive keratinocyte immunohistochemistry analysis. This result aligns with earlier reports that exogenous collagen extraction from aquatic fish vitalizes collagen production, triggers the extracellular matrix (ECM), and upregulates the proliferation, migration, and growth of fibroblasts and keratinocytes, which are essential in wound healing (47,55).

## Conclusion

Skin carp collagen extraction is a typical biomaterial in regenerative medicine; it can positively accelerate the repair and regeneration of skin wounds, particularly related to functional groups' activity and its ability to maintain the humidity of the surgical wound area. Additionally, it improves wound healing by increasing collagen deposition and accelerating granulation tissue maturation without scar formation while enhancing re-epithelialization through the upregulation of both VEGF and keratinocyte gene expression. Thus, this preliminary research evaluates the activity of collagen extracted from carp fish skin in wound healing through traditional histological methods and immunohistochemistry (IHC), using descriptive charts and both semi-quantitative and semi-qualitative analyses of the wound site. However, further details about the molecular aspects of remarkable wound healing must be elucidated in future studies.

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## Conflict of interest

The author has no conflicts of interest.

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وإعادة التكوّن الظهاري) إضافة للتعبير الجيني للبروتين المرتبط بالكولاجين الثالث، وعوامل نمو بطانة الأوعية الدموية والكيراتين - ١٤. تم استخلاص الكولاجين كيميائياً من جلد أسماك الكارب السليمة و تم وضعه ثلاث مرات يومياً على الجرح المحدث في المنطقة القطنية للأرناب. تميز الكولاجين المستخلص بالزوجة القليلة والشفافية والقوام المائي، وتم الكشف عن المجموعات الوظيفية للكولاجين بواسطة التحليل الطيفي بالأشعة تحت الحمراء. اظهر التحليل الشبه النوعي عن تمييز في الاستجابة الالتهابية والانخفاض المعنوي في معدل مساحة الجرح و عالي المعنوية في التقلص في المجموعة المعاملة، و اظهر الرسم البياني الوصفي الارتفاع المعنوي لمعدل الالتئام ٠,٥٩ في المجموعة المعاملة، وتمثلت معايير الالتئام بارتشاح خفيف للخلايا الالتهابية ونسج النسيج الحبيبي و اظهر التحليل الكيميائي النسجي سمك وتوازي حزم الكولاجين عند اليوم السابع في المجموعة المعاملة، ورافقت هذه الأحداث الفسلجية المرضية صبغة الكيمياء المناعية الشديدة للكولاجين الثالث وعوامل نمو بطانة الأوعية الدموية والكيراتين ١٤ عند خزعة الجرح. تستنتج هذه الدراسة أن مادة الكولاجين المستخلصة من جلد سمك الكارب يمكن اعتبارها مادة علاجية مبتكرة في الطب التجديدي، حيث تعمل على تسريع شفاء الجروح.

## طريقة مبتكرة للإسراع من التئام الجرح الجراحي في الأرناب بالكولاجين المستخلص من جلد اسماك الكارب الاعتيادي الشائع

شهباء خليل الطائي

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### الخلاصة

تعتبر إعادة تدوير المخلفات الحيوية للبيئة المائية مصدراً للمواد الحيوية وتحدي في الطب الحيوي ، لذا هدفت هذه الدراسة الكشف عن المجاميع الوظيفية للكولاجين المستخلص من جلد الأسماك وتقييم فعاليتها في تسريع التئام الجروح بالاعتماد على الرسم البياني الوصفي الإحصائي لمعدل مساحة وتقلص الجرح ومعدل الالتئام مع التقييم الشبه النوعي العياني ، والتقييم النسجي لكل من معايير الشفاء (الخلايا الالتهابية، وترسب الكولاجين، ونسج النسيج الحبيبي، وتكون الأوعية