

Original Article

Open Access



Hyaluronic acid skin booster injection and cold laser therapy in oral wounds: an experimental study

Noury Adel¹, Nenad Stankovic²

¹Oral and Maxillofacial Surgery Specialist, Private practice, Cairo 11799, Egypt.

²Doctor of Dental Surgery, Specialist of Cosmetology, Private Practice, Belgrade 11000, Serbia.

Correspondence to: Dr. Noury Adel (MSc, DHM), Oral and Maxillofacial Surgery Specialist, Private Practice, Cairo 11799, Egypt.
E-mail: dr.noury100@gmail.com

How to cite this article: Adel N, Stankovic N. Hyaluronic acid skin booster injection and cold laser therapy in oral wounds: an experimental study. *Plast Aesthet Res.* 2025;12:22. <https://dx.doi.org/10.20517/2347-9264.2025.25>

Received: 13 Mar 2025 **First Decision:** 29 Apr 2025 **Revised:** 26 May 2025 **Accepted:** 16 Jun 2025 **Published:** 27 Jun 2025

Academic Editors: Xianwen Wang, Giuseppe Minervini **Copy Editor:** Shu-Yuan Duan **Production Editor:** Shu-Yuan Duan

Abstract

Aim: This study aimed to investigate the impact of combining cold laser therapy with hyaluronic acid skin booster injections on intraoral wound healing, specifically comparing two different incision techniques.

Materials and methods: A total of 24 Wistar Albino rats were included in this study and randomly assigned to four groups; two treatment groups and two control groups. In the treatment groups, incisions using blade or 976 nm diode laser were made, followed by cold laser therapy combined with hyaluronic acid skin booster injections. The control groups underwent incisions using either a surgical blade or a 976 nm diode laser (Woodpecker LX16 Plus, Woodpecker, China) without any additional treatment. Tissue samples were collected at baseline and on postoperative days 3 and 7. Histological analysis was performed using Hematoxylin and Eosin staining and Masson's Trichrome staining to evaluate the wound healing process.

Results: Among the experimental groups, the second treatment group demonstrated significantly enhanced wound healing, particularly on days 3 and 7. This group showed increased collagen deposition, better tissue organization, and enhanced angiogenesis compared to the control groups.

Conclusion: The combination of cold laser therapy and hyaluronic acid skin booster injections significantly accelerated wound healing following both laser and scalpel incisions. Notably, wounds created using the 976 nm diode laser showed superior healing outcomes compared to those made with a scalpel.



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.



Keywords: Low-level laser therapy, laser surgery, hyaluronic acid, skin boosters, experimental study, wound healing, oral surgery, regenerative medicine

INTRODUCTION

Wound healing represents a highly intricate biological process involving a finely tuned interplay among various cell types that proceed through sequential phases: hemostasis, inflammation, proliferation, and finally, tissue remodeling^[1]. Immediately following tissue injury, vasoconstriction occurs in the affected blood vessels, prompting the activation of clotting cascades. This leads to fibrin clot formation, which not only halts hemorrhage but also serves as a reservoir for growth factors essential for initiating the healing process^[1]. A primary objective of using topical therapies for wounds is to minimize infection risks, limit scar formation, and alleviate pain^[2-4].

It is widely recognized that the oral cavity and the skin exist within markedly different environmental contexts. While the skin is subject to external conditions such as air exposure, humidity, and temperature variation, the oral mucosa remains in a consistently moist and warm environment, ideal for microbial colonization. Additionally, the oral tissues are regularly subjected to mechanical forces from chewing and exposure to dietary antigens. The substances that interact with these tissues - ranging from sweat and sebum in the skin to mucus and saliva in the mouth - differ substantially in pH, biochemical makeup, and biological roles. These variances directly influence how each tissue type heals. For instance, cutaneous healing is enhanced in moist environments that support re-epithelialization, angiogenesis, and wound bed maturation. In contrast, oral healing benefits from the inherent moisture of saliva, which contains biologically active proteins and peptides such as fibroblast growth factor, epidermal growth factor, and vascular endothelial growth factor (VEGF), all of which actively participate in the tissue repair process^[5,6].

A wide array of therapeutic approaches has been introduced for wound management, including autologous platelet gel, cold laser, and hyaluronic acid (HA) application. Autologous platelet gel (APG) is a concentrated biological product derived from the patient's own blood, rich in platelets and embedded growth factors such as platelet-derived growth factor, transforming growth factor-beta (TGF- β), and VEGF. When applied to surgical or wound sites, APG acts as a bioactive scaffold that supports cellular migration, angiogenesis, and matrix remodeling, thereby accelerating the healing process. Its autologous nature eliminates the risk of immunogenic reactions or disease transmission, making it particularly advantageous in oral surgical procedures. Clinical and preclinical studies have demonstrated that APG enhances both soft and hard tissue regeneration, improves hemostasis, and contributes to a reduction in postoperative inflammation and pain^[6].

Cold laser (Photobiomodulation, low-level laser, non-thermal laser) is well-documented for promoting the synthesis of collagen types I and III and for exerting beneficial effects on soft tissue regeneration. It is an effective modality for managing cutaneous injuries and scar tissue. Cold laser therapy, a form of low-level laser therapy, has demonstrated efficacy in enhancing post-extraction healing outcomes in dental settings. Research findings suggest that cold laser has the potential to reduce pain, limit swelling, and improve the overall postoperative experience for patients undergoing tooth extractions. The promising outcomes advocate for its future integration into standard dental practice, with further studies recommended to validate its utility in clinical care settings^[7].

In addition, recent animal studies have examined the synergistic effect of cold laser in conjunction with lipid nanoparticles and hyaluronic acid on full-thickness skin wounds in Wistar rats. These studies revealed improvements in wound contraction, suppression of pro-inflammatory cytokines, and elevation of anti-inflammatory markers. Histological evaluations confirmed that the combined treatment significantly

promoted tissue repair. HA, meanwhile, contributes to wound repair by enhancing epithelial regeneration and stimulating collagen production, thereby facilitating tissue recovery^[8-10].

Although both cold laser and HA have been independently explored for their roles in therapeutic and cosmetic interventions, current literature lacks any comprehensive investigation into their combined use for intraoral wounds produced by either surgical blades or lasers. This study, therefore, aims to introduce and assess a novel therapeutic strategy that leverages both modalities to accelerate and enhance the wound healing process in oral tissues.

MATERIALS AND METHODS

This *in vivo* experimental study involved 24 healthy adult male Wistar albino rats (*Rattus norvegicus*), aged between 4-6 months and weighing 110-170 grams. These animals were selected due to their genetic homogeneity, manageable temperament, and well-documented healing patterns, especially in oral mucosal models. Wistar rats also exhibit an immune response and histological wound repair sequence that closely resembles that of human oral mucosa, making them a reliable model for translational research in oral soft tissue healing. All animals were procured from a certified laboratory animal facility and were housed in standard plastic cages under controlled temperature (22 ± 2 °C), humidity ($55 \pm 10\%$), and a 12-h light/dark cycle. A one-week acclimatization period was provided before initiating any experimental procedures to allow for physiological and psychological adjustment.

Given the location of the surgical wounds (buccal mucosa), special attention was given to dietary consistency to minimize mechanical trauma and ensure uniform wound healing conditions. The rats were fed a soft, nutritionally complete pellet diet that was moistened with sterile distilled water to form a soft mash. This modification prevented disruption or contamination of the intraoral wound during mastication, reduced mechanical irritation, and supported consistent nutritional intake without compromising the integrity of the healing tissues. Food and water were provided *ad libitum*, and all cages were cleaned and inspected daily. The study protocol was approved by the Institutional Animal Care and Use Committee, and all procedures complied with international ethical guidelines for animal experimentation.

Following random allocation, rats were divided into four groups ($n = 6$ per group). General anesthesia was administered using intraperitoneal injection of ketamine (80 mg/kg) and xylazine (10 mg/kg) before any surgical intervention. The following protocols were performed:

Group 1: A 2 mm × 2 mm incision (1 mm deep) was made in the buccal mucosa using a scalpel. Hemostasis was achieved by gentle compression with sterile gauze. Cold laser therapy was then applied using a Woodpecker LX16 Plus diode laser (Woodpecker, China), emitting at a wavelength of 650 nm. Following cold laser, 0.05 mL of non-crosslinked hyaluronic acid skin booster (Apriline Hydro®, Suisselle SA, Switzerland) was injected into the wound bed and margins. Cold laser therapy was repeated once more on the third postoperative day.

Group 2: The same incision was made using a 976 nm diode laser (Woodpecker LX16 Plus), followed by the same steps as in Group 1 (Cold laser and HA injection).

Group 3 (Control): A scalpel incision of identical dimensions was performed, with no further intervention.

Group 4 (Control): A 976 nm diode laser (Woodpecker LX16 Plus) was used to create the incision, with no additional treatment applied.

The Woodpecker LX16 Plus diode laser device used for creating wounds was a fiber-optic delivered diode laser with standardized settings. The laser was operated at a 2-watt power in continuous mode for 2 s per application. Cold laser therapy was applied for 5 minutes for all wounds in the study groups using 200 mW. The device was calibrated before each procedure to ensure consistency across all treatments. The wavelengths of 650 nm and 976 nm were selected based on their specific tissue absorption characteristics, which are critical in promoting wound healing. The 650 nm wavelength has been shown to effectively penetrate soft tissues and stimulate cellular processes such as collagen production and angiogenesis, which are key to wound healing. The 976 nm wavelength is known for its high penetrating power deep into the tissues and optimum coagulation effect during cutting. Both wavelengths were chosen to maximize the therapeutic benefits of photobiomodulation in oral mucosal healing.

All rats received the same volume of non-crosslinked hyaluronic acid injection (0.05 mL), which was sourced from Apriline Hydro® (Suisselle SA, Switzerland). In this study, hyaluronic acid was injected immediately post-wounding. This timing was chosen based on the rationale that early administration of hyaluronic acid can accelerate the initial inflammatory and proliferative phases of wound healing. Although multiple time points were not tested, the focus was to assess the effects of early post-injury administration.

No postoperative dressing was applied to any of the wounds, nor was there any antibiotic ointment or suturing used to close the incisions. Tissue biopsies were collected at three time points - baseline (immediately post-procedure), postoperative day 3, and postoperative day 7. At each interval, two rats from each group were euthanized using a high-dose anesthesia protocol. Specimens were harvested for histological analysis, including Hematoxylin and Eosin (H&E), Masson's Trichrome (MT) staining for collagen fiber evaluation. To minimize observational bias, histological analysis was conducted by an independent pathologist who was blinded to the experimental groups. This was to ensure objectivity in the interpretation of the healing progression, including tissue architecture, collagen deposition, and angiogenesis, without bias introduced by the experimenter's expectations [Figure 1].

Sample size calculation

The sample size for this study was determined using a power analysis to ensure sufficient statistical power to detect significant differences between groups. The analysis was based on an expected effect size (Cohen's d), the desired alpha level ($\alpha = 0.05$), and the required power ($1 - \beta = 0.80$), which is typically considered adequate for experimental studies. Using an effect size of 1.0, which is considered a large effect size based on previous studies involving similar interventions in wound healing, and an alpha level of 0.05 (5% significance level), the required sample size for detecting differences between the groups with 80% power was calculated. The results of the power analysis indicated that a minimum of 6 animals per group would provide sufficient power to detect significant differences between the experimental groups (treatment vs. control groups) for the primary outcome measures. This sample size calculation was performed using G*Power software (Version 3.1), which is widely used for determining statistical power and sample size in experimental studies.

Statistical analysis

To assess the normality of the data, both the Kolmogorov-Smirnov and Shapiro-Wilk tests were applied. Descriptive statistics, including both the mean and median, were calculated to understand the distribution of the data. Since the data followed a normal distribution, the results were presented as the mean \pm standard deviation (SD). A two-way analysis of variance was used to analyze the impact of different experimental

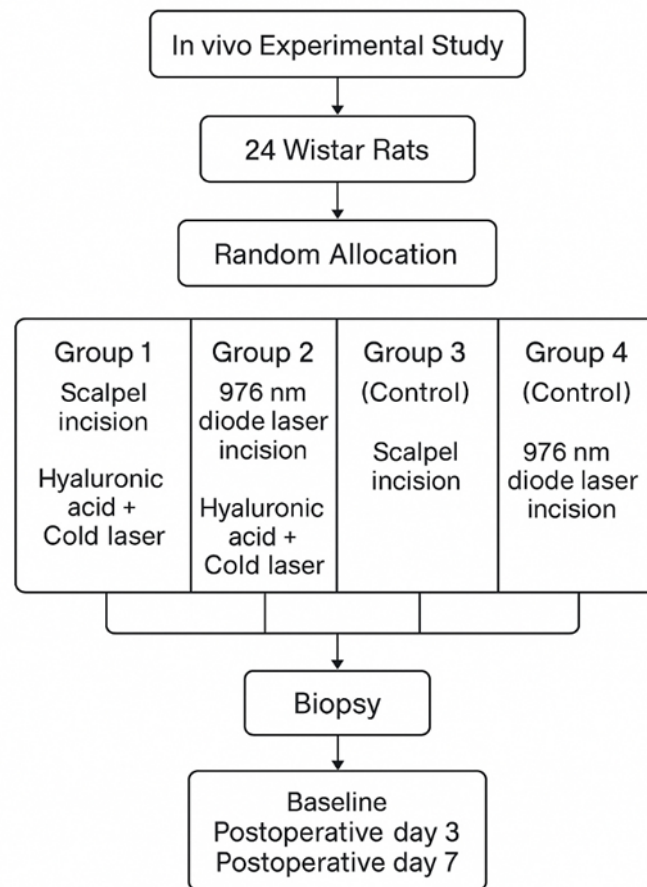


Figure 1. Study Design Flowchart. This *in vivo* experimental study was conducted using 24 Wistar rats, randomly allocated into four groups. Group 1 received a scalpel incision followed by the application of hyaluronic acid and cold laser treatment. Group 2 underwent a 976 nm diode laser incision with hyaluronic acid and cold laser treatment. Groups 3 and 4 served as control groups, with group 3 receiving a scalpel incision and group 4 undergoing a 976 nm diode laser incision. Biopsy samples were collected at baseline, postoperative day 3, and postoperative day 7 for histological analysis.

factors and their interactions. For pairwise comparisons of the effects, t-tests with Bonferroni correction were utilized to adjust for multiple comparisons. A significance threshold of $P \leq 0.05$ was established for all statistical tests. All statistical computations were carried out using IBM® SPSS® Statistics Version 26 (Windows).

RESULTS

Histological analysis, using H&E staining, revealed significant differences in the wound healing response between the groups at baseline, day 3, and day 7.

At baseline, Group 1 showed clean, sharp incision edges with minimal bleeding, indicating minimal immediate tissue disruption. Group 2 demonstrated thermal damage at the wound site, but the combination of hyaluronic acid and biostimulation promoted early stabilization and reduced inflammation. Group 3's baseline samples exhibited immediate disruption of both the epithelial layer and connective tissue, with inflammatory cell infiltration and hemorrhage evident. Group 4 samples, in contrast, showed more extensive coagulative necrosis and tissue dehydration at the incision edges compared to other groups, indicating greater tissue damage at baseline.

On day 3, Group 1 displayed a mild inflammatory response, primarily characterized by lymphocytes, with early re-epithelialization, granulation tissue formation, and fibroblast proliferation evident. Additionally, angiogenesis was noted in the wound area, and edema was minimal. In Group 2, the inflammatory response was also mild, and the combination of hyaluronic acid and biostimulation appeared to reduce edema and enhance fibroblast activation. Early granulation tissue formation was observed, and the wound demonstrated early re-epithelialization and limited inflammatory cell infiltration. Group 3 exhibited acute inflammation with the presence of neutrophils, alongside disrupted epithelial layers and early re-epithelialization. The connective tissue showed edema and early fibroblast proliferation. Group 4, however, showed more pronounced inflammation, with delayed granulation tissue formation, slower fibroblast activity, and a disrupted epithelial layer compared to the other groups.

On day 7, Group 1 demonstrated nearly complete re-epithelialization, with a thin epithelial layer covering the wound. The connective tissue exhibited increased fibroblast activity, collagen deposition, and well-organized granulation tissue, leading to minimal scarring. Group 2 showed near-complete re-epithelialization and more advanced collagen organization, with increased fibroblast activity and collagen deposition. Active angiogenesis contributed to tissue repair, and only minimal inflammation was noted, facilitating effective wound closure. Group 3 displayed more advanced re-epithelialization, with the wound covered by a thick epithelial layer. The connective tissue showed increased fibroblast activity and collagen deposition, with improved angiogenesis. Minimal inflammation was present, indicating active wound healing. In contrast, Group 4 displayed incomplete re-epithelialization, with less organized collagen deposition and delayed tissue remodeling, reflecting prolonged tissue damage.

MT staining further confirmed these findings. Group 1 showed disruption of the collagen network at baseline, but on day 3, enhanced collagen production and organized extracellular matrix restoration were noted, as evidenced by intense blue staining. On day 7, the collagen fibers were well-organized, with dense blue-green staining indicating advanced wound healing. In Group 2, baseline samples exhibited lighter blue-green staining due to the extent of tissue injury. However, by day 3, collagen deposition was significantly enhanced, with more intense blue staining, indicating rapid extracellular matrix restoration. By day 7, collagen fibers were densely stained in blue-green, reflecting advanced tissue maturation and well-organized extracellular matrix remodeling.

Group 3's baseline samples showed a clear disruption of collagen fibers at the incision site, with minimal collagen deposition. On day 3, granulation tissue was forming, but collagen deposition remained disorganized. By day 7, collagen deposition was more pronounced, with thicker and more organized fibers in the wound area.

In Group 4, baseline samples exhibited extensive necrosis and fragmentation of the collagen matrix. By day 3, collagen regeneration was slower, and fibroblast activity was delayed, with disorganized collagen fibers. On day 7, collagen deposition was visible but still less organized compared to other groups, indicating slower tissue remodeling and healing.

Overall, histological analysis using H&E and MT staining demonstrated that Group 2, treated with hyaluronic acid skin booster injection and cold laser therapy, showed the most advanced wound healing, with complete re-epithelialization, enhanced fibroblast activity, and well-organized collagen deposition by day 7. This group exhibited superior wound closure and tissue remodeling compared to the other groups [Figures 2-7].

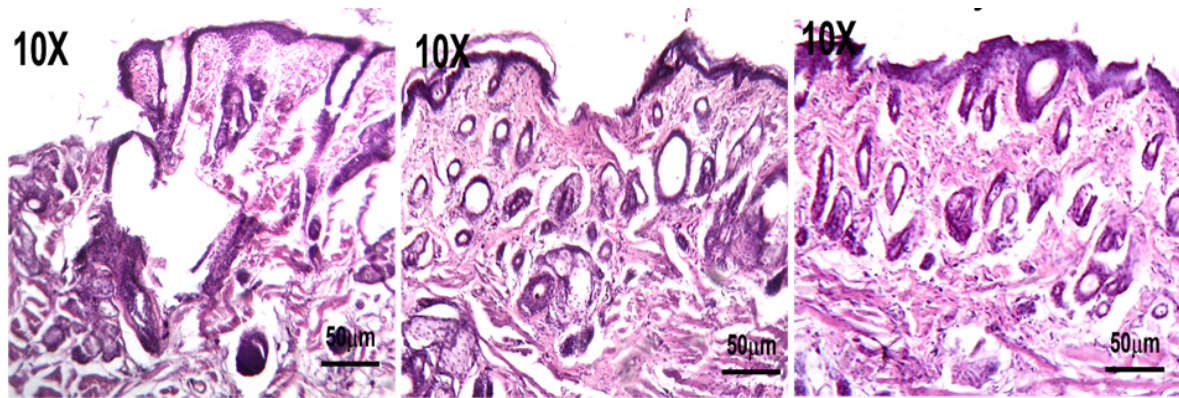


Figure 2. H&E staining of samples from Group 1. From left to right: baseline sample, Day 3 sample, and Day 7 sample. H&E: Hematoxylin and Eosin.

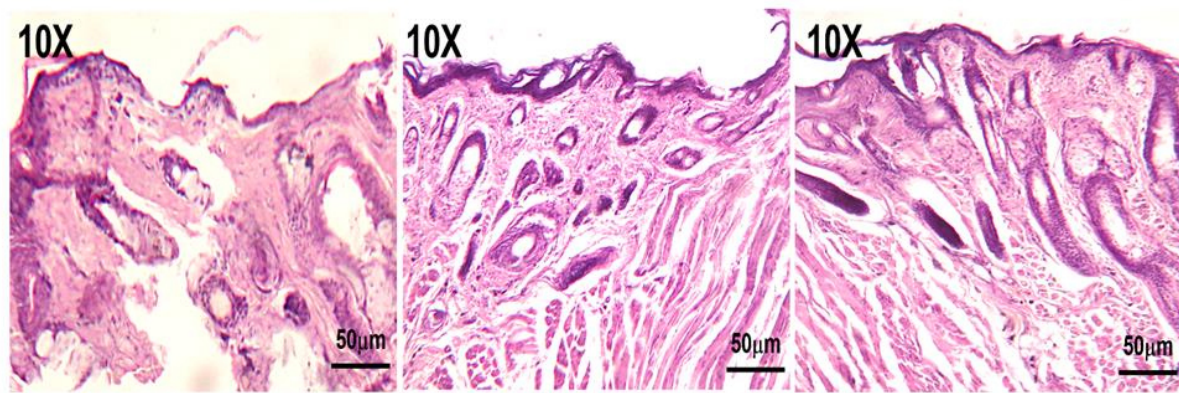


Figure 3. H&E staining of samples from Group 2. From left to right: baseline sample, Day 3 sample, and Day 7 sample. H&E: Hematoxylin and Eosin.

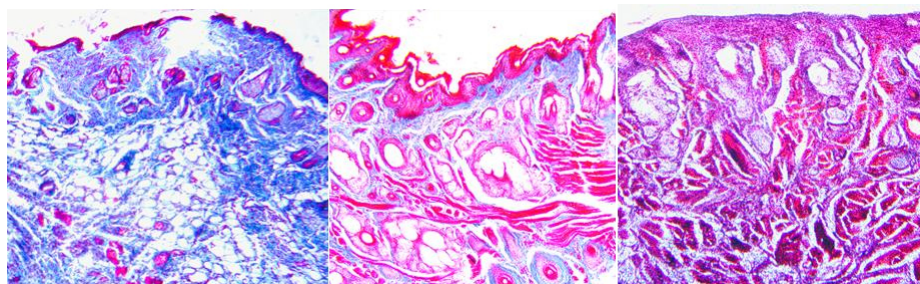


Figure 4. MT staining of samples from Group 1. From left to right: baseline sample, Day 3 sample, and Day 7 sample. MT: Masson's Trichrome.

DISCUSSION

Wound healing in the oral cavity is a complex process influenced by multiple local and systemic factors. In this experimental model, soft tissue incisions made using a 976 nm diode laser, followed by cold laser therapy with a 650 nm laser and hyaluronic acid (HA) injection, demonstrated superior healing outcomes compared to traditional scalpel incisions receiving the same adjunctive treatments.

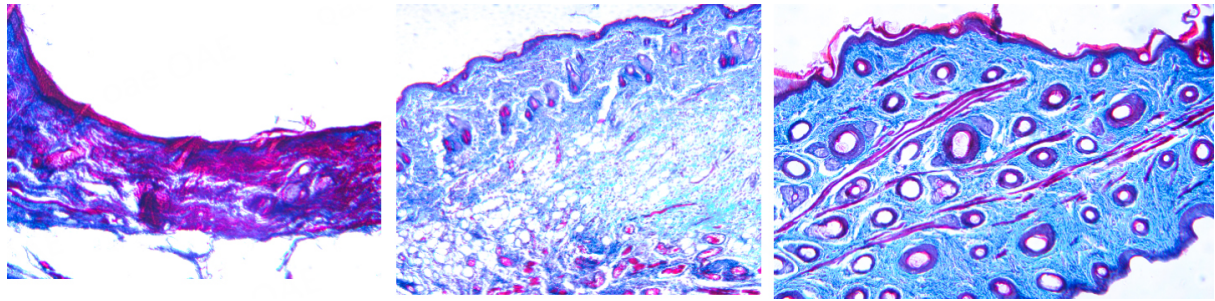


Figure 5. MT staining of samples from Group 2. From left to right: baseline sample, Day 3 sample, and Day 7 sample. MT: Masson's Trichrome.

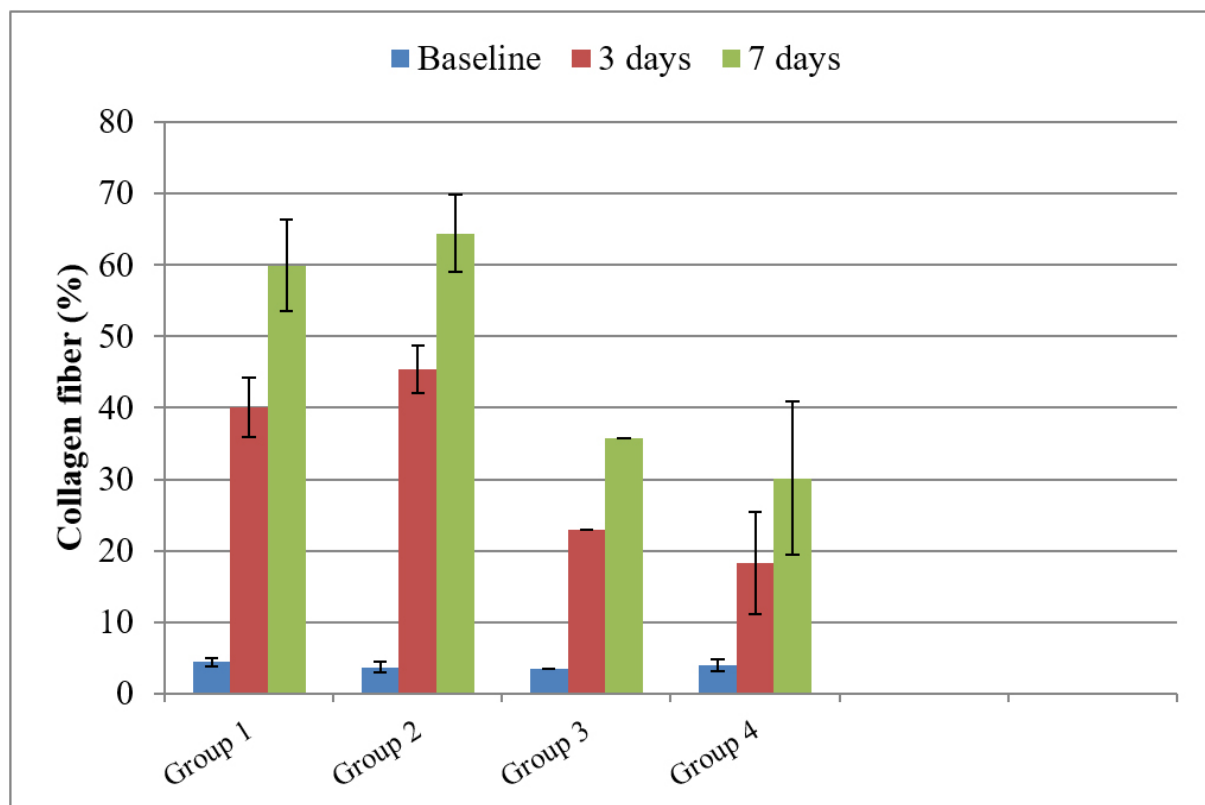


Figure 6. Bar chart showing the average collagen fiber content at different time points within each group.

The diode laser at 976 nm, operating in the near-infrared spectrum, exhibits high absorption in water and hemoglobin, enabling effective soft tissue incision with simultaneous coagulation. This results in improved hemostasis and a cleaner surgical field, reducing intraoperative bleeding and postoperative edema. Although laser-tissue interaction inherently involves thermal effects, careful parameter control in this study minimized collateral damage. Histologically, the laser group showed improved epithelial regeneration, increased fibroblast proliferation, and more organized collagen fiber deposition by the 14th postoperative day. These findings are consistent with previous reports emphasizing the regenerative potential of high-wavelength diode lasers when used appropriately^[11-17].

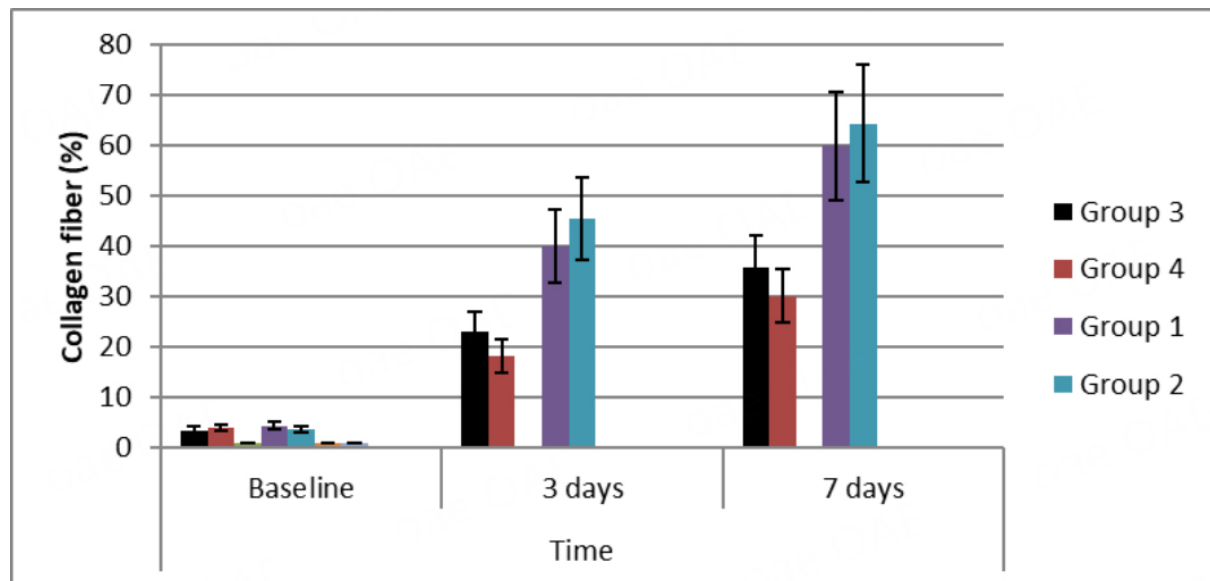


Figure 7. Bar chart showing the average collagen fiber content across different groups at each time point.

Cold laser therapy using a 650 nm low-level laser was employed postoperatively in all groups. Red light at this wavelength is well-documented to penetrate tissue efficiently, with absorption peaks in cytochrome c oxidase, leading to increased ATP production, modulation of reactive oxygen species, and upregulation of transcription factors involved in cell proliferation and migration^[18,19]. These effects contribute to accelerated wound closure, reduced inflammation, and enhanced collagen synthesis - outcomes corroborated by the histological findings in both groups^[20-25].

Hyaluronic acid, also administered in all animals, likely played a significant adjunctive role in promoting wound healing. As a major component of the extracellular matrix, HA supports tissue hydration, modulates the inflammatory response, and facilitates cellular activities essential for tissue regeneration. Its interaction with CD44 receptors on fibroblasts and keratinocytes activates signaling pathways that promote granulation tissue formation, neovascularization, and epithelialization^[20]. While its contribution cannot be quantified independently in this study design, its synergistic effect with cold laser therapy and the type of incision method is strongly suggested by the enhanced outcomes observed.

Despite the advantages of laser incision and the biological support provided by HA and cold laser, thermal damage to surrounding tissues remains a potential concern with high-power diode lasers. In this study, although some early inflammatory infiltration and mild peripheral necrosis were noted in the laser group, these effects were transient and did not impair overall healing. This aligns with findings from Al-Ani *et al.*^[17], who documented localized thermal effects with 980 nm lasers but observed rapid tissue recovery. The regenerative response appears to outweigh the temporary injury when energy parameters are well controlled.

When cold laser therapy using a 650 nm diode laser and non-crosslinked HA skin booster injections were applied in conjunction with the 976 nm diode laser, they significantly improved the healing process compared to the use of the 976 nm diode laser alone. This combination therapy enhanced tissue regeneration, reducing inflammation and promoting faster wound closure. However, in the absence of this adjunctive treatment, the scalpel incision demonstrated superior healing outcomes compared to the 976 nm

diode laser, as evidenced by the control groups. These findings suggest that while the 976 nm diode laser is effective for soft tissue incisions, the addition of cold laser and HA skin boosters is crucial for optimizing wound healing, surpassing the results achieved by laser treatment alone.

Statistical analysis confirmed significant differences in healing parameters between the groups, particularly in terms of inflammatory cell count and fibroblast density. While p-values supported these findings, future studies should incorporate effect sizes and confidence intervals to provide a more comprehensive understanding of the clinical relevance of these differences. Additionally, objective quantification of pro-inflammatory and proliferative markers through immunohistochemistry would strengthen mechanistic interpretations.

A notable limitation of this study is the uniform application of cold laser and HA in both groups, which prevents direct assessment of the individual contributions of each adjunctive modality. A more granular study design, including groups receiving HA or cold laser alone, would be valuable in delineating their respective roles. Furthermore, long-term follow-up extending beyond the inflammatory and proliferative phases would clarify whether laser-assisted healing provides lasting histological and functional benefits.

Clinically, the integration of laser surgery with biostimulatory therapy and regenerative agents holds promise for optimizing wound healing in oral and periodontal procedures. The use of 976 nm diode lasers offers practical advantages, including precision, reduced bleeding, and patient comfort, while adjunctive 650 nm cold laser and HA application may further enhance outcomes. However, clinical trials in human subjects are needed to validate these findings and establish standardized protocols for combined therapies.

Conclusion

The combination of a 976 nm diode laser for incision creation, followed by cold laser therapy with a 650 nm diode laser and non-crosslinked hyaluronic acid skin booster injection, shows considerable promise in enhancing the healing of oral wounds. This integrated approach appears to foster improved tissue regeneration, reduce inflammation, and accelerate wound closure, making it a potential adjunct in oral and maxillofacial surgical procedures. This research could pave the way for establishing more effective, evidence-based treatment protocols aimed at optimizing post-surgical healing and patient recovery in oral surgery.

DECLARATIONS

Authors' contributions

Conceptualization and study design, experimental work, data collection and analysis, manuscript writing and revision: Adel N

Provision of essential products and research materials: Stankovic N

Availability of data and materials

Data are available from the corresponding author upon reasonable request.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

This animal study was conducted with the approval of the Institutional Animal Care and Use Committee of Cairo University, under approval number CU I F 34 24, as stated in the methodology section.

Consent for publication

Not applicable.

Copyright

© The Author(s) 2025.

REFERENCES

1. Criollo-Mendoza MS, Contreras-Angulo LA, Leyva-López N, Gutiérrez-Grijalva EP, Jiménez-Ortega LA, Heredia JB. Wound healing properties of natural products: mechanisms of action. *Molecules*. 2023;28:598. DOI PubMed PMC
2. Saifullah Q, Sharma A. Current trends on innovative technologies in topical wound care for advanced healing and management. *Curr Drug Res Rev*. 2024;16:319-32. DOI PubMed
3. Ishi S, Kanno E, Tanno H, et al. Cutaneous wound healing promoted by topical administration of heat-killed *Lactobacillus plantarum* KB131 and possible contribution of CARD9-mediated signaling. *Sci Rep*. 2023;13:15917. DOI PubMed PMC
4. Frykberg R, Andersen C, Chadwick P, et al. Use of topical oxygen therapy in wound healing. *J Wound Care*. 2023;32:S1-S32. DOI
5. Misra P, Kalsi R, Anand Arora S, Singh KS, Athar S, Saini A. Effect of low-level laser therapy on early wound healing and levels of inflammatory mediators in gingival crevicular fluid following open flap debridement. *Cureus*. 2023;15:e34755. DOI PubMed PMC
6. Scarano A, Inchingolo F, Rapone B, Lucchina AG, Qorri E, Lorusso F. Role of Autologous Platelet Gel (APG) in bone healing: a rabbit study. *Appl Sci*. 2021;11:395. DOI
7. He K, Zhou X, Zheng F, Ju X, Fu SN, Wong AYL. Histological, physiological and biomechanical effects of low-level laser therapy on tendon healing in animals and humans: a systematic review. *Ann Biomed Eng*. 2023;51:2659-707. DOI
8. Wekwejt M, Małek M, Ronowska A, et al. Hyaluronic acid/tannic acid films for wound healing application. *Int J Biol Macromol*. 2024;254:128101. DOI
9. Oliveira JA, da Silveira MI, de Oliveira Alves R, Bezerra FJB, de Oliveira GJPL, Pigossi SC. Effect of a gel containing green tea extract and hyaluronic acid on palate pain scores and wound healing after free gingival graft: a quasi-randomized controlled clinical trial. *Clin Oral Investig*. 2023;27:6735-46. DOI
10. Lee JH, Lee KE, Kang SW, et al. Effect of orodispersible hyaluronic acid film on palatal mucosa wound healing. *Oral Dis*. 2024;30:518-27. DOI
11. Abesi F, Derikvand N. Efficacy of low-level laser therapy in wound healing and pain reduction after gingivectomy: a systematic review and meta-analysis. *J Lasers Med Sci*. 2023;14:e17. DOI PubMed PMC
12. Jiang D, Liu G, Yang B, et al. 450-nm blue diode laser: a novel medical apparatus for upper tract urothelial lesions. *World J Urol*. 2023;41:3773-9. DOI PubMed PMC
13. Fornaini C, Merigo E, Rocca JP, et al. 450 nm blue laser and oral surgery: preliminary *ex vivo* study. *J Contemp Dent Pract*. 2016;17:795-800. DOI
14. Fornaini C, Fekrazad R, Rocca JP, Zhang S, Merigo E. Use of blue and blue-violet lasers in dentistry: a narrative review. *J Lasers Med Sci*. 2021;12:e31. DOI PubMed PMC
15. Etemadi A, Taghavi Namin S, Hodjat M, Kosarieh E, Hakimiha N. Assessment of the photobiomodulation effect of a blue diode laser on the proliferation and migration of cultured human gingival fibroblast cells: a preliminary *in vitro* study. *J Lasers Med Sci*. 2020;11:491-6. DOI PubMed PMC
16. Palaia G, Renzi F, Pergolini D, et al. Histological *ex vivo* evaluation of the suitability of a 976 nm diode laser in oral soft tissue biopsies. *Int J Dent*. 2021;2021:6658268. DOI PubMed PMC
17. Al-Ani AJ, Taher HJ, Alalawi AS. Histological evaluation of the surgical margins of oral soft tissue incisions using a dual-wavelength diode laser and an Er, Cr:YSGG laser; an *ex vivo* study. *J Appl Oral Sci*. 2024;32:e20230419. DOI
18. Sourvanos D, Lander B, Sarmiento H, Carroll J, Hall RD, Zhu TC, Fiorellini JP. Photobiomodulation in dental extraction therapy: Postsurgical pain reduction and wound healing. *J Am Dent Assoc*. 2023;154:567-79. DOI PubMed PMC
19. Zaccaron RP, Barbieri RT, Mendes C, et al. Photobiomodulation associated with lipid nanoparticles and hyaluronic acid accelerate the healing of excisional wounds. *J Biomater Appl*. 2022;37:668-82. PubMed
20. Frankowski DW, Ferrucci L, Arany PR, et al. Light buckets and laser beams: mechanisms and applications of photobiomodulation (PBM) therapy. *Geroscience*. 2025. DOI
21. Oliveira PC, Correia LO, Lopes NMD, Molossi J, Fornazieri MA. Efficacy of using photobiomodulation therapy in allergic rhinitis: a placebo-controlled randomized clinical trial. *Int Forum Allergy Rhinol*. 2025;15:594-601. DOI PubMed
22. Barati S, Motevasseli S, Saedi HS, Amiri P, Fekrazad R. Effectiveness of Photobiomodulation (low-level laser therapy) on treatment of oral mucositis (OM) induced by chemoradiotherapy in head and neck cancer patients. *J Photochem Photobiol B*. 2025;264:113115. DOI PubMed

23. Khalil M, Hamadah O, Saifo M. Photobiomodulation preconditioning for oral mucositis prevention and quality of life improvement in chemotherapy patients: a randomized clinical trial. *BMC Oral Health.* 2025;25:190. [DOI](#) [PubMed](#) [PMC](#)
24. Wang L, Mao L, Huang Z, Switzer JA, Hess DC, Zhang Q. Photobiomodulation: shining a light on depression. *Theranostics.* 2025;15:362-83. [DOI](#) [PubMed](#) [PMC](#)
25. Vianna Camolesi GC, Prado-Pena IB, Gómez-Caamaño A, et al. Photobiomodulation for the prevention of oral side effects secondary to head and neck cancer therapy: results of a randomised, single-blind clinical trial. *Oral Oncol.* 2025;164:107266. [DOI](#)