Chapter 13

Laser Technology in Medicine: Types, Mechanisms, and Applications With a Focus on Stem Cell Biology and Regenerative Medicine

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Abstract

Laser technology has profoundly restructured the biomedical field by providing selective, minimally invasive therapeutic interventions. Lasers with quantum electronics principles can generate coherent, monochromatic light with the potential to influence microorganisms. Recent data have confirmed the putative stimulatory and inhibitory role of laser irradiation on the regulation of different stem cell bioactivities and obtaining regenerative outcomes. The

potential effect of laser irradiation on stem cell differentiation capacity, paracrine activity, proliferation, dynamic growth, etc., has been proven using several *in vitro*, pre-clinical, and clinical studies. Therefore, laser technology can be used as a complementary and alternative approach in the control of cell therapy efficiency. Here, in this chapter, we aimed to illuminate laser applications through stem cell and regenerative biology. Remarkably, the advent of LLLT[1] as a non-thermal light-based technique with positive effects on different cell activities will be discussed. Data from the current chapter can help us in the translation of laser technology to the clinical setting with cutting-edge advances to improve stem cell-based therapy outcomes.

Keywords: Low-level Laser Irradiation, Stem Cells, Cell Therapy, Regenerative Medicine.

1. Introduction

Laser beams are emitted by photons via optical amplification based on the stimulated emission of electromagnetic radiation [1, 2]. Parameters like monochromaticity, coherence, and collimation are integral to laser irradiation [2]. Of note, an energy source excites electrons within a lasing medium and emits photons, stimulating the emission of more photons of identical phases and energy [3]. Hence, this phenomenon creates a focused, amplified beam of light capable of precise interaction with biological tissues. It is thought that absorption, reflection, scattering, and transmission are involved in laser-tissue interactions [4-6]. During the past decades, various laser types, including CO_2, argon, and Nd: YAG[2] lasers, have been fabricated for different therapeutic purposes (**Table 1**) [7-10]. Considering the unique features, such as fewer toxic effects, precision,

[1]. Low-level laser therapy
[2]. Neodymium-doped yttrium aluminum garnet

and biological effects on unicellular and multicellular creatures, the application of lasers has been extended in biomedicine [11-13]. These effects are generated via the physical properties of the lasing medium and the emission of photons with certain wavelengths, with the potential to penetrate deep layers inside the cells and interact directly with the signaling biomolecules or subcellular compartments [14, 15]. Therefore, the classification of lasers in biomedicine is done based on the active lasing medium and emission wavelength [4, 15-17]. For instance, a CO_2 laser produces an infrared radiation beam at a wavelength of 10600 nm, which can be absorbed by water in biological systems [18, 19]. This laser type can be used for the destruction and removal of soft tissues with high accuracy and less damage to the neighboring tissues. Therefore, it can be applied to the regulation of scar tissue and cutaneous tissue rejuvenation, alleviation of various vocal cord and pulmonary system pathologies, and removal of masses from the reproductive system with the necessity for LEEP[1]. In dentistry, laser application is common in gingivectomy and periodontal interventions [20-22]. The CO_2 laser can incise the tissues and simultaneously stimulate the coagulation for the inhibition of intraoperative bleeding [20, 23]. In contrast, Er: YAG[2] laser functions at 2940 nm and primarily targets aqueous phases in the biological systems [24-28]. Compared to the CO_2 laser, the Er: YAG laser exhibits less thermal diffusion with less collateral damage [4, 29-33]. These features can contribute to fidelity and rapid post-operative healing [34, 35]. The Nd: YAG laser emitting at 1064 nm can penetrate deep tissues [36]. Due to the stimulation of coagulation and photo-thermolysis, this laser type is applicable for the inhibition of tumor cell growth and treatment of

[1]. Loop electrosurgical excision procedure
[2]. Erbium-doped yttrium aluminum garnet

cardiovascular disease [37, 38]. However, uncontrolled thermal stress can damage the surrounding tissues [39].

Diode lasers made of semiconductors emitting at ranges between 630–980 nm are used in surgical processes and therapeutic purposes [39-41]. In recent years, several studies related to LLLT and/or PBM[1] have led to profound insights into the regulation of cells and tissue for regenerative purposes. For instance, the potency of LLLT in the control and modulation of mitochondrial function can alter the metabolic profile and dynamic growth of the irradiated cells [42-47]. It was suggested that LLLT can be applied to control the regenerative properties of stem cells via the oxidative phosphorylation capacity and control of mitochondria in the injured recipient cells [47]. It has been proposed that the restoration of mitochondrial function or replacement of dysfunctional mitochondria with healthy counterparts can help the cells resist bioenergetic stress [48, 49]. The application of these laser types has been extended to dental soft tissue surgery, wound healing, and pain treatment [50-52]. The direct application of a diode laser inside the vascular system makes it possible to alleviate several pathologies, such as varicose veins, etc. [53].

Gas-based argon laser emitting at the range of 488–514 nm with blue to green spectra is efficiently absorbed by natural pigments such as hemoglobin and melanin [54, 55]. This laser type has been applied to the treatment of several cutaneous tissue injuries, anomalies, diabetic retinopathies, and macro- and micro-vasculopathies [56, 57]. The existence of parallel light scattering patterns and precise sensitivity improves its application in the clinical system [58, 59]. Along with these lasers, excimer lasers emitting UV at 193–308 nm can damage the biomolecules and intermolecular bonds. Excimer lasers remove the

[1]. Photobiomodulation

tissues by different mechanisms, such as photothermal, photomechanical, and photochemical properties [60]. In ophthalmology, excimer lasers are used for LASIK[1] and PRK[2], and treatment of chronic cutaneous tissue conditions such as psoriasis and vitiligo [61-63]. In line with these comments, excimer lasers are beneficial in cellular layer removal with submicron precision, with less invasion [61, 64].

Femtosecond lasers emitting NIR[3] regions with short duration (about 10^{-15} seconds) help us in non-thermal ablation and ultrafine tissue dissection with minimal collateral injuries [65, 66]. Due to these properties, femtosecond lasers are suitable for LASIK flap creation, cataract modification, and neurosurgery [67, 68]. This laser type is eligible to exert subcellular changes with the potential to be used in molecular surgery [69-72]. A He-Ne[4] laser emitting red light at 632.8 nm has been used extensively in LLLT [73, 74]. This laser has the potency to stimulate ATP production and induce the transcription of several genes related to oxidative phosphorylation, dynamic growth, and differentiation potential [41, 50, 75]. The low energy output increases this laser's safety with prominent effects at cellular levels without collateral tissue injury [76-79].

Thulium lasers with emitting wavelengths of 1940 nm are cutting-edge laser technology and can be suitably absorbed by the aqueous phase [80-82]. These features make the thallium laser appropriate for soft tissue manipulation and the treatment of conditions such as strains and sprains [83, 84]. Ho: YAG[5] laser operating at 2100 nm is also absorbed by water, but is distinguished by its pulsed emission mode. Therefore, this laser type

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1. Laser-assisted in situ keratomileusis
2. Photorefractive keratectomy
3. Near-infrared
4. Helium-Neon
5. Holmium-doped yttrium aluminum garnet

is suitable for lithotripsy and elimination of soft masses, especially in the urinary system [85]. Besides, some surgeons tend to use this laser in other tissues such as the gastrointestinal tract and spine for cutting, ablating, and clotting purposes [86, 87]. In fiber laser technology, rare-earth-doped optical fibers such as ytterbium are used to produce laser beams transmitted through flexible fiber-optic cables [88-90]. This technology enables efficient energy transmission using laser beams for accurate surgical purposes and soft tissue manipulations [90-93].

Along with these descriptions, the application of laser technologies has been extended to stem cell biology and regenerative medicine [94]. Data have confirmed that LLLT using diodes and He-Ne lasers is eligible to stimulate the dynamic growth of stem cells and bioactivities *in vitro* and *in vivo* via engaging several intracellular chromophores (**Figure 1**) [74, 95, 96].

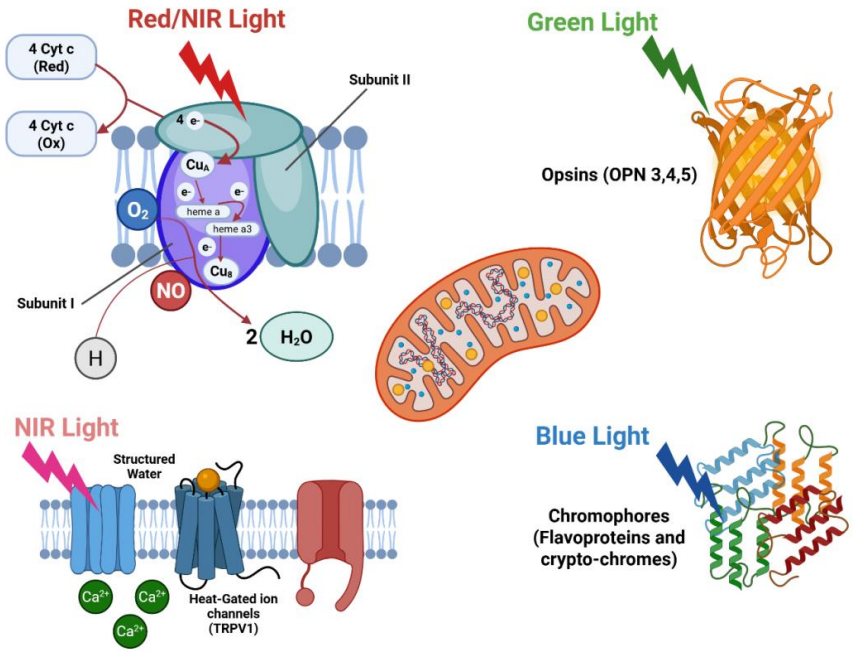

Figure 1. Mitochondrial Cytochrome c oxidase in the respiratory chain can absorb light at red and/or NIR wavelengths via heme and copper elements. NIR and blue wavelengths activate heat-gated TRP[1] ion channels by absorbing via structured water. Opsins mostly absorb blue and green wavelengths via cis-retinal. Blue wavelength via pterin is the most efficacious agent for the absorption of flavoproteins and cryptochromes. Created by Online BioRender software. 2025.

[1]. Transient receptor potential channel

Table 2. Laser types and their medical applications

Laser Type	Wavelength (nm)	Active Medium	Primary Mechanism of Action	Medical Applications	Advantages
CO_2 Laser	10600	Gas (Carbon Dioxide)	Ablation, vaporization	Dermatology (scar revision, warts), ENT (vocal cord surgery), gynecology (LEEP), dentistry	High water absorption; precise tissue cutting
Er: YAG Laser	2940	Solid (Er: YAG crystal)	Ablation, minimal thermal damage	Dentistry, dermatology (resurfacing), orthopedics	Very high-water absorption; minimal collateral damage
Nd: YAG Laser	1064	Solid (Nd: YAG crystal)	Deep coagulation, photo-thermolysis	Oncology (tumor ablation), vascular lesions, urology (prostate surgery), ophthalmology	Deep tissue penetration; strong coagulative capacity
Diode Laser	630–980	Semiconductor	Photobiomodulation, coagulation	LLLT (wound healing, pain relief), dental surgery, varicose vein treatment	Portable, cost-effective, ideal for therapeutic use
Argon Laser	488–514	Gas (Argon)	Photocoagulation	Ophthalmology (retinal photocoagulation), dermatology (vascular lesions)	Specific for oxyhemoglobin; minimal scatter
Excimer Laser	193, 248, 308	Gas (XeCl)	Photoablation (UV range)	Ophthalmology (LASIK, PRK), dermatology (psoriasis, vitiligo)	The ultraviolet laser breaks molecular bonds precisely
Femtosecond Laser	~1030 (IR)	Solid (Yb-based)	Non-thermal ablation (optical breakdown)	LASIK flap creation, neurosurgery, nanosurgery	Ultra-short pulses; minimal thermal damage
Helium-Neon (He-Ne)	632.8	Gas (He and Ne mixture)	Photobiomodulation	Research, LLLT, ophthalmic diagnostics	Low energy; ideal for cellular stimulation
Thulium Laser	1940	Solid (Thulium-doped fiber)	Ablation, coagulation	Urology (BPH surgery), ENT	High absorption in water; adequate tissue resection
Holmium: YAG Laser	2100	Solid (Holmium-doped crystal)	Pulsed ablation	Urology (stone fragmentation), orthopedics, spinal surgery	Precise cutting; safe in wet environments
Fiber Laser	980–2000+	Optical Fiber Doped	Tunable, photothermal, PBM	Surgical cutting, tissue welding, and photothermal therapy	Flexible delivery; high beam quality

2. Laser-stem cell interaction and regenerative potential

Lasers such as LLLT have been extensively used because of their biological effects (**Table 2**) [97]. LLLT-exposed stem cells are prone to accelerate tissue healing via proliferation, differentiation, and migration capacities [98, 99]. At the cellular level, the laser-stem cell interaction is done via the absorption of laser beams (especially red or NIR wavelengths) by subcellular components that contribute to the activation of stem cells [100]. For instance, the entry of red laser beams can stimulate mitochondrial function and biogenesis [101, 102]. To be specific, the activation of the electron transport chain cytochrome c oxidase increases the function of mitochondria [44, 50]. In line with these statements, the local intensity of ATP[1] increases, which can help to proceed with several cellular functions [103]. Additionally, PBM[2] also facilitates the generation of ROS[3]. Excessive amounts of ROS can sensitize their host cells to oxidative stress and thereby cause injuries. However, normal levels of ROS can activate specific signaling pathways and metabolic activity [104, 105]. Of note, the regulation of specific effectors such as MAPK[4] and PI3K[5]/Akt by laser irradiation can influence the gene expression and activity of several factors inside the stem cells. Some of these factors are directly or indirectly involved in the promotion of regeneration [50, 106]. It was suggested that LLLT-related ROS can promote stem cell maturation and differentiation into the different cell lineages [107]. Along with the increase of ROS, other factors such as HSPs[6] are also activated, and these factors can increase the cell resistance against various insulting conditions [108]. Some studies have indicated that HSPs such as

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[1]. Adenosine triphosphate
[2]. Photobiomodulation
[3]. Reactive oxygen species
[4]. Mitogen-activated protein kinase
[5]. Phosphoinositide 3-kinase/Akt
[6]. Heat shock proteins

HSP27 are involved in the maturation of NPCs[1] into the mature NeuN$^+$ neuron [109]. LLLT has the potential to influence the angiocrine profile of stem cells by the release of VEGF[2], FGF[3], TGF-β[4], etc., leading to the increase of local microvascular density and cell migration into remote sites (**Figure 2**) [75, 110, 111].

[1]. Neural progenitor cells
[2]. Vascular endothelial growth factor
[3]. Fibroblast growth factor
[4]. Transforming growth factor beta

Table 2. LLLT effects on stem cell types: parameters, mechanisms, and clinical potentials

Stem cell type	Wavelength range (nm)	Energy density (J/cm^2)	Mechanistic effects	Functional outcomes	Potential clinical applications
MSCs	630–850	0.5–5.0	ATP production via cytochrome c oxidase stimulation; reduction of oxidative stress; ERK/MAPK pathway activation	Proliferation, migration, and differentiation into osteoblasts, chondrocytes, and adipocytes	Bone/cartilage regeneration, spinal fusion, osteoarthritis treatment
NSCs	780–810	1.0–4.0	BDNF↑; ↑ mitochondrial biogenesis, Notch1/Hes1 signaling, and reduction of inflammation	Neuronal differentiation, neurogenesis; Neuronal survival	Traumatic brain injury recovery, spinal cord injury, AD, and PD therapies
HSCs	660–810	0.5–2.0	Expression of GATA-2, Nitric oxide modulation; ROS production within the physiological range	Engraftment efficiency, increase of colony-forming units, and cell survival in hypoxic conditions	Bone marrow transplantation, recovery from chemotherapy, and immune modulation
ADSCs	630–850	1.0–5.0	VEGF, HIF-1α expression; activation of SDF-1/CXCR4 axis; increase of mitochondrial membrane potential, and reduction of apoptosis	Angiogenic potential, Endothelial and myogenic differentiation; Tissue repair capabilities	Wound healing, ischemic limb repair, facial aesthetics, soft tissue regeneration
iPSCs	780–830	0.5–3.0	Mitochondrial metabolism, stemness features (OCT4, SOX2), and telomerase activity	↑ Directed differentiation (preliminary); improved reprogramming efficiency (early studies)	Organ-on-chip systems, disease modeling, and autologous regenerative therapies
DPSCs	660–810	1.0–4.0	BMP-2, Runx2 expression, mineralization capacity, Neurite outgrowth; NGF release	↑ Odontogenic and neurogenic differentiation; ↑ Matrix deposition	Dental pulp regeneration, peripheral nerve repair, and craniofacial tissue engineering
EpSCs	635–670	1.0–3.0	KGF production, activation of Wnt/β-catenin signaling; angiogenesis (ANGPT1, VEGF-A)	Proliferation, Epidermal repair, Epithelial barrier formation	Burn treatment, chronic ulcer healing, epidermal thinning disorders

Abbreviations: Adipose-Derived Stem Cells: ADSCs; Angiopoietin-1: ANGPT1; Brain-derived neurotrophic factor: BDNF; Dental Pulp Stem Cells: DPSCs; Epidermal Stem Cells: EpSCs; Hematopoietic Stem Cells: HSCs; Induced pluripotent stem cells: iPSCs; Keratinocyte growth factor: KGF; Mesenchymal Stem Cells: MSCs; Nerve growth factor: NGF; Neural Stem Cells: NSCs

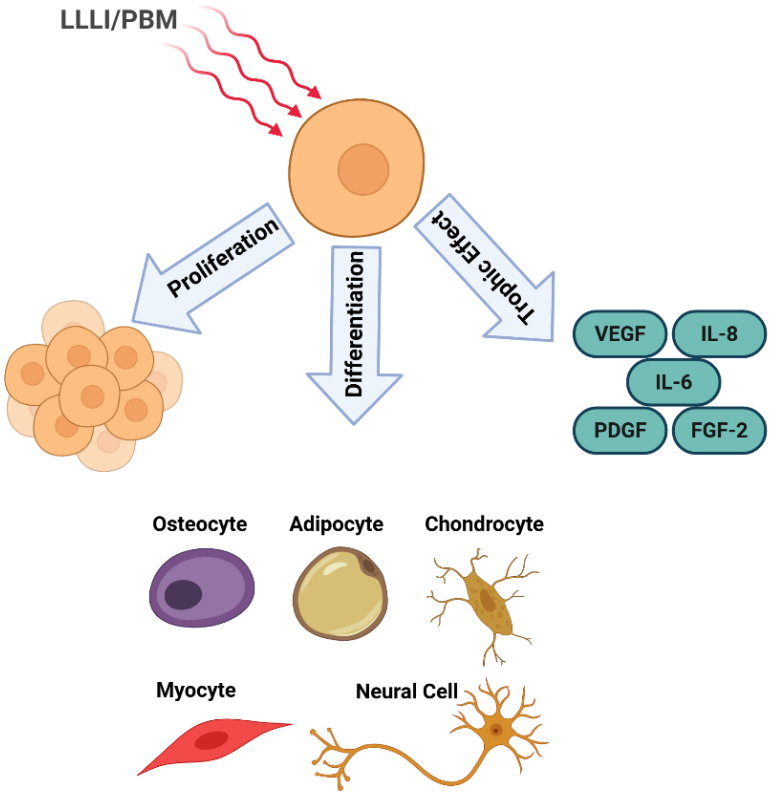

Figure 2. The potential impact of PBM[1] on stem cells. Created by Online BioRender software. 2025

By the regulation of LLLT intensity and irradiation time, it is possible to control the stemness feature of stem cells. For instance, it was suggested that LLLT can control the expression of Oct-4, Sox-2, and Nanog, which are involved in the maintenance of stemness features and self-renewal [112, 113]. These factors belong to regulatory networks with the potential to preserve stem cell phenotypes and undifferentiated status in iPSCs[2] and

[1]. Photobiomodulation
[2]. Induced pluripotent stem cells

ESCs[1] [114]. Thus, the regulation of gene expression enables us to control the stem cell bioactivity and behavior after transplantation into the target sites [115, 116]. The release of the abovementioned cytokines along with PDGF[2] is also important in the remodeling of ECM[3] [117, 118]. The production and release of such growth factors in LLLT-treated stem cells can contribute to the stimulation of angiogenesis and *de novo* blood formation, resulting in the synthesis and production of collagen and other ECM components [119, 120]. These features are critical in the healing and regeneration of ischemic/hypoxic tissues. Of note, laser irradiation cannot only improve stem cell bioactivity but also increase the homing and recruitment of these cells in the target tissues. Numerous studies have shown that LLLT treatment dramatically increases CPCs[4] and MSC[5] recruitment, promoting tissue regeneration and functional recovery [114, 121]. Despite these advantages, it is thought that the right therapeutic effects of LLLT in human and animal medicine are closely related to the standardization of PBM parameters like wavelength, intensity, duration, and pulse mode [41]. Among various laser types, red and NIR wavelengths ranging from 600 to 1000 nm seem effective in biological systems because of penetration properties and further interaction with subcellular components such as mitochondria (**Figure 3**) [122-124]. Taken together, laser-tissue interaction is thought to be a relatively non-invasive modality in the alleviation and therapy of several pathological conditions [125, 126].

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[1]. Embryonic stem cells
[2]. Platelet-derived growth factor
[3]. Extracellular matrix
[4]. Cardiac progenitor cells
[5]. Mesenchymal stem cell

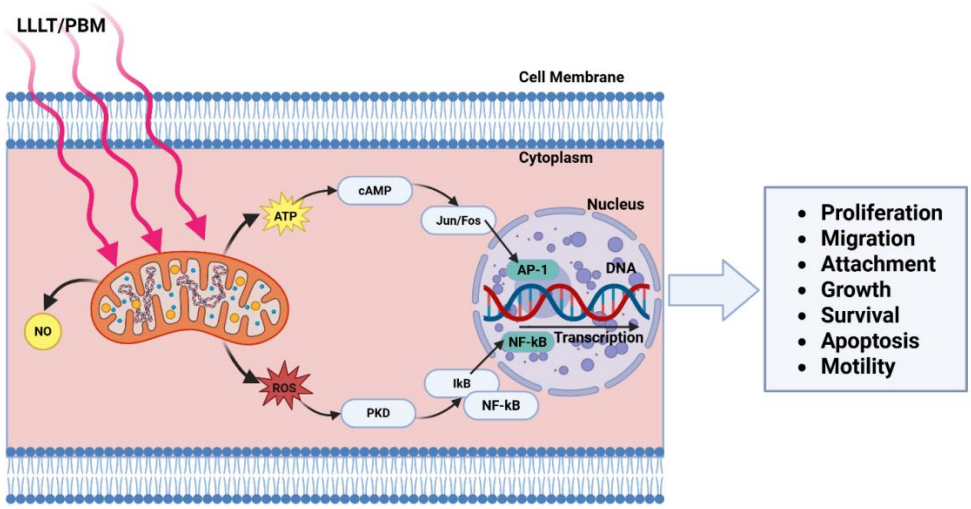

Figure 3. The LLLT-induced cellular signaling pathways are shown schematically. Chromophores in mitochondria absorb light, which increases respiration and ATP synthesis as well as the creation of signaling chemicals, including NO and ROS. Created by Online BioRender software. 2025

3. Clinical applications of laser technology in stem cell-based regenerative medicine

Recent data have confirmed the eligibility of LLLT for enhancing stem cell function and bioactivity in the target sites [112, 127-129]. Here, we focused on the recent works related to laser technology in stem cell-based treatments. As mentioned above, LLLT can boost the dynamic growth and function of MSCs and iPSCs [128, 130]. This strategy has been applied in the induction of osteogenesis, articular and joint regeneration, and wound healing via the control of stem cell bioactivity [128, 131]. Such effects can also be documented in other cell types, like stem cells. For example, LLLT promotes the healing process by regulating the proliferation of various cell types such as fibroblasts, keratinocytes, ECs[1], and lymphocytes [132]. Based on research conducted by our group, LLLT can modulate different signaling

[1]. Endothelial cells

pathways inside the ECs, leading to the regulation of cell paracrine activity via the release of Exos[1] [133]. These data indicated that the LLLT can influence both cell growth and secretome production (**Figure 4**) [110]. It has been found that such mechanisms exist in stem cells as well [110]. Based on the frequency and irradiation time, laser treatment has helped increase the osteoarticular and adipogenesis capacity of MSCs [134]. Via the activation/inhibition of certain signaling pathways, LLLT can exert its therapeutic effects. For instance, LLLT helps NSCs[2] make new neurons and protect existing neurons via the regulation of the Notch signaling system [135]. To be specific, the appropriate irradiation protocol has benefits to treat several neurological illnesses like PD[3] and AD[4] [102, 136-138]. LLLT treatment can increase the migration of endogenous and exogenous stem cells toward the injured sites in a cytokine gradient manner [16]. Besides, laser irradiation is thought of as an innovative modality to promote neurogenesis via increasing neural plasticity and reducing oxidative stress inside the brain parenchyma [139-141]. The local increase of chemotactic factors post-LLLT, i.e., VEGF, SDF-1α[5] , and other factors, can orchestrate the homing of stem cells [142]. VEGF can stimulate the formation of blood vessels while SDF-1α recruits several cell types, which are important for the angiogenesis and healing of injured tissues [143-145]. In MI[6] patients exposed to LLLT, the rate of recruited stem cells in the infarcted myocardium was stimulated. Likewise, laser irradiation can speed up the homing of stem cells in individuals with bone tissue fractures [146, 147]. It has been thought that MSC-to-osteoblast differentiation is stimulated in the presence of LLLT [148]. Several pre-clinical

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[1]. Exosomes
[2]. Neural stem cells
[3]. Parkinson's disease
[4]. Alzheimer's disease
[5]. Stromal cell-derived fact
[6]. Myocardial infarction

and clinical studies have proved the induction of osteogenesis and bone mineral deposition after the LLLT [149]. In addition to osteogenesis properties, LLLT can also improve chondrocyte differentiation of MSCs in patients suffering from osteoarthritis and joint injuries [150]. LLLT can lower scar formation in MI patients by improving CPC differentiation into mature and functional cardiomyocytes, leading to restoration of myocardium function [151-153].

Despite the advantages related to the application of lasers in human regenerative medicine, the lack of standard laser irradiation protocols is the main problematic issue. Therefore, it is suggested to use calibrated therapeutic irradiation regimes with precise power intensity, frequency, etc. Although some early and preclinical studies have shown promising results, more randomized controlled studies must be conducted to prove these results and look into the possible adverse effects of long-term LLLT radiation.

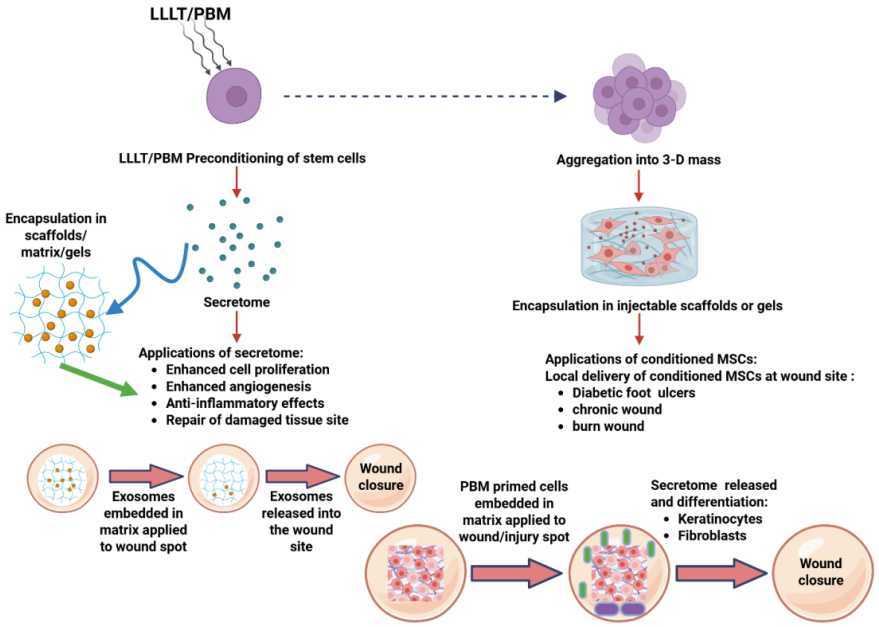

Figure 4. Potential pathways of LLLI/PBM-stimulated stem cells' secretome production. Created by Online BioRender software. 2025.

4. Conclusions

Using certain types of LLLT, it is possible that the intracellular signaling pathways of stem cells can be modulated, which accelerates their regenerative potential following several pathologies. Due to the existence of intricate molecular mechanisms inside the stem cells and involvement of diverse effectors, several studies should be done to find the beneficial impact of LLLT on stem cell regulation and differentiation into the target cell lineages. By developing sophisticated PBM systems, human medicine will witness splendid progress in laser-based therapies.

References

1. Band, Y.B., *Light and matter: electromagnetism, optics, spectroscopy and lasers*. Vol. 1. 2006: John Wiley & Sons.
2. Schawlow, A.L., *Lasers: The intense, monochromatic, coherent light from these new sources shows many unfamiliar properties.* Science, 1965. **149**(3679): p. 13-22.
3. Csele, M., *Fundamentals of light sources and lasers*. 2004: John Wiley & Sons.
4. Niemz, M.H., *Laser-tissue interactions*. Vol. 322. 2007: Springer.
5. Keiser, G., *Light-Tissue Interactions*, in *Biophotonics: Concepts to Applications*. 2022, Springer. p. 169-221.
6. Ge, J., *Stimuli-Responsive Polymers: in Particles and on Surfaces*. 2025, Case Western Reserve University.
7. Bradley, P.F., *A review of the use of the neodymium YAG laser in oral and maxillofacial surgery.* British Journal of Oral and Maxillofacial Surgery, 1997. **35**(1): p. 26-35.
8. Scherer, K. and M. Waner, *Nd: YAG lasers (1,064 nm) in the treatment of venous malformations of the face and neck: challenges and benefits.* Lasers in medical science, 2007. **22**: p. 119-126.
9. Nie, J., et al., *Research trends and hotspots of laser therapy in hemangioma: a bibliometric and visualization analysis.* Lasers in Medical Science, 2025. **40**(1): p. 107.
10. Palleschi, V., et al., *Laser-induced breakdown spectroscopy.* Nature Reviews Methods Primers, 2025. **5**(1): p. 17.
11. Sarbadhikary, P., B.P. George, and H. Abrahamse, *Paradigm shift in future biophotonics for imaging and therapy: Miniature living lasers to cellular scale optoelectronics.* Theranostics, 2022. **12**(17): p. 7335.
12. Insero, G., F. Fusi, and G. Romano, *The safe use of lasers in biomedicine: Principles of laser-matter interaction.* Journal of Public Health Research, 2023. **12**(3): p. 22799036231187077.
13. Khan, W.Z., et al., *Advancements in Laser Technology: Bridging Historical Milestones and Modern Applications in Science, Industry, and Sustainability.*
14. DURMUŞ, H.O., *FUNDAMENTALS OF MEDICAL LASER TECHNOLOGY AND ITS VARIOUS MEDICAL APPLICATIONS.* Current Research in, 2024: p. 73.
15. Saxena, A., *Laser Physics: Fundamental Principles*. 2025: Educohack Press.
16. Ban, S., et al., *Advances in Photonic Materials and Integrated Devices for Smart and Digital Healthcare: Bridging the Gap Between Materials and Systems.* Advanced Materials, 2025: p. 2416899.

17. Premcheska, S., A.G. Skirtach, and A.M. Kaczmarek, *Roadmap to Nanomedical Applications: Nanotoxicology and In Vitro Guidelines for Lanthanide-Doped Luminescence Nanothermometers.* Advanced NanoBiomed Research, 2025: p. 2500003.
18. Chen, Y., et al., *An extensive evaluation of laser tissue welding and soldering biotechnologies: Recent advancements, progress, and applications.* Current Research in Biotechnology, 2024: p. 100234.
19. Prasad, V.M. and M. Remacle, *CO2 Laser Surgery for the Larynx*, in *Textbook of Surgery of Larynx and Trachea*. 2022, Springer. p. 69-80.
20. Kesty, C.E. and K.R. Kesty, *A Novel Technique for Eye Rejuvenation: A Case Series of the Combined Use of CO2 Laser Blepharoplasty and Erbium: YAG Resurfacing and A Novel Artificial Intelligence Model to Quantify Laser Results.* Journal of Cosmetic Dermatology, 2025. **24**(2): p. e70022.
21. Liang, J., et al., *Safety and efficacy of carbon dioxide laser therapy for vocal cord leukoplakia: A systematic review and meta-analysis.* Medicine, 2025. **104**(7): p. e41539.
22. Talon, M., A. McQuitty, and R. Zapata-Sirvent, *115 Pediatric Laser Resurfacing in 579 Patients: Efficacy Analysis of a Multimodal Perioperative Pain Regimen.* Journal of Burn Care & Research: Official Publication of the American Burn Association, 2025. **46**(Suppl 1): p. S89.
23. Li, Z., et al., *Exploring the optimal parameter settings of a thulium fiber laser during soft tissue resection.* Lasers in Medical Science, 2025. **40**(1): p. 118.
24. Almoharib, H., *Erbium-Doped Yttrium Aluminium Garnet (Er: YAG) Lasers in the Treatment of Peri-Implantitis.* Cureus, 2025. **17**(1).
25. Ustuner, P., *Comparative Analysis of Laser Therapies for Striae Distensae: Fractional CO2 vs Combined Q-Switch Nd: YAG.* Medical Science Monitor: International Medical Journal of Experimental and Clinical Research, 2025. **31**: p. e947464.
26. Gómez, C. and E. Alberdi, *Light-Based Therapies for Treatment of Onychomycosis.* 2025.
27. Guo, J., et al., *In vivo efficacy investigation of long-wavelength infrared femtosecond lasers for skin rejuvenation.* Optics Letters, 2025. **50**(4): p. 1421-1424.
28. Zhang, O.L., et al., *Advanced Lasers and Their Applications in Dentistry.* Dentistry Journal, 2025. **13**(1): p. 37.
29. Salman, Z.A., Z.T. Al-Dahan, and A.R. Al-Hamaoy, *Review of laser skin treatments: parameters effects and common treatment cases.* Journal of Optics, 2025: p. 1-15.

30. Chen, B., et al., *Thermo-elastic model and surface evaporation model to Reveal the damage mechanism of melanocytes induced by laser ablation.* International Journal of Heat and Fluid Flow, 2025. **112**: p. 109763.
31. Fulton, J.E. and P.K. Shitabata, *CO2 laser physics and tissue interactions in skin.* Lasers in surgery and medicine, 1999. **24**(2): p. 113-121.
32. Peavy, G.M., *Lasers and laser–tissue interaction.* Veterinary Clinics: Small Animal Practice, 2002. **32**(3): p. 517-534.
33. Steiner, R., *Laser-tissue interactions*, in *Laser and IPL technology in dermatology and aesthetic medicine*. 2010, Springer. p. 23-36.
34. Chertov, S., et al., *Evaluating the Impact of Modern Laser Technologies on Dentistry in European Union Countries.* 2024.
35. Sachelarie, L., et al., *Laser Technology in Dentistry: From Clinical Applications to Future Innovations.* Dentistry Journal, 2024. **12**(12): p. 420.
36. Cheng, J., et al., *Comparison of the efficacy and adverse effects of long pulsed 1064 nm Nd: YAG laser and sclerotherapy in the treatment of pyogenic granuloma in children: a retrospective study.* Scientific Reports, 2025. **15**(1): p. 2843.
37. Dover, J.S., et al., *The History and Advancement of Light, Lasers, and Energy-Based Devices in Dermatologic Surgery.* Dermatologic Surgery, 2025. **51**(2): p. 113-122.
38. Al Timimi, Z., A.F. Al-Rubaye, and D.M. Diwan, *A comprehensive study of laser use in dermatology: assessing the safety, innovations, and effectiveness of laser technology for skin treatment.* Irish Journal of Medical Science (1971-), 2025: p. 1-10.
39. Chamkouri, H., et al., *Biomedical optics and photonics for advanced clinical technologies.* Optics & Laser Technology, 2024. **179**: p. 111265.
40. Jawad, H.J. and A.F. Sultan, *Review recent developments in high-power diode lasers for biomedical applications.* Journal of Optics, 2024: p. 1-6.
41. Raja, I.S., et al., *Tailoring photobiomodulation to enhance tissue regeneration.* Biomaterials, 2024: p. 122623.
42. Woźniak, J., et al., *Near-Infrared Stimulation in Psychiatry Disorders: A Systematic Review of Efficacy and Biological Mechanisms.* NeuroSci, 2025. **6**(1): p. 26.
43. Ahmad, A. and S.A. Zainal, *Photobiomodulation Therapy for Wound Healing: A Narrative Review.* IIUM Medical Journal Malaysia, 2025. **24**(01).

44. Trajano, L.A.d.S.N., et al., *Does photobiomodulation alter mitochondrial dynamics?* Photochemistry and Photobiology, 2025. **101**(1): p. 21-37.
45. Laakso, E.-L., et al., *Efficacy and Safety of Photobiomodulation in MELAS: Protocol for a Series of N-of-1 Trials.* Journal of Clinical Medicine, 2025. **14**(6): p. 2047.
46. Wang, S., et al., *Non-pharmacological treatment of Alzheimer's disease: an update.* Frontiers in Aging Neuroscience, 2025. **17**: p. 1527242.
47. Bagheri, H.S., et al., *Mitochondrial donation in translational medicine; from imagination to reality.* Journal of Translational Medicine, 2020. **18**: p. 1-18.
48. Guth, M., *Mitochondrial Dysfunction, a Hallmark of Aging: Mechanisms, Consequences and Therapeutic Strategies.* J Cell Sci Regenerative Med 2025. **1**(2): p. 44-51.
49. Liu, Y., W.L. Dissanayaka, and C. Yiu, *Therapeutic implications of mitochondrial transfer on stem cell fate in regenerative medicine.* Journal of Translational Medicine, 2025. **23**(1): p. 1-29.
50. Tamimi, R., et al., *Review on the molecular mechanisms of low-level laser therapy: gene expression and signaling pathways.* Lasers in Medical Science, 2025. **40**(1): p. 160.
51. Neeta, N.P., V.D.K. Vedant, and K.D. Deepika, *Comparative evaluation of soft tissue laser therapy and topical anaesthetic gel in the treatment of removable prosthesis induced traumatic ulceration: an in-vivo study.* Lasers in Dental Science, 2025. **9**(1): p. 1-7.
52. Kui, A., et al., *From Pain to Recovery: The Impact of Laser-Assisted Therapy in Dentistry and Cranio-Facial Medicine.* 2025.
53. Nasser, M.M., et al., *Comparative study between endovenous laser ablation (EVLA) with 1940 nm versus EVLA with 1470 nm for treatment of incompetent great saphenous vein and short saphenous vein: A randomized controlled trial.* Journal of Vascular Surgery: Venous and Lymphatic Disorders, 2025. **13**(1): p. 101960.
54. Wollweber, M. and B. Roth, *Raman sensing and its multimodal combination with optoacoustics and OCT for applications in the life sciences.* Sensors, 2019. **19**(10): p. 2387.
55. Bone, R.A., W. Schalch, and J.T. Landrum, *5 Quantitative Methods.* Carotenoids: Physical, Chemical, and Biological Functions and Properties, 2009: p. 75.
56. Wang, M., *The Applications of Photo-mediated Ultrasound Therapy in Vascular Diseases*. 2024.

57. Tiwary, A.K., et al., *The Skin and the Eyes*, in *Atlas of Dermatology, Dermatopathology and Venereology: Inflammatory Dermatoses*. 2021, Springer. p. 743-791.
58. Specht, A., M. Klimezak, and S. Cambridge, *Seeing in the Future–a Perspective on Combining Light with Chemical Biology Approaches to Treat Retinal Pathologies.* ChemMedChem, 2025: p. e202400827.
59. Palaghia, S.-M., S.-I. Georgescu, and C. Sarafoleanu, *The Blue Light LASER technology: a new progress in ENT surgery.* Romanian Journal of Rhinology, 2025. **15**(57).
60. Manickam, S., S.R. Haromuchadi, and R. Naik, *Application of Ultraviolet Light in Solid and Semi-Solid Foods*, in *Nonthermal Light-Based Technologies in Food Processing*. 2025, Apple Academic Press. p. 107-161.
61. Valonen, E., *Contraindications of Corneal Laser Refractive Surgery.* 2024.
62. Assessment, O.P.P., *Excimer laser photorefractive keratectomy (PRK) for myopia and astigmatism.* 1999.
63. PANDEY, B., et al., *BIOMEDICAL APPLICATIONS OF EXIMER LASERS.*
64. Bohač, M. and M. Jagić, *Introductory Chapter: Refractive Surgery*, in *Refractive Surgery-Types of Procedures, Risks, and Benefits*. 2022, IntechOpen.
65. Harooni, M., *Laser Ablation: Applications and Modeling*. 2024: BoD–Books on Demand.
66. Mthunzi-Kufa, P., *Optical sorting and photo-transfection of mammalian cells.* 2010.
67. Yu, M., et al., *Randomized controlled trial on corneal denervation, neuroinflammation and ocular surface in corneal lenticule extraction for advanced refractive correction (CLEAR) and small incision lenticule extraction (SMILE).* Eye and Vision, 2025. **12**(1): p. 1-15.
68. Diebold, Y. and L. García-Posadas, *Ex vivo applications of porcine ocular surface tissues: Advancing eye research and alternatives to animal studies.* Histology and histopathology: p. 18873.
69. Chang, C.C., et al., *Bioactive Hyperbranched Polymer Dots Combined Laser-Induced Optical Breakdown for Accelerating Wound Repair and Regeneration in Nude Mice Model.* Materials Advances, 2025.
70. Khan, A.Z. and D.K. Naik, *Applications of laser surface texturing in biomedical field: a review.* Bioinspired, Biomimetic and Nanobiomaterials, 2025: p. 1-21.
71. Liu, J., et al. *Bioactive scaffolds for tissue engineering: A review of decellularized extracellular matrix applications and innovations*. in *Exploration*. 2025. Wiley Online Library.

72. El-Sayed, J.M., et al., *Therapeutic effects of a femtosecond laser on rheumatoid arthritis in rats: Attenuation of oxidative stress and inflammation.* Journal of Photochemistry and Photobiology B: Biology, 2025: p. 113150.
73. Pradal, L.d.A., et al., *Photobiomodulation in Burn Wounds: A Systematic Review and Meta-Analysis of Clinical and Preclinical Studies.* Photobiomodulation, Photomedicine, and Laser Surgery, 2025. **43**(1): p. 8-23.
74. Yan, B., et al., *Unlocking the potential of photobiomodulation therapy for brain neurovascular coupling: The biological effects and medical applications.* Journal of Cerebral Blood Flow & Metabolism, 2025: p. 0271678X241311695.
75. Anders, J.J. and A.K. Ketz, *Basic principles of photobiomodulation and its effects at the cellular, tissue, and system levels.* Laser therapy in veterinary medicine: photobiomodulation, 2025: p. 24-39.
76. de Sousa Furtado, R.G. and T.R. Damasceno, *Low-Level Laser Therapy (LLLT).* Pressure Injury, Diabetes and Negative Pressure Wound Therapy, 2020. **3**: p. 193.
77. Baxter, D., *Low-intensity laser therapy.* Electrotherapy. Evidence-Based Practice, 12th ed. T. Watson (ed.). Edinburgh: Churchill Livingstone, 2008: p. 161-178.
78. Chhabra, K. and N. Kashyap, *Electrotherapy Interventions for Diabetic Peripheral Neuropathy*, in *Rehabilitation in Diabetic Peripheral Neuropathy*. 2025, Springer. p. 99-119.
79. GELGÖR, İ.E., *The Use of Lasers in Dentistry.* PIONEER AND INNOVATIVE STUDIES IN HEALTH SCIENCES: p. 49.
80. Vodopyanov, K.L., *Laser-based mid-infrared sources and applications*. 2020: John Wiley & Sons.
81. Zhang, X., et al. *Kilowatt level high-power thulium-doped fiber laser*. in *Advanced Fiber Laser Conference (AFL 2024)*. 2025. SPIE.
82. Švejkar, R., M.P. Buckthorpe, and W.A. Clarkson. *High-power tunable Tm-doped nested-ring fibre laser emitting from 1940 to 2090 nm*. in *Advanced Solid State Lasers*. 2024. Optica Publishing Group.
83. Borisenko, A.S., et al., *Application of Thulium Fiber Laser in Plastic Surgery.* Cosmetics, 2025. **12**(2): p. 39.
84. Proietti, S., et al., *Effectiveness and safety of thulium fiber laser in the conservative management of patients with upper tract urothelial carcinoma.* European Urology Open Science, 2022. **46**: p. 99-104.
85. Čáp, I., et al., *Electromagnetic waves.* Electromagnetic and Acoustic Waves in Bioengineering Applications, 2021: p. 97.
86. Zhang, C., D.M. Dibardino, and K.C. Ma, *Bronchoscopic treatment of thoracic malignancy.* AME Medical Journal, 2023. **8**.

87. Takasaki, A.A., et al., *Er: YAG laser therapy for peri-implant infection: a histological study.* Lasers in medical science, 2007. **22**: p. 143-157.
88. Kobtsev, S. *Fibre Lasers: Promising Solutions*. in *Photonics*. 2025. MDPI.
89. Amiri, I., et al., *Optical networks performance optimization based on hybrid configurations of optical fiber amplifiers and optical receivers.* Journal of Optical Communications, 2025. **45**(s1): p. s1-s13.
90. Nemova, G., *Brief review of recent developments in fiber lasers.* Applied Sciences, 2024. **14**(6): p. 2323.
91. Jobin, F., et al., *Recent developments in lanthanide-doped mid-infrared fluoride fiber lasers.* Optics Express, 2022. **30**(6): p. 8615-8640.
92. Sohail, M.T., et al., *Recent Advancements and Challenges in High-Power Thulium-Doped Laser.* Advanced Materials Technologies, 2024. **9**(24): p. 2400496.
93. Liang, L., et al., *Optical Microfiber Biomedical Sensors: Classification, Applications, and Future Perspectives.* Advanced Sensor Research, 2025: p. 2400185.
94. Gursel, A.T., *Fiber lasers and their medical applications.* Optical Amplifiers—A Few Different Dimensions, 2018: p. 13.
95. Kang, M.H., et al., *Parameter-Tuned Pulsed Wave Photobiomodulation Enhances Stem Cells From Apical Papilla Differentiation: Evidence From Gene and Protein Analyses.* Journal of Biophotonics, 2025: p. e202400348.
96. Hamblin, M.R., *Mechanisms and applications of the anti-inflammatory effects of photobiomodulation.* AIMS biophysics, 2017. **4**(3): p. 337.
97. Amaroli, A., et al., *A narrative review on oral and periodontal bacteria Microbiota photobiomodulation, through visible and near-infrared light: from the origins to modern therapies.* International Journal of Molecular Sciences, 2022. **23**(3): p. 1372.
98. Ahrabi, B., et al., *The effect of photobiomodulation therapy on the differentiation, proliferation, and migration of the mesenchymal stem cell: a review.* Journal of lasers in medical sciences, 2019. **10**(Suppl 1): p. S96.
99. Hamblin, M.R. and T.N. Demidova, *Mechanisms of low level light therapy.* Mechanisms for low-light therapy, 2006. **6140**: p. 614001.
100. Kaffash, Z., et al., *Photobiomodulation Therapy; Survey and Principal Study Leading to Design Rules for Implants.* IEEE Transactions on Biomedical Engineering, 2025.
101. Frankowski, D.W., et al., *Light buckets and laser beams: mechanisms and applications of photobiomodulation (PBM) therapy.* GeroScience, 2025: p. 1-13.

102. da Silva, L.E., et al., *Photobiomodulation of gut microbiota with low-level laser therapy: a light for treating neuroinflammation.* Lasers in Medical Science, 2025. **40**(1): p. 1-9.
103. Da Silva, D., et al., *Photobiomodulation: a novel approach to promote trans-differentiation of adipose-derived stem cells into neuronal-like cells.* Neural Regeneration Research, 2025. **20**(2): p. 598-608.
104. Asgari, R., et al., *Management of oxidative stress for cell therapy through combinational approaches of stem cells, antioxidants, and photobiomodulation.* European Journal of Pharmaceutical Sciences, 2024. **196**: p. 106715.
105. Courtois, E., et al., *Mechanisms of PhotoBioModulation (PBM) focused on oral mucositis prevention and treatment: a scoping review.* BMC Oral Health, 2021. **21**(1): p. 220.
106. Rastogi, M., K. Sahu, and S.K. Majumder, *Light assisted modulation of stem cell function and secretome production: a systematic review on current status and new avenues for regenerative medicine.* Lasers in Medical Science, 2025. **40**(1): p. 1-17.
107. Li, Y., et al., *Low-level laser therapy induces human umbilical vascular endothelial cell proliferation, migration and tube formation through activating the PI3K/Akt signaling pathway.* Microvascular Research, 2020. **129**: p. 103959.
108. Seo, I., et al., *Enhancing viability and angiogenic efficacy of mesenchymal stem cells via HSP90 α and HSP27 regulation based on ROS stimulation for wound healing.* Bioengineering & Translational Medicine, 2023. **8**(5): p. e10560.
109. Shokrollahi, E., et al., *Treatment of human neuroblastoma cell line SH-SY5Y with HSP27 siRNA tagged-exosomes decreased differentiation rate into mature neurons.* Journal of Cellular Physiology, 2019. **234**(11): p. 21005-21013.
110. Rastogi, M., K. Sahu, and S.K. Majumder, *Light assisted modulation of stem cell function and secretome production: a systematic review on current status and new avenues for regenerative medicine.* Lasers in Medical Science, 2025. **40**(1): p. 83.
111. Gumede, D.B., H. Abrahamse, and N.N. Houreld, *Targeting Wnt/β-catenin signaling and its interplay with TGF-β and Notch signaling pathways for the treatment of chronic wounds.* Cell communication and signaling, 2024. **22**(1): p. 244.
112. El-Dahab, M.M.A., et al., *The efficacy of infrared diode laser in enhancing the regenerative potential of human periodontal ligament stem cells (hPDLSCs).* BMC Oral Health, 2024. **24**(1): p. 1310.

113. Zadeh, Z.E., et al., *Mining human clinical waste as a rich source of stem cells for neural regeneration.* Iscience, 2024.
114. Alt, D.S., *Prevascular Cell Condensations for Modular Tissue Engineering*. 2020, Case Western Reserve University.
115. Luttrell, T., *Trauma and inflammation of soft tissue: rehabilitation and wound healing and remodeling of collagen*, in *Foundations of Orthopedic Physical Therapy*. 2024, Routledge. p. 2-37.
116. Lazarus, E., et al., *Engineering tools for stimulating wound healing.* Applied Physics Reviews, 2024. **11**(2).
117. Dipalma, G., et al. *Photobiomodulation and growth factors in dentistry: a systematic review*. in *Photonics*. 2023. MDPI.
118. Xue, G., et al., *Analysis of the effects of concentrated growth factor and low-level laser therapy on the bone healing.* Heliyon, 2023. **9**(1).
119. Arany, P.R., *Photobiomodulation-activated latent transforming growth factor-β1: a critical clinical therapeutic pathway and an endogenous optogenetic tool for discovery.* Photobiomodulation, Photomedicine, and Laser Surgery, 2022. **40**(2): p. 136-147.
120. Mehrotra, S., et al., *Evaluation of the Effect of Diode Laser on Healing after Gingivectomy.* Pesquisa Brasileira em Odontopediatria e Clínica Integrada, 2025. **25**: p. e230116.
121. Lichtbroun, A., *The therapeutic potential of stimulating endogenous stem cell mobilization.* Acupuncture & electro-therapeutics research, 2017. **42**(1): p. 27-38.
122. Passarella, S. and T. Karu, *Absorption of monochromatic and narrow band radiation in the visible and near IR by both mitochondrial and non-mitochondrial photoacceptors results in photobiomodulation.* Journal of Photochemistry and Photobiology B: Biology, 2014. **140**: p. 344-358.
123. Arranz-Paraíso, D., et al., *Mitochondria and light: An overview of the pathways triggered in skin and retina with incident infrared radiation.* Journal of Photochemistry and Photobiology B: Biology, 2023. **238**: p. 112614.
124. Agrawal, T., et al., *Pre-conditioning with low-level laser (light) therapy: light before the storm.* Dose-Response, 2014. **12**(4): p. dose-response. 14-032. Agrawal.
125. Bajpai, R. and A. Raj, *Illuminating Relief: The Efficacy of Low-Level Laser Therapy (LLLT) in Managing Orofacial Pain Disorders–A Comprehensive Review.*
126. Parker, S.P., *Laser-tissue interaction*, in *Lasers in Dentistry—Current Concepts*. 2024, Springer. p. 35-63.

127. Nowacka, A., et al., *Therapeutic Potential of Infrared and Related Light Therapies in Metabolic Diseases.* International Journal of Molecular Sciences, 2025. **26**(11): p. 5134.
128. Zhang, L., et al., *Advanced progress of adipose-derived stem cells-related biomaterials in maxillofacial regeneration.* Stem Cell Research & Therapy, 2025. **16**(1): p. 110.
129. Ye, R., et al., *LLLT accelerates experimental wound healing under microgravity conditions via PI3K/AKT-CCR2 signal axis.* Frontiers in Bioengineering and Biotechnology, 2024. **12**: p. 1387474.
130. Karimi, N. and A.B. Dinçsoy, *The Role of Mesenchymal Stem Cell-Derived Exosomes in Skin Regeneration, Tissue Repair, and the Regulation of Hair Follicle Growth*. 2025, Springer.
131. Alves, J.C., *Laser Therapy in Veterinary Regenerative Medicine.* Laser Therapy in Veterinary Medicine: Photobiomodulation, 2025: p. 458-469.
132. Al-Timimi, Z., S. Haddawi, and S.A.H. Nukhailawi, *Comparative Histological Assessment of Zinc Oxide Nanoparticles and Low-Power Laser Treatment at 810nm Wavelength on the Recovery of Second-Degree Burn Wounds in Rat Models.* The International Journal of Lower Extremity Wounds: p. 15347346241313009.
133. Bagheri, H.S., et al., *Low-level laser irradiation at a high power intensity increased human endothelial cell exosome secretion via Wnt signaling.* Lasers in Medical Science, 2018. **33**(5): p. 1131-1145.
134. Fu, Y., et al., *Mesenchymal stem cell exosomes enhance the development of hair follicle to ameliorate androgenetic alopecia.* World Journal of Stem Cells, 2025. **17**(3): p. 102088.
135. Remboutsika, E., *The Art of Neuroregeneration De Novo and In Situ*. 2025, Springer.
136. Firoozi, A., M. Shadi, and A. Rezagholizadeh, *The role of low-level laser therapy in Alzheimer's disease: a review of the potential benefits of vitamin D enhancement.* Lasers in Medical Science, 2025. **40**(1): p. 159.
137. Amirazodi, E., *Emerging Therapies for Neurodegenerative Disorders like Alzheimer's and Parkinson's.* Eurasian Journal of Chemical, Medicinal and Petroleum Research, 2025. **4**(1): p. 309-329.
138. Alam, J., et al., *Neuromodulation via brain stimulation: A promising therapeutic perspective for Alzheimer's disease*, in *Artificial Intelligence in Biomedical and Modern Healthcare Informatics*. 2025, Elsevier. p. 257-266.
139. Johnson, K.J., et al., *Photobiomodulation therapy increases neural stem cell pool in aged 3xTg-AD mice.* PloS one, 2025. **20**(4): p. e0321668.

140. Huang, Y., et al., *Recent advances in near-infrared photobiomodulation for the intervention of acquired brain injury.* Journal of Innovative Optical Health Sciences, 2025. **18**(1).
141. Middleham, W., *Advancing Stroke Recovery: Addressing Reperfusion Failure, and Promoting Neuronal Plasticity*. 2025, University of Zurich.
142. Ge, J., et al., *Photobiomodulation inhibits retinal degeneration in diabetic mice through modulation of stem cell mobilization and gene expression.* Experimental Eye Research, 2025. **251**: p. 110218.
143. Biniazan, F., A. Stoian, and S. Haykal, *Adipose-derived stem cells: angiogenetic potential and utility in tissue engineering.* International Journal of Molecular Sciences, 2024. **25**(4): p. 2356.
144. Das, P., et al., *Unveiling advanced strategies for therapeutic stem cell interventions in severe burn injuries: a comprehensive review.* International Journal of Surgery, 2024. **110**(10): p. 6382-6401.
145. Cao, B., et al., *Unlocking new Frontiers: The cellular and molecular impact of extracorporeal shock wave therapy (ESWT) on central nervous system (CNS) disorders and peripheral nerve injuries (PNI).* Experimental Neurology, 2024: p. 115052.
146. Wu, S., et al., *The role and prospects of mesenchymal stem cells in skin repair and regeneration.* Biomedicines, 2024. **12**(4): p. 743.
147. Luttrell, T., *Trauma and Inflammation of Soft Tissue.* Foundations of Orthopedic Physical Therapy, 2024.
148. Saberian, E., et al., *Scaffold application for bone regeneration with stem cells in dentistry: literature review.* Cells, 2024. **13**(12): p. 1065.
149. Berni, M., et al., *The role of low-level laser therapy in bone healing: systematic review.* International Journal of Molecular Sciences, 2023. **24**(8): p. 7094.
150. Tanideh, N., et al., *The effects of combined and independent low-level laser and mesenchymal stem cell therapy on induced knee osteoarthritis: an animal study.* The Knee, 2024. **47**: p. 208-218.
151. Carlos, F.P., et al., *Role of low-level laser therapy on the cardiac remodeling after myocardial infarction: A systematic review of experimental studies.* Life sciences, 2016. **151**: p. 109-114.
152. Blatt, A., et al., *Low-level laser therapy to the bone marrow reduces scarring and improves heart function post-acute myocardial infarction in the pig.* Photomedicine and laser surgery, 2016. **34**(11): p. 516-524.
153. Liang, J., et al., *Concise review: reduction of adverse cardiac scarring facilitates pluripotent stem cell-based therapy for myocardial infarction.* Stem Cells, 2019. **37**(7): p. 844-854.