Blue light therapy device for wound healing

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ABSTRACT

Cuts, diabetic ulcers, and pressure sores are examples of chronic skin wounds that pose a serious healthcare danger because of their delayed healing rates. This problem emphasizes the necessity of creating non-invasive, economical, and successful wound treatment plans. Conventional treatments, such as skin grafting, negative pressure wound therapy, and hyperbaric oxygen therapy, have demonstrated effectiveness; nevertheless, they are frequently costly, intrusive, and have possible side effects. On the other hand, blue light treatment has become a viable substitute due to its antimicrobial characteristics and capacity to encourage cellular restoration. However, there is a crucial gap in the development of a portable, non-invasive, and cost-effective photobiomodulation device for wound treatment and monitoring, despite its demonstrated potential in wound healing. This work aims to address this gap by creating a novel blue light therapy tool specifically suited for wound healing. The gadget allows for controlled blue light exposure and real-time temperature monitoring to minimize overheating. It has a portable arm housing with integrated blue light strips, a temperature sensor, and an integrated fan. An STM 32 microcontroller powers the system's pulse width modulation (PWM) technology, which modifies light intensity and therapy duration in response to conditions unique to each wound. This novel strategy seeks to improve the effectiveness of wound healing, lower the likelihood of adverse effects, and offer patients and healthcare providers a workable alternative that is non-invasive, inexpensive, and easy to use.

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1. INTRODUCTION

Wounds are a major global health issue that impacts millions of people annually, generally accidentally. According to the World Health Organization (WHO), 40 million individuals globally suffer from chronic wounds annually [1]. These wounds come in a variety of forms and intensities, such as cuts, pressure injuries, venous ulcers, and diabetic ulcers. Wounds can arise from a variety of sources, including traumatic accidents and underlying medical disorders including diabetes and vascular illnesses. In addition, the occurrence of wounds varies among groups and is influenced by environmental variables, healthcare availability, and socioeconomic factors [2]. Wounds have an effect that goes beyond the physical pain; they frequently result in a lower quality of life, incapacity, and higher medical costs.

Wound healing is a complex and pervasive process. The first stage of wound healing is called inflammation, and it usually lasts for three to five days after the damage. Immune cells are drawn to the wound site during this period, and pro-inflammatory cytokines are generated to aid in the clearance of debris and the fight against infections [3]. The next step is proliferation, which takes 3-14 days on average. During this time, fibroblasts, endothelial cells, and keratinocytes multiply and move to produce extracellular matrix components that are necessary for tissue regeneration [4]. The remodeling phase entails the maturation of scar tissue and the restructuring of collagen fibers and can last for several weeks to months. The remodeling phase makes up around 80% of the wound-healing process. Collagen deposition and cross-linking help restore tissue strength and functionality [5]. Figure 1 shows the stages of wound healing.

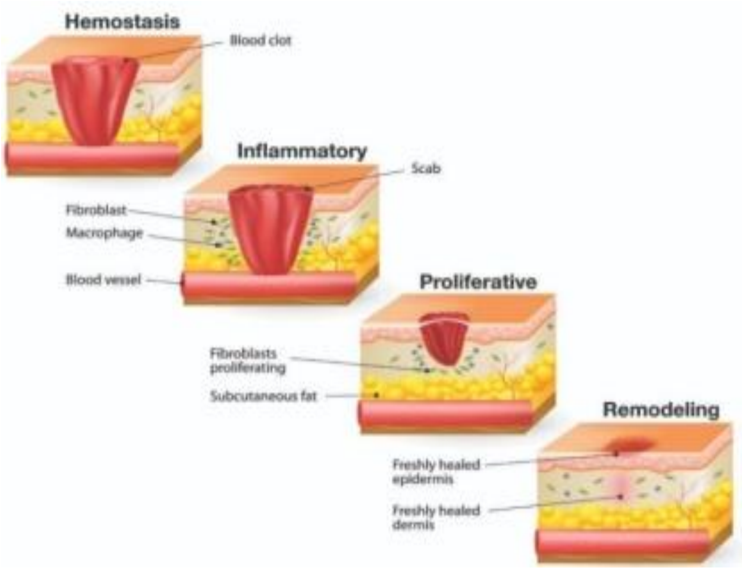

Figure 1. Stages of wound healing

The wounds heal at different rates, generally slowly, depending upon various factors [6]. Examples include people with diabetes because their wounds heal up to 50% more slowly than healthy people [7]. In addition, and to varied degrees in different populations, factors like aging, poor circulation, and specific medical problems can also cause delayed wound healing. Considering this, the application of traditional wound care techniques, like debridement and dressings, is essential to fostering an environment that promotes wound healing. Using the right wound dressings can cut the chances of infection by as much as 70%, demonstrating their effectiveness in preventing infections [8]. Moreover, debridement-the removal of necrotic tissue-helps prepare the wound bed and makes tissue regeneration easier. New developments in wound care technologies have further transformed the profession and provided creative ways to improve healing results. When compared to using standard dressings alone, negative pressure wound care has been demonstrated to expedite wound closure by as much as 50% [9]. In a similar vein, bioengineered skin substitutes have shown effectiveness in speeding up the healing process for chronic wounds like diabetic foot ulcers by encouraging tissue regeneration. However, in addition to being crucial for patient welfare, optimal wound care techniques have major financial ramifications. The centers for disease control and prevention (CDC) released that over $20 billion is spent on healthcare annually for the 6.5 million Americans who suffer from chronic wounds [10]. This highlights the enormous cost that wounds place on both patients and healthcare systems.

The rising cases of chronic wounds and the shortcomings of traditional therapies have led to a surge in the desire for non-invasive, affordable, and effective wound-healing modalities. Wound treatment techniques that have been around for a while, like dressings, topical ointments, and surgical procedures, have proven to be successful. These techniques do, however, frequently have serious side effects, specifically among them being extremely slow wound healing [11], [12]. While surgical procedures, such as skin grafting are a useful surgical technique in many situations, they can also be expensive, invasive, and have risks of infections and other consequences. Comparably, although topical ointments and dressings are less intrusive, they might not always produce the best results, particularly leading to slow healing for complicated or chronic wounds [13], [14].

Modern wound management technologies including laser therapy, hyperbaric oxygen therapy (HBOT), and negative pressure wound therapy (NPWT) have been promising in replacing conventional methods. NPWT applies controlled negative pressure to the wound site, which helps to promote tissue granulation, increase blood flow, and reduce edema-all factors that contribute to wound healing [15], [16]. HBOT delivers oxygen at a higher atmospheric pressure, which helps to promote wound healing and tissue oxygenation [17], [18]. In contrast, laser therapy uses particular light wavelengths to speed up tissue restoration and promote biological processes [19], [20].

Contemporary treatments have many advantages, but they may also have drawbacks including high costs, invasiveness, and the requirement for specialist facilities or medical equipment. As a result, the need for creative wound healing treatments that put accessibility, cost, and usability first is becoming more and more apparent. Several cost-effective, non-invasive, and portable modalities that are easily used in different contexts have a lot of potential to help treat the increasing number of chronic wounds [21]. Researchers and healthcare professionals seek to create innovative wound care strategies that improve patient outcomes, lower healthcare costs, and improve overall quality of life by utilizing innovation and technology. This demand paved the way for the inclusion of light, particularly blue light in wound healing systems, the significance of which has commonly been discussed. So, considerable advancements in photobiomodulation, aiming at improving healing processes and patient outcomes have resulted from the investigation of innovative technologies in wound healing. The effectiveness and safety of organic light-emitting diodes (OLEDs) for wound healing and skin rejuvenation were examined in research by Young in Lee *et al.* [22]. The study emphasized how regulated light exposure by OLEDs can boost cellular responses and stimulate tissue regeneration, providing a non-invasive wound care option. In research by Li *et al.* [23]; an intelligent ZIF-8 composite was created to target drug-resistant infections in burn wounds using fluorescence imaging-guided photodynamic treatment. This strategy showed the value of smart materials in wound care by addressing infection and promoting healing through targeted therapy. Zheng *et al.* [24] have presented a wearable hydrogel composite that was bioinspired and offered both sustained medication release and optical indications to provide early warning of wound dehiscence. This invention blended real-time therapy delivery with continuous monitoring, improving patient safety and treatment efficacy.

An injectable wound dressing based on thermosensitive hydrogel and near-infrared (NIR) photothermal conversion was presented by Wu *et al.* [25]. By encouraging localized heating, which improves blood flow and cellular activity at the wound site, this hydrogel speeded up the healing of skin wounds. Bimetallic oxide Cu–Fe3O4 nanoclusters with a variety of enzymatic activity were investigated by Jin *et al.* [26] for the treatment and healing of wound infections. These nanoclusters demonstrated the promise of nanotechnology in wound care by having antimicrobial qualities and promoting wound healing through increased enzyme activity. An arginine-nanoenzyme that stimulated prompt angiogenesis in diabetic wound healing was the subject of research by Yang *et al.* [27]. This work emphasized the significance of improving blood vessel creation in long-term wounds, offering a focused therapy strategy to enhance healing results. The function of phototherapy in wound care was covered in detail in a review by Malan [28], which emphasized the use of several light modalities, such as laser and LED therapies. The paper emphasized how light might enhance cellular proliferation and reduce inflammation to promote wound healing.

The Bradlee *et al.* [29] study looked at how blue light therapy affects the quality of sleep for those who have had concussions. The results indicated that blue light therapy may have effects on wound healing by increasing cellular repair pathways, despite the primary focus being on neurological outcomes. In order to speed up wound healing hindered by bacterial infection, Wang *et al.* [30] research examineed a visible light cross-linking hydrogel filled with bioactive peptides for sequential release. This two-pronged strategy improved wound healing and infection control, highlighting the hydrogels' adaptability in wound care. The review by Fernández-Guarino *et al.* [31] emphasized how physical therapies, such electrical stimulation and ultrasound, can improve wound healing and lessen scarring. These techniques supported conventional therapies and provided up new possibilities for bettering patient outcomes. The effects of blue light exposure from digital screens on skin health were investigated in research by Kumari *et al.* [32]. This study emphasized the necessity for balanced light therapy applications in wound care by bringing attention to the possible negative consequences of prolonged exposure to blue light. The importance of the light source in antimicrobial photodynamic treatment was covered in the Piksa *et al.* [33]. The results showed that adjusting light conditions can greatly improve the effectiveness of photodynamic therapies, offering guidance for creating more potent wound-healing techniques.

In wound healing research, the combination of unique materials, light therapies, and novel delivery methods offers a bright way forward. All of these research point to the possibility of non-invasive, successful therapies that deal with the difficulties of wound care, especially in complex and long-term situations. However, these photobiomodulation therapies have not been commonly incorporated into wound healing systems yet and are still not a common practice in wound management, hence are not easily accessible in clinical or domestic settings and are not cost-friendly [34]. It is therefore essential to justify undertaking the proposed research, perhaps in the light of previous work done. It should be possible in most cases to anticipate the specific and general benefits likely to be achieved as a result of the completion of the proposed research.

In order to address the gap of inaccessible, expensive and invasive wound healing technologies, this proposed research aims to meet the increasing demand for novel approaches in wound healing, by concentrating on the creation and thorough assessment of a blue light therapy device designed especially for wound healing applications. In this context, blue light therapy is particularly promising since it uses the special therapeutic qualities of blue light to activate vital cellular processes that aid in tissue repair. Blue light has a wavelength range of about 400-500 nm [35]. It is distinguished by its antimicrobial qualities and promotes wound closure and tissue regeneration by promoting vital mechanisms like collagen synthesis, angiogenesis, and fibroblast proliferation [36].

The equipment designed in this work combines blue light strips into a lightweight, easily operated device that allows therapeutic light to be delivered precisely and specifically to the wound site. Moreover, the apparatus has been expertly designed to integrate real-time temperature sensing technology, guaranteeing precise tissue temperature monitoring during treatment sessions. By enhancing the therapeutic environment, this feature not only helps minimize treatment efficacy but also helps prevent potential side effects. Furthermore, the apparatus provides adjustable options for light intensity and therapy time, enabling medical professionals to customize treatment plans following the distinct requirements and ailments of each patient.

The blue light therapy device presented in this study aims to significantly transform the field of wound care by providing a painless, non-invasive, and economical option for wound care. Because of its built-in portability and user-friendly design, it may be used in a variety of therapeutic settings, including home care and hospitals. The ultimate target of this presented device is to serve humanity by greatly enhancing patient outcomes and lessening the costs of chronic wound treatment. The device utilizes advanced technology capabilities and the therapeutic potential of blue light to improve the quality of life for both patients and medical professionals by offering innovation in the field of wound treatments.

The subsequent sections of this study will briefly describe the proposed blue light therapy device for wound healing. Section 2 offers a thorough description of the proposed methodology, including a basic idea of the work, the hardware design, connections and implementation, experimental study protocol, and data analysis. This is followed by section 3 which presents the detailed results obtained in wound healing by the use of this device, including statistical representation of the subject data, and the comprehensive discussions for the system, to prove its accuracy. The study will conclude in section 4 with a discussion of these findings, acknowledging limitations and making helpful recommendations for future research endeavors. This research aims to fill gaps in existing wound healing techniques through the proposed device.

2. MATERIALS AND METHOD

2.1. Basic idea of the research

The basic idea of this proposed research is to create a blue light therapy device that is specially designed to cure wounds by taking advantage of the healing effects of blue light and driving the process of tissue repair. The device intends to activate important biological processes including collagen synthesis, angiogenesis, and fibroblast proliferation, which are critical for facilitating wound healing and tissue regeneration, by applying precise dosages of blue light to the wound site. The proposed design integrates sophisticated technological features to provide optimal therapy efficacy while minimizing the risk of unwanted effects. These features include temperature sensor technology and programmable settings for light intensity and treatment time. This blue light therapy device aims to transform wound care by giving patients a non-invasive and effective treatment as an alternative for a variety of conditions. It does this by offering a portable, user-friendly, and cost-effective solution. Figure 2 shows the pictorial representation of the proposed idea.

Figure 2. Basic idea of proposed research

2.2. Hardware design, connection, and implementation

The proposed device design revolves around an advanced system made especially for applications related to wound healing. A microprocessor, STM 32, as the programmable core of this device allows for exact control over the settings of the therapy. Users can modify the therapy length and blue light intensity throughout a session by utilizing the system's user-friendly adjusting knobs. The devices carefully placed blue light strips provide focused lighting on the damaged area, resulting in the best possible treatment results. The device's portability, which allows users to effortlessly attend therapy sessions anytime, anyplace, is enhanced by its 12-volt rechargeable battery, to power the entire system. Figure 3 shows the block diagram of our hardware design.

To improve the therapeutic process, a portable arm case with a hinge and proper support to place the arm comfortably has been created. Blue light strips are positioned inside the arm casing to provide targeted and efficient illumination of the affected area. The case also includes an integrated fan and a temperature sensor system that are carefully adjusted to keep therapeutic settings at their best. Real-time temperature modifications are made possible by this continuous monitoring technology, which guarantees that the therapeutic environment will always be favorable to the healing process.

The arm case's circuitry has adjustable parts that provide accurate control over therapy parameters. With the use of pulse width modulation (PWM), a 10 kΩ potentiometer coupled to an STM32 microcontroller enables users to modify light intensity per the unique needs of the wound state. In addition, a push button interface, in a Pull-Up configuration through a 10 kΩ resistor lets the users customize how long therapy sessions last, where each press adds 10 seconds, ranging from a minimum of 10 seconds to a maximum of 1 hour, with adjustable blue light intensity levels varying from 1% to 100%. By customizing the therapy to each wound's specific requirements, these user-friendly controls maximize treatment results.

The designed circuit of this device includes parts like a capacitor and a Darlington pair transistor (TIP 142) that cooperate to control the blue light's intensity during therapy. This transistor functions as a switch. The PWM output signals from the microcontroller are switched to the transistor's base via this switch. The blue light-emitting diodes (LEDs) receive PWM signals from the transistor when it becomes a closed switch, causing the blue LEDs to light up during the therapy session. In addition to the transistor, the blue LEDs are directly linked to a 12V power source, enabling them to illuminate as soon as the PWM impulses start. Furthermore, the STM 32 is directly connected to a 16x2 LCD. This LCD functions as an interface that displays a digital display with information about how long the therapy will last and how strong the blue light is. The capacitor filters noise in the PWM signals, resulting in smooth and steady illumination of the blue light strips, while the Darlington pair transistor amplifies PWM signals, guaranteeing exact control over light intensity. This all-inclusive system guarantees the safety and effectiveness of the treatment in addition to providing precise control over therapeutic parameters, which in turn accelerates the healing process for a variety of wounds.

The blue light therapy device for wound healing hardware circuit has been put into practice with success. The completed hardware circuit, which has been painstakingly designed to guarantee peak performance and ease of use, is depicted in Figure 4. The device's user-friendly settings, which include knobs for modifying the treatment time and the intensity of the light, let users customize their therapy sessions to meet their individual needs. Furthermore, Figure 5 presents an illustration of the apparatus, illustrating the positioning of LED strips inside the apparatus's framework. To ensure constant and efficient therapy, these LED strips are positioned strategically to supply light intensity to the wound site uniformly. The blue light therapy device for wound healing's precise control mechanisms and user-friendly design make it easy to use and accessible, resulting in a comfortable and effective treatment experience for patients.

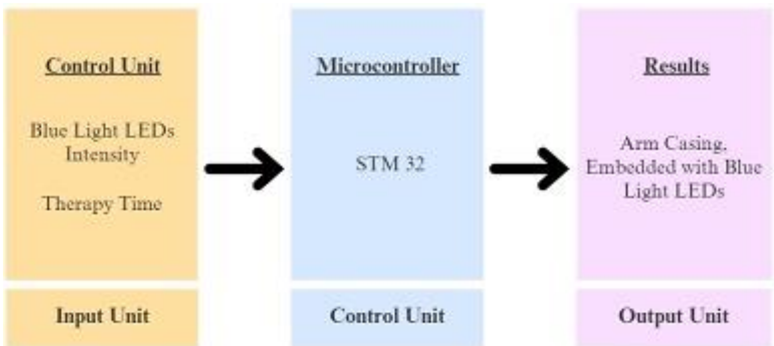

Figure 3. Block diagram of hardware system

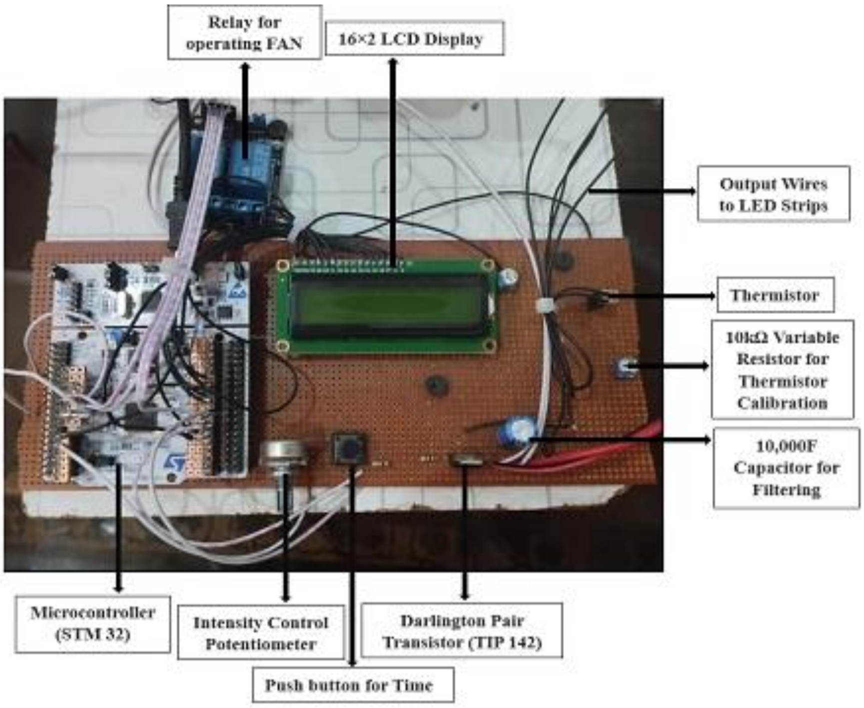

Figure 4. Hardware connection of the circuit components

Figure 5. Blue light therapy device and its LCD display

2.3. Experimental study protocol, setup, and procedure

A 6-week trial with 20 volunteers was run to determine the effectiveness of our blue light treatment device for wound healing (12 females and 8 males). In compliance with the study's inclusion and exclusion criteria, which are outlined in Table 1, each subject filled out their consent form and was then considered as a volunteer for the study being conducted.

Table 1. Inclusion and exclusion criteria for our study

Criteria	Inclusion	Exclusion
Age	Adults aged 18 years and above	Minors (below 18 years)
Wound type	Wounds such as cuts, stitches, diabetic ulcers, venous ulcers, pressure injuries	Acute wounds requiring immediate medical intervention
Medical history	No history of photosensitivity or contraindications to light therapy	History of skin cancer or other malignancies Active infection at the wound site Severe immunosuppression Chronic conditions affecting wound healing (e.g., uncontrolled diabetes, peripheral vascular disease)
Medications	Stable medication regimen with no known interactions with blue light therapy	Chemotherapy or immunosuppressive therapy Systemic corticosteroid therapy
Pregnancy	Not pregnant or breastfeeding	Pregnant or breastfeeding

Table 2 lists the instructional materials that were given to the participants. These materials described the different kinds of wounds and their features. Participants were then asked to determine the precise sort of wound they had sustained using the information that had been supplied.

Eight individuals with superficial wounds, 6 with partial-thickness wounds, and 6 with full-thickness wounds made up the study cohort. Every day, participants with superficial wounds received 20 minutes of therapy at a 50% light intensity. Every other day, individuals with partial-thickness wounds got therapy at a light level of 75% for 30 minutes per session. Participants with full-thickness wounds got therapy at a light intensity of 90%, for 40 minutes per session, 3 times a week.

Weekly checks, for up to 6 weeks on the participants' wound healing status were conducted during the study period, and measurements of the size, depth, and look of the wounds were made, according to the protocol set for conducting the study. Any negative side effects or discomfort that arose during therapy sessions was noted and quickly resolved.

Table 2. Types and description of wounds

Wound type	Description
Diabetic Ulcer	Open, deep sores that usually appear on the lower limbs or feet of people with diabetes, either partial or full-thickness wounds
Venous Ulcer	Shallow, painful sores that are frequently the result of venous insufficiency and are caused by inadequate leg circulation, either superficial or partial thickness wounds
Pressure Injury	These lesions, which are often referred to as bedsores or pressure ulcers, occur when continuous pressure on the skin lowers blood supply to the area, ranging from superficial to full-thickness wounds
Surgical Wound	Surgical incisions that have not yet healed completely, either partial or full-thickness wounds
Traumatic Wound	Cuts, lacerations, and abrasions that result from trauma or physical harm, ranging from superficial to full-thickness wounds

2.4. Data collection and analysis

Data on the development of wound healing, such as granulation and wound size decrease, were gathered on a regular basis. Additionally, participants' responses to blue light exposure were observed for any unfavorable side effects. The criteria that were used to exclude any outliers or abnormal data points included that if the participant did not follow the recommended therapy regimen, or if there were other medical issues that had a substantial impact on the treatment and wound healing outcomes. Mean percentage improvements were used in the statistical analysis of the collected data for all wound categories. To determine how differently blue light therapy works for each type of wound and severity degree, comparative analysis was done. For the results to be accurate and repeatable, control variables including participant age and overall health were taken into consideration.

2.5. Significance of the proposed methodology

Based on well-established studies on the biological advantages of blue light in stimulating tissue regeneration, this study's methodology was developed. Our goal was to overcome the shortcomings of current wound care therapies by combining blue light therapy with unique hardware and control technologies. For the therapy to be both safe and effective, real-time temperature monitoring and programmable light intensity were essential components. This methodical approach guarantees that the methodology not only answers the research questions but also offers a solid foundation for further researchers to build upon the work. Due to its versatility and adaptability, the system can be used in both home and clinical settings for a wide range of wound care applications.

3. RESULTS AND DISCUSSION

The study's results regarding the use of blue light therapy to treat wounds showed encouraging improvements in the participant cohort's wound states. 7 of the 8 individuals who had superficial wounds showed a discernible improvement in the results of wound healing. In particular, 85% of instances showed better tissue granulation and a decrease in the size of the incision. Furthermore, 4 of the 6 participants who had partial-thickness wounds showed noteworthy improvements, including enhanced epithelialization and a reduction in the depth of the incision. 3 of the 6 participants in the subgroup with full-thickness wounds showed significant improvement, with improved wound closure and reduced exudate generation. One group member did, however, show only modest improvement, which was explained by underlying medical issues that affected the healing of the lesion. Overall, the findings show that blue light treatment is well-received, confirming its effectiveness as a non-invasive technique for accelerating tissue regeneration and wound healing. Figure 6 shows the results of one of the subjects, after 6 sessions of blue light therapy for wound healing.

Figure 6. Results of one of the subjects for wound healing, after 6 sessions

Table 3 displays the statistical analysis of the study participants who underwent blue light treatment for wound healing. The table shows how the participants were distributed according to how well they responded to treatment, with each category denoting how much the wound state improved.

Table 3. Statistical analysis of the wound analysis

Subject	Gender	Wound condition	Improvement
1st-6th	Female	Superficial	75%-80%
7th-8th	Male	Superficial	60%-70%
9th-10th	Female	Partial Thickness	60%-70%
11th-14th	Male	Partial Thickness	50%-55%
15th-17th	Female	Full Thickness	50%-55%
18th-19th	Male	Full Thickness	45%-50%
20th	Male	Full Thickness	Less than 35%

The results validate blue light therapy’s efficacy as a non-invasive strategy to accelerate wound healing, especially for minor to moderate lesions. The most noticeable benefits were seen by those with superficial wounds, suggesting that the device is effective in less severe situations. Full-thickness wounds, on the other hand, recovered relatively more slowly, especially in individuals with concomitant medical conditions. This suggests that more treatment modalities would be required for the best outcomes. So, the propsed technology has demonstrated noteworthy increases in wound healing outcomes for people with superficial and partial-thickness lesions. However, the device’s efficacy has been seen as restricted for participants with full-thickness wounds, especially those with underlying medical disorders that affect wound healing. To attain the best results, these situations could need more specialized and extensive treatment techniques including regenerative therapies or advanced surgical interventions. However, the technology has been warmly received by those with mild to severe wounds, providing a non-invasive, easy-to-use, and efficient way to encourage wound healing and tissue regeneration. The device’s painlessness and convenience of use have been praised by participants, indicating that it has the potential to be a useful supplement to traditional wound care techniques.

The outcomes are consistent with earlier studies that emphasize blue light therapy’s antibacterial and regenerative qualities. Studies like those by Jabbar and Abid [37] and Brüning *et al.* [38], have shown that blue light can successfully encourage fibroblast growth, which is essential for wound closure. Similar gains in tissue granulation and epithelialization were noted in this investigation, especially in superficial and partially-thickened wounds, which have been demonstrated to respond well to blue light therapy. However, the findings for full-thickness wounds were not as strong as those of trials on more invasive treatments like HBOT or NPWT. Although NPWT has been shown by Keenan *et al.* [39] to accelerate wound closure by as much as 50% in deep or serious wounds, the blue light therapy device showed less dramatic outcomes in these instances. According to this, blue light therapy may be beneficial, but it may also need to be combined with other treatments for serious or complicated wounds, especially in individuals who have underlying medical conditions such diabetes or poor circulation.

The study’s conclusions imply that the blue light therapy device, especially for superficial and intermediate wounds, might be a useful addition to the present arsenal of wound care technologies. The outcomes further emphasize how crucial customisation is in therapeutic environments. The device’s programmable light intensity and treatment time allowed for a customized strategy that maximized results according to the degree of the wound. In clinical terms, the gadget provides a portable, affordable, and non-invasive option that may be applied in home health and hospital environments. Because it works so well on superficial wounds, it might be used widely in cases when more traditional therapies would be too costly or invasive. Furthermore, people in need of routine, low-risk treatment can get it due to its portability.

Even with the encouraging outcomes, the study has several drawbacks. The device’s long-term efficacy may not be adequately captured by the 6-week follow-up time and the relatively small sample size, especially for chronic wounds. Furthermore, the full-thickness wound participants’ varied results indicate that more device design improvements or its conjunction with other therapies may be required for more complicated situations. The areas that should be the focus of future research include expanding the follow-up duration and sample size to offer a more thorough understanding of the device’s long-term performance. This can be followed by examining changes to the device architecture, such adding more treatment modalities like infrared or red light, or increasing light intensity for deeper lesions. The subsequent one can be broadening the scope of the research to include burns, surgical wounds, and traumatic injuries in order to evaluate the device’s adaptability to a wider variety of wound types. Furthermore, to gain a better understanding of the benefits and drawbacks of each strategy, comparison studies between blue light therapy and currently available wound care technologies, such as NPWT and HBOT, should be conducted.

Particularly for less severe cases, the blue light therapy device has shown significant promise as an inventive, non-invasive wound healing technique. The device is a convenient and approachable choice because of its real-time temperature monitoring, configurable light intensity, and mobility. This work is a positive step toward the advancement of blue light therapy as an effective wound care option, even though more investigation and development are required to optimize its efficacy for more serious wounds.

4. CONCLUSION

This study highlights the potential of blue light therapy as a non-invasive, efficient treatment for wounds of superficial and partial thickness that can speed up the healing process. Through promoting essential biological functions like collagen synthesis and angiogenesis, the apparatus facilitates quicker tissue regeneration while lowering the potential for infection. Blue light therapy for mild to moderate wounds is a safe, cost-effective, and easy-to-use alternative, even though the outcomes for full-thickness wounds and more serious conditions were not as strong. This research is significant because it takes a novel approach to a problem in global healthcare. Many people cannot afford the invasive surgeries or costly therapies associated with traditional wound care methods. The suggested device’s small size and portability enable more flexibility and accessibility in both home and clinical settings. Furthermore, the system is flexible enough to accommodate different kinds of wounds and patient requirements due to its customizable therapy parameters, which include light intensity and duration. But the study also points to certain drawbacks that would limit how broadly the results can be applied, such as the small sample size and short follow-up period. The low efficaciousness of the device in treating full-thickness wounds highlights the necessity for additional investigation to investigate improvements in the development and incorporation of supplemental therapies. Subsequent research endeavours ought to concentrate on trials with greater scale and longer durations of follow-up, and explore the potential benefits of integrating blue light therapy with other modalities for more intricate wounds. The results of this study offer a solid basis for the wider use of blue light therapy in wound care. The encouraging findings imply that, with further development and verification, this technology may considerably enhance patient outcomes, lower medical expenses, and turn into an invaluable resource for medical practitioners everywhere. Maximizing its potential and treating a greater spectrum of wound diseases would require increased research and innovative device design.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Aleena Kamal		✓						✓	✓		✓	✓		
Azka Abid	✓		✓	✓					✓		✓		✓	
Sarah Ahmed					✓				✓					
Syed Muddusir Hussain					✓		✓			✓		✓		✓
Jawwad Sami Ur Rahman						✓				✓				
Sathish Kumar Selvaperumal					✓					✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, Sathish Kumar Selvaperumal. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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