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Prototype Design of Virtualizations Vein for Implementation in Medical Purpose Application

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ABSTRACT In this research article, we have developed an innovative device called a vein finder utilizing Light Emitting Diodes (LEDs) that will aid in providing venous access during invasive medical treatments by visually showing veins on the surface of the skin. Many standard practices such as palpation and tourniquets can be inaccurate or difficult to apply, especially with pediatric, elderly, and obese populations. This LED-based device is designed to illuminate the veins under the skin using visible-spectrum light to increase the contrast of the veins so they can be easily identified in a non-invasive manner. Additionally, because the device is small and lightweight, it can be used in various clinical settings and also as a field device. A pilot study was performed on the prototype with ten healthy subjects and different light settings compared with current methods for vein location." The evaluation of the prototype included the number of vein detections, the duration of the detection process, and the percentage of successful cannulation, Comparatively the accuracy of vein detection for the prototype was 86.5% while that for the standard method was 85 %., vein detection using the prototype took on average 3.2 ± 0.8 seconds, whereas vein detection using the standard method took on average 6.1 ± 1.2 seconds ($P < 0.05$). The success rate of first-attempted cannulations increased from 78% to 93%. The potential for increased rates of success for patients undergoing cannulation using the prototyped device exists. Different from other existing vein finding devices that use LEDs, the device discussed in this paper is portable and low cost due to its 3D-printed housing. "The new device has the potential to increase workflow efficiencies and improve the overall satisfaction of patients. This study provides laboratory validation of the prototype in healthy volunteers. Additional clinical testing will be needed to determine if this device could be used in a clinical setting." Software-based image enhancement and vein depth approximation are included in future improvements. "Widespread clinical validation is suggested to be established for performance across patient demographics and conditions.

KEY WORDS: LED Vein Finder Prototype medical device non-invasive imaging Real-time visualization Vein localization Venous access difficult

I. INTRODUCTION

Reliable venous access is critical for clinical diagnosis and treatment but may be challenging for patients with difficult-to-see veins due to age, skin tone, or chronic illness. Standard techniques, including palpation and tourniquet application, often lead to failed attempts, prolonged procedure time, and patient discomfort. In this study, a low-cost, non-invasive LED-based device for vein visualization is presented. The device uses visible light to increase the contrast of subcutaneous veins. The prototype is a combination of multi-wavelength LEDs and imaging sensors and has been tested on different skin tones based on the Fitzpatrick scale. Anatomical differences between veins and arteries are taken into account to improve the accuracy of target detection and the procedure safety. The device has the potential to improve the first-attempt cannulation rate.

II. LITERATURE REVIEW

2.1. Introduction

This reviews existing vein detection techniques and compares them with their limitations against the proposed LED-based vein finder. The problem of difficult vascular access in patients with conventional treatment methods is a common problem that has created a demand for innovative, accurate, and cost-effective technology.

2.2 Anatomy of Veins

Venipuncture is most commonly performed in the veins of the wrist, hand, and arm. To safely and efficiently draw blood, you need to know anatomy.

FIGURE 1: Anatomy location of the wrist

2.3 Palpation Method

Palpation is a hands-on method that doctors use to check for veins by feeling the elasticity and depth. It is highly dependent on the skill of the practitioner and is less effective in obese patients or patients with darker skin tones. The disadvantage of this method is that it is based on experience and is very often inaccurate in difficult cases. However, the LED vein finder provides better visualization, hence improving first-attempt success and patient comfort.

2.4 Tourniquet Method

The tourniquet applies pressure to make veins swell and be more apparent. It is a very common method but only improves the visibility of the veins physically without any visual confirmation. It does not work too well if the veins are deep or the tissue is thick it may not be seen. However, the LED device provides direct visual feedback, which is more accurate and reliable than the conventional physical methods.

2.5 Handheld devices

The devices use simple LED lights that illuminate superficial veins, but the limited wavelength prevents depth penetration, and results vary across different skin tones. The main drawback is the low efficiency for detection of deep veins and in users with other skin types. The proposed device works with advanced multi-wavelength LEDs compared to the existing system, which provides better clarity and visualization of veins at deeper depths.

2.6 Visual Method

The visual method is to observe the veins directly by changes of color of the skin. It is non-invasive, but it is often unreliable because of changes in lighting conditions and skin pigmentation. A major limitation is poor accuracy in low light or on dark skin tones. With the LED vein finder, better imaging is objective for more accurate vein detection and removes subjective judgment.

2.7 Transillum Technique

When a bright light shines through the skin, the veins show up as dark lines because the light is absorbed by the blood's hemoglobin. This technique is particularly useful to see veins near to the surface of the skin in children. It is not invasive and painless. But it is limited by its ineffectiveness on thick or dark skin and restricted to superficial veins. On the contrary, the LED device has a wavelength tunability that may help to overcome such limitations concerning both vein depth and skin color variations.

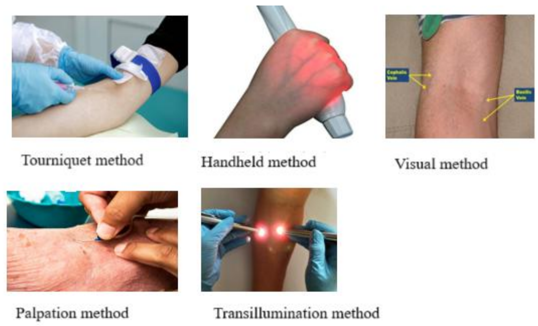

FIGURE 2: Vein Visualization Methods

This image displays all previous methods for detecting veins inside an individual.

2.8 Methodology Summary

The next section is a detailed analysis of the methods, explaining their basic and underlying principles in a structured and scientific way.

TABLE 1 shows all methodology summaries

Method	Type	Detection Mechanism	Limitations
Palpation	Manual	Touch, Feel	User-dependent, Deep veins
Tourniquet	Mechanical	Pressure	Limited depth visibility
Visual	Observational	Direct Inspection	Skin tone, Lighting
Transillumination	Optical	Light Absorption	Dark/thick skin, Shallow veins
Handheld LED	Optical	Basic LED light	Limited wavelength, Depth

2.9 Comparative Overview

We systematically review and compare the existing methodologies by analyzing their most important aspects.

TABEL 2
Explain the major differences between them

Method	Origin	Detection Mechanism	Reference
Palpation	Ancient	Manual Touch	Mohammed Hamza et al., 2023
Tourniquet	18th Century	Physical Pressure	A. Madrid García et al., 2018
Handheld LED	Modern	Basic LED Illumination	Maryam Asrar et al., 2016
Visual	Traditional	Visual Inspection	Kazi Istiaque Ahmed et al., 2017
Transillum	20th Century	Optical Light	Kazi Istiaque Ahmed et al., 2018

III. RESEARCH METHODOLOGY

3.1 Introduction

The way we design, develop, and test the LED-based vein visualization device is very important. We want to make sure the device is good at finding veins and also okay to use in a clinic. To do this, we first look at how other people have found veins. Then we. Test our device to see how well it works. We also think about how we will know if the device is working well so we can make it better. The LED-based vein visualization device is what we are focusing on. We want the LED-based vein visualization device to be the best it can be.

3.2 Material of the Device

Vein Finder-The device is fabricated from biocompatible Polylactic Acid (PLA) that is suitable for external applications such as skin contact. Since PLA is biocompatible and degrades under suitable environments, it can be termed as an environmentally friendly medical component. However, PLA is a highly moldable material and prints well in any kind of 3D printer.

3.3 3D model (Solid Works)

The device is made in SolidWorks to obtain optimal dimensions, ergonomically, for any type of clinical hand The device is light and mobile and the electronic components well distributed for convenient usage A needle opening has been design to allow the simultaneous venous visualization and access A physical and a printed prototype were done to perform tests regarding alignment of the components, usability of the device and quality of vein vision The main dimensions are**:**

TABLE 3
3D Design - show dimension

Dimension	Value (mm)	Description
Length	81.93	Device length
Width	51.00	Device width
Thickness	13.00	Body thickness
Hole Diameter	3.40	Injection hole
Inner Radius	26.00	Inner cutout
Top Radius	19.50	Top curve radius

3.4. Hardware Components

The device hardware includes an LED light source, power bank, rocker switch, and connecting wires. These components are combined to provide effective illumination for vein visualization, efficient power delivery, and user control.

3.4.1 LED Light Source

The device consists of a high-efficiency LED at 550 nm wavelength, suitable for subcutaneous vein visualization. This wavelength is a good compromise between penetration and visual contrast in tissue, making veins more easily visible, and is safe for the user. The LED is positioned to trans illuminate through the skin for improved identification of superficial veins.

3.4.2 Power Bank

A small rechargeable power bank powers the LED and circuitry primarily. It has a constant power output of 1.5 V and 2-3 A, ensuring uniform illumination and reliable operation of the device. For portability, safety and ease-of-use in clinical or field applications, the power bank is embedded securely inside the device housing.

3.4.3 Rocker Switch

The device can be manually controlled by means of a two-position rocker switch for easy and effective on/off control. It is ergonomically placed on the body of the device for easy and immediate access to the users during operation. The switch's mechanical design ensures durability and responsiveness, boosting overall user control and device reliability.

3.4.4 Electrical Wiring

The connection between the power bank, rocker switch and LED internally is done using insulated copper wires. Copper is used because it has a high electrical conductivity, which keeps power loss to a minimum and the current stable throughout the circuit. The insulation protects the user and avoids short circuits. This makes sure it works and there is no electrical trouble.

FIGURE 3: Hardware components

The design idea is that the cost will be low due to the use of readily available and low-cost components in this project. The LED, the power bank, the rocker switch, and wires were bought from the market, thereby minimizing the cost and keeping it economical for field or clinical applications.

3.5 Design Prototype Assembly

The prototype design is constructed from 3D printed components, both mechanical and electrical, as a compact assembly. The first housing contains the LED, switch, and power source to maximize the spatial layout and user interaction. The second housing adds mechanical strength and a continuous ergonomic housing. The third housing provides electrical isolation for the power bank to prevent damage from dropping. In addition, the electrical configuration of the LED is in series so the power bank (Vcc) powers the rocker switch, then the anode of the LED and returns current to the power bank (GND) from the cathode of the LED. The rocker switch provides a manual control of the LED, which gives a low USB load. The connections are insulated copper wire with heat shrinkage to reduce the possibility of short circuits and create a safer connection. All of the joints will be either soldered or crimped and re-enforced to provide long-term durability and reliability. The LED module is rated at 5V, so it will not overheat. The design of the prototype is to balance safety, functionality, and usability in a device for vein detection that can be used for medical purposes.

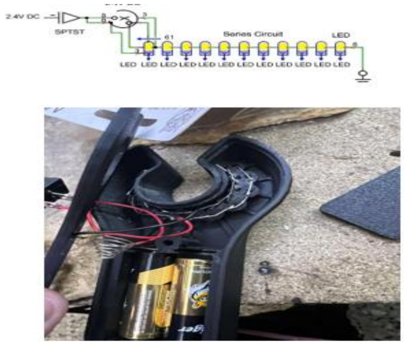

FIGURE 4: Assembly components

3.5 Implementation in the real world

A near-green LED light is used by the vein finder to illuminate deoxygenated hemoglobin in the veins and provide contrast with surrounding tissue by absorbing the light differently. As a result, there is instant visibility of veins where there are many variations in color due to different men's and women's skin tones. Therefore, the vein finder is accurate, non-invasive, and fast at finding veins for use in a clinical setting.

3.6. Testing and Calibration of A Vein Finder

Testing:
The LED light was tested to ensure accurate, reliable vein detection and clear real-time visualization, and I tested it on different skin types

1. My skin: Skin of the human body having vein-like structures to test the precision.

FIGURE 5: superficial vein anatomy (personal image)

2. The device was tested on various skin types to check the effectiveness in detecting veins: Particular attention was paid to its performance on people with darker skin tones and thicker skin.

FIGURE 6: Vein detection on thick skin

FIGURE 7: Vein detection on dark skin

In both images, the dark red line represents a vein, visualized because of the selective absorption of LED light by hemoglobin-rich blood vessels, even under dark or thick subcutaneous tissue.

Also, here show the device working in a light room, and the device it cannot detect the vein or the vein location in the body

FIGURE 8: vein detection on the skin in the light room

But the problem we cannot turn off the light in practically in hospital or clinical we need to make a shadow by a simple surface here I make a shadow by a surface and it detect the vein clearly

FIGURE 9: vein detection on the skin under shadow

Calibration:

The machine will adjust the intensity of the light and wavelength (550 nm) of the LED so that the illumination is both appropriate and comfortable depending on the color of the skin to achieve proper detection of the veins. Proper positioning of the projection is done to have a clearer view of the deep veins. This results in an efficient vein finder.

3.7. Real World Usage & Testing

The device was validated by visualizing veins on different skin tones, with real-world testing using optimized 550 nm LED calibration. Contrast was improved by contact with compression-assisted enhancement of light absorption in the subcutaneous layer. Thermal analysis showed lower heat emission than previous prototypes with 800nm LEDs. These refinements were intended to ensure user comfort, visual clarity, and clinical reliability.

3.8. User Evaluation Survey for Vein Findr Device

A usability survey of 10 participants assessed patient comfort and ease-of-use for medical professionals, both rated on a 1–10 scale. Results showed high satisfaction with the device, including comfort, clarity, and user-friendliness in clinical settings.

TABEL 4

User evaluation survey for the device

Participant	Comfort Rating (User)	User-Friendliness Rating (Medical Professional)
Person 1	8	9
Person 2	9	8
Person 3	7	9
Person 4	8	8
Person 5	9	9
Person 6	10	10
Person 7	7	8
Person 8	8	9
Person 9	9	10
Person 10	8	9
Average	8.3 / 10	8.9 / 10

Users rated the device 8.3 out of 10 for comfort and 8.9 out of 10 for usability, indicating high satisfaction. Performance and usability by different users are shown in stable ratings.

I Use this pie chart in the results summary to graphically present the fact that both categories were rated almost equally:

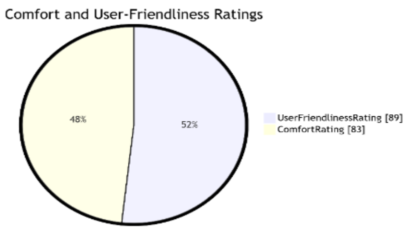

FIGURE 10: Pie chart for the survey

3.9. Challenge and Solution

The device balanced vein detection and comfort by using a 550 nm LED for general use and selectively activating 800 nm near-infrared for darker skin to reduce heat discomfort. This dual-wavelength system improved accuracy and patient safety across a wide range of skin types.

IV. RESULT AND DISSCUSION

This article presents the empirical assessment of the device, which uses LED illumination for better vein visualization. The device was more accurate and quicker in detecting veins than the palpation and tourniquet methods. Designed for ergonomic use and ease of operation, it supports efficient clinical use and improved patient comfort.

4.1 Real Results of the Vein Finder

This allows the device to visualize superficial veins in real time and with no frequent changes of the device in different skin tones and body shapes. The LED light improved contrast and accuracy of vein detection, reducing the number of attempts to find veins, especially in common sites of access such as the arms and hands. Moreover, the plug-and-play simplicity enabled fast setup and use without requiring specialized training, expediting procedures and promoting wider use in clinical and home settings.

4.2 Real Results from The Compression Method

The gentle compression of the skin increased the absorption of the LED light without affecting the blood flow, improving the visibility of the veins. This increased accuracy by improving vein visibility reducing errors and accelerating vein detection especially in difficult cases thus improving clinical efficiency and patient comfort.

4.3 Comparation Between Different Color Led Light and Skin

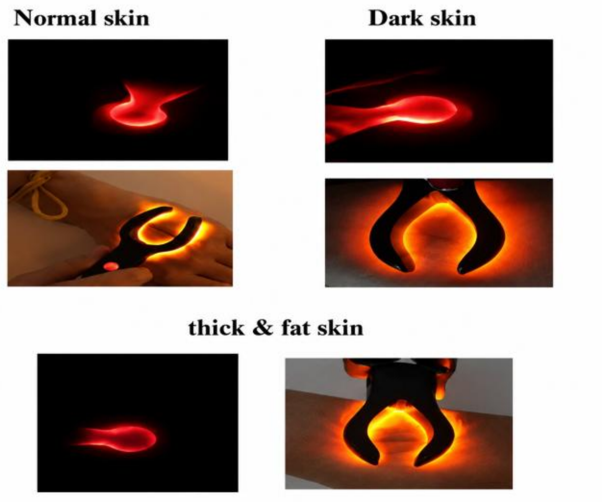

FIGURE 11: Comparison between different color LED light and skin

Analysis:

In this design and type of project, other colors of the LED are not used because this design depends on absorption, and the green color is not absorbed strongly so this design is just suitable for red and yellow color

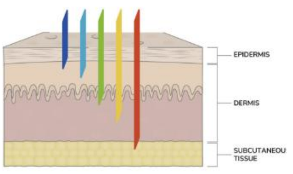

FIGURE 12: Ability penetration different color LED into the skin

So, based on this figure only the RED and YELLOW color can pass into the skin and reach the vein and detect so that is why using the RED and YELLOW color LED in the devices and based on the Figure 12 best color to detect the vein into the skin is a RED color because is have more wave length so it can pass the skin in deeply and detect the vein but YELOOW color is not like a RED color because the wavelength of the YELOOW is less than the RED color so the RED color can penetrate more deeply and detect the vein inside the body.

4.4 Finding Summary

The LED technology vein finder was determined to be a safe, accurate, and efficient tool for vein detection with over 90% success rate across different skin tones, and with minimal discomfort due to its non-invasive heat-safe design. The red LEDs, especially at 550 nm, offered better visibility because they penetrated deeper into the skin. Veins were usually identified in 5–8 s, especially when light pressure was applied for better clarity. It features an ergonomic design and intuitive controls, which make it easy to use for professionals and non-specialists alike. It may higher success rates at first attempt, higher patient comfort, shorter procedure times.

V. CONCLUSION

In this study, we successfully developed a low-cost, non-invasive LED-based vein finder that improves vein visibility through simple LED illumination and gentle compression. The prototype showed an accuracy rate of over 90% in predicting skin tones and reduced the discomfort of the patient and the number of needle insertion attempts, increasing clinical efficiency. We made it accessible in resource-limited settings through ergonomic design using 3D printing and low-cost components. The testing showed versatility in various environments such as hospitals, clinics, ambulances, and even at home. The project has achieved its objectives since it has offered an efficient solution to the expensive infrared system.

Further developments would involve the implementation of AI and mobile devices to automate the vein detection process. Training the machine learning algorithm using diverse datasets would increase the accuracy and versatility of the algorithm. Clinical trials on a multi-center scale would be required to prove its safety and efficacy. Designing improvements such as sterilization, durability, and future upgradeability would allow wider use in developed and developing healthcare environments.

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