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Therapeutic applications of polarized light: Tissue healing and immunomodulatory effects

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ABSTRACT

As the population grows and ages, non-pharmaceutical options for the treatment and management of wounds, disease and injury are required to ensure adequate care. Polarized light therapy (PLT) utilizes visible-spectrum polarized light for a number of clinical applications. The advantage of polarized light is that it is able to penetrate the skin to a depth of up to 5 cm, reaching deeper tissues involved in wound healing. PLT has been shown to accelerate the healing process for ulcers, surgical wounds and dermal burns as well as a small number of musculoskeletal injuries. As research into the histological and physiological effects of PLT is largely absent, studies related to other light therapy modalities, largely low-level laser therapy, may pave the way to identify putative mechanisms by which PLT might exert its effects. Changes to cell signalling and secretion of substances required for wound healing have been identified in response to phototherapies. The reviewed literature suggests that PLT may be efficacious in some wound and injury healing contexts, though a gap in the literature exists regarding its mechanisms of action. Future studies should fully explain the therapeutic effects of PLT and the physiological mechanisms underpinning them.

1. Introduction

Healing is a complex process comprising a wide variety of cell types, secreted factors and other physiological parameters. In a normal, healthy patient, the human body is capable of healing completely from a wide range of wounds and injuries. However when the system is compromized by external factors such as ageing, chronic disease or malnourishment, the healing response can be delayed, or incomplete, placing the patient at risk [1]. Despite this common problem, there are a limited number of interventions available, most of which are supportive in nature. The therapeutic use of light can be traced back to ancient Egypt. The sun god Ra was worshipped as their highest deity, and the Egyptians would bask in the sun to increase their energy levels [2]. The ancient Greeks, who were medically advanced for their time, also used sunlight to help treat illness [3], and in modern times, seasonal affective disorder is treated with bright artificial lights [4].

According to the International Commission on Illumination, light is "any radiation capable of causing a visual sensation directly" [5]. Its physical properties are described by its wavelength (i.e. the distance between the two nearest peaks in the wave), with visible light spanning from 390 to 700 nm in humans. Specific wavelengths correlate with the visual phenomenon of color when processed by the brain. Light wavelengths below this are known as ultraviolet (UV) light, and above as infrared (IR), both of which are not detectable by the human retina. In its typical setting light is incoherent or unpolarized, with individual waves travelling in all planes and directions. Polarization is achieved by passing incoherent light through specially designed filters, which allow waves travelling in the desired plane to pass and blocking those outside the desired parameter (Fig. 1). Polarized light can be of a single wavelength or polychromatic, as long as all waves travel in the same plane.

There exist a range of phototherapeutic modalities, exploiting different parts of the visible spectrum (Fig. 2). The major modalities are: UV-A and UV-B therapies, low level laser therapy (LLLT), light emitting diode (LED) therapy and IR therapies. UV therapies are often used to reduce the severity of some chronic skin conditions such as psoriasis

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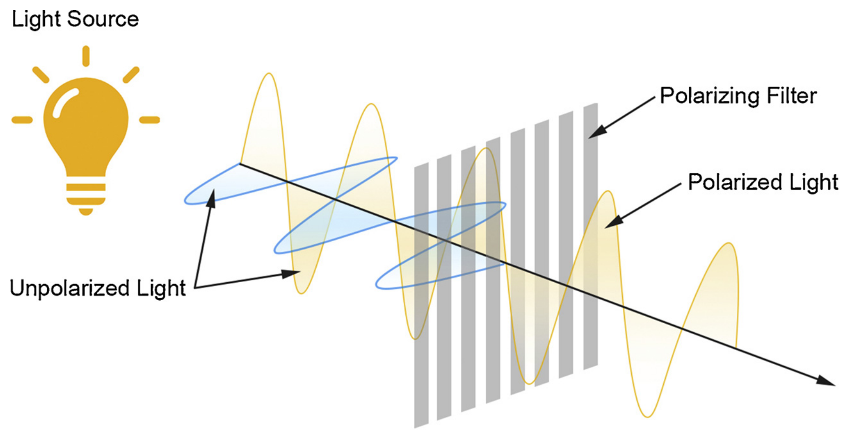

Fig. 1. Schematic diagram of the polarization process.

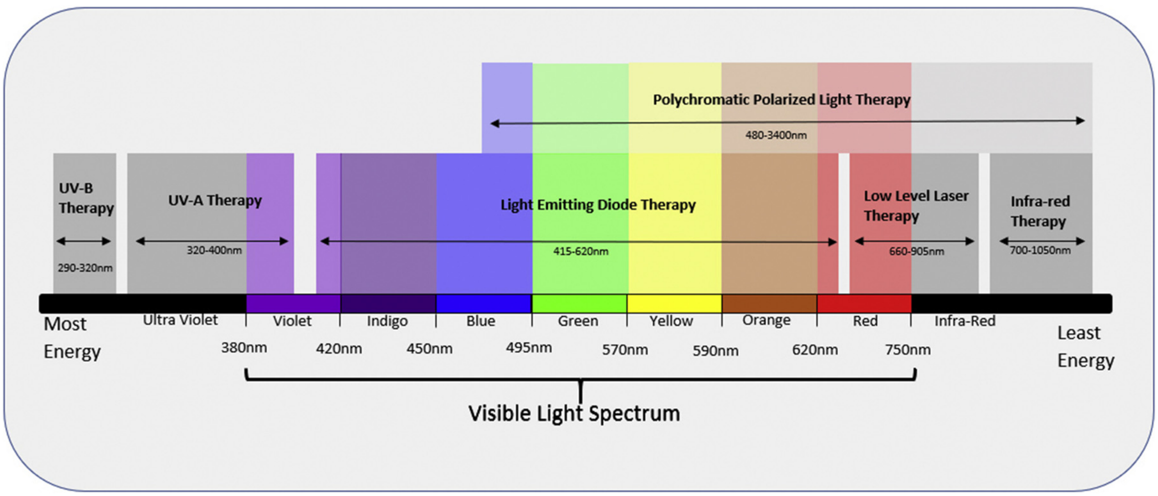

Fig. 2. Summary detailing the light parameters of commonly used phototherapies.

[6], and there is some evidence to support its use in atopic dermatitis [7]. UV-A therapies typically utilize light in the 320–400 nm range, and are generally considered safe for use, though due to the high energy of light in this range, burns can occur [8]. Narrow band UV-B therapy utilizes light in the 290–320 nm range. Though correct application is generally considered safe, UV-B radiation is strongly associated with development of a wide range of skin cancers and so it's use must be tightly controlled [9]. Following its invention in the 1960s, laser light has been successfully used therapeutically with much of the relevant research focused on low level laser therapy for its low risk of burns and other adverse effects. LLLT is used in a range of conditions, such as musculoskeletal injuries, pain relief and wound healing [10], and has the strongest evidence to inform its use compared to other forms of phototherapy. IR therapies utilize either "near" or "far" wavelengths in the IR light spectrum (700 nm–1050 nm), and traditionally has been used to warm premature infants in hospital due to its low energy levels. These low energy levels make IR light very safe, however it has questionable capacity for penetration, limiting its use to dermatological application. LED therapies are a newer entity, which utilize light of a single specific wavelength, typically characterized by color. The most common modalities are blue and red LED therapies, however yellow and green devices are also available. As there is little evidence surrounding its clinical use, these devices are largely limited to cosmetic applications, for conditions such as acne vulgaris. The low manufacturing cost of LED systems has prompted a number of commercial entities to begin the development and sale of these devices despite lacking evidence supporting their use.

Light therapy using broad, visible spectrum polarized light (PLT) has also gained in popularity over the past 30 years. Personalized 'at home' devices exist for many of these therapies, allowing patients to use laser or PLT devices to self-administer their own treatment. These devices are marketed as aids for the treatment of various skin conditions such as psoriasis, atopic dermatitis, acne vulgaris and vitiligo. Despite these assertions by device manufacturers, there is a dearth of evidence supporting the efficacy of PLT in many of these scenarios.

Over 3 decades ago, it was proposed that when the cell membrane phospholipid bilayer is exposed to a laser or polarized light, the random distribution of polar-headed phospholipids is replaced by a more structured configuration, possibly redistributing the biologically active proteins and enabling more efficient function [11]. Additionally, it has been suggested that PLT could also improve cellular processes such as active and passive transport, recognition of antibodies and hormones, release and reception of neurotransmitters or energy transmission and conversion [12,13], all of which may contribute to improving the healing process. More recently, it was proposed that different wavelengths cause different rates of cellular apoptosis, however the physiological mechanisms are still unclear [14].

In more recent years, the use of PLT has been proposed in the treatment of various conditions and is reported to accelerate the healing process. PLT utilizes broad spectrum, polarized light, typically within the visible, and infra-red ranges (400 nm – 3400 nm). The polarization reduces the amount of energy emitted by the light, making it safer to use, whilst still allowing it to penetrate into deeper tissues. PLT has been associated with improved outcomes in *in-vivo* models as well as in