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Role of Light Emitting Diode Therapy in Prosthodontics - A Narrative Review

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ABSTRACT

Photobiomodulation therapy (PBMT), encompassing the therapeutic application of non-ionizing light sources such as LEDs and lasers, has gained recognition for its benefits in wound healing and tissue regeneration. PBMT, particularly using LEDs, involves non-thermal photophysical and photochemical interactions at various biological scales, making it a versatile tool in medical and dental fields. This narrative review highlights the importance of LED-based PBMT as a promising adjunctive therapy in prosthodontics, offering significant benefits in tissue healing, pain management, and improving the success of dental implants. Its non-invasive nature and minimal side effects make it a valuable tool in modern dental practice. Further research and clinical trials are essential to optimize protocols and fully integrate LED PBMT into prosthodontic care.

Keywords

Photobiomodulation therapy, PBMT, particularly using LEDs,

INTRODUCTION

Today, photo biomodulation therapy (PBMT) have gained popularity in medical and some dental sub specialty due to enhanced wound healing in both healthy and medically compromised patients. [1] PBMT, developed in the 1960s, involves the therapeutic application of non-ionizing forms of light sources, including LASERS, LEDs, and broadband light, in the visible and near-infrared spectrum. PBMT is a non-thermal process that affects biological

processes at various scales through photophysical and photochemical events involving endogenous chromophores. [2] Two common types of PBMT used in medical and dental fields: LED (Light Emitting Diode) therapy, which involves visible light and photochemical reactions; LASER (Light Amplification by Stimulated Emission of Radiation) therapy, specifically diode lasers, which use invisible infrared light and elicit photophysical reactions, often used for wound healing processes.

Light-Emitting Diode (LED) Therapy working principle

It works base on the principle of electro lumninance. LED phototherapy stimulates the production of adenosine triphosphate (ATP) within cells, particularly those that are ischemic or wounded. [3-9] It is noninvasive and effective in stimulating wound healing in various tissues, including bone, skin, and nerve tissue.

Characteristics of the LED

The frequency of light emitted by LED is related to the band gap of the semiconductor used in LED i.e., a type of material used in making the LED. The intensity of light emitted by LED depends upon the doping level of the semiconductor used. The driving current ranges from 50 to 100 mA and its bandwidth range of 10 to 50 THz. It emits incoherent light and consists of various colours. The numerical aperture of the obtained light beam is higher and its efficiency on power to light is approximately about 20%. The cost of LED is low and thus its economical [9-10]

Wavelength Penetration and Biological Effects of Light

Wavelength is a crucial parameter in light-based therapies as different wavelengths can penetrate tissues to varying depths and exert distinct biological effects. Below is a detailed explanation of how different wavelengths interact with biological tissues, focusing on LEDs and lasers.

1. Blue Light (440 - 500 nm)

- **Penetration Depth**: Blue light can penetrate the dermal layers.
- **Biological Effects**:
  - **Stimulation of Complex IV**: Blue light has been shown to stimulate complex IV (cytochrome c oxidase) of the electron transport chain, which is crucial for cellular respiration and energy production.
  - **Activation of Endogenous Porphyrins**: This activation can produce reactive oxygen species (ROS) that have antibacterial properties, making blue light useful in antibacterial applications, such as acne treatment.

2. Green Light (500 - 570 nm)

- **Penetration Depth**: Green light can penetrate through the dermal and basal cells into the fat cells.
- **Biological Effects**:
  - Green light's penetration allows it to affect deeper skin layers, potentially influencing fat cells and promoting various therapeutic effects, such as calming inflammation and improving pigmentation issues.

3. Red Light (620 - 750 nm)

- **Penetration Depth**: Red light, particularly at the shorter end (620-680 nm), can penetrate 0.5 to 1 mm deep into the fat cell layers.
- **Biological Effects**:
  - **Stimulation of Cytochrome c Oxidase**: Red light at around 620-680 nm is known to stimulate

cytochrome c oxidase, enhancing cellular metabolism and energy production. This is beneficial for skin rejuvenation, wound healing, and reducing inflammation.

4. Near-Infrared (NIR) Light (750 - 3,000 nm)

- **Penetration Depth**: NIR light can penetrate the deepest into tissues, reaching depths of up to 2 mm before losing 37% intensity.
- **Biological Effects**:
  - **Stimulation of Cytochrome c Oxidase**: Similar to red light, NIR light in the range of 760-820 nm stimulates cytochrome c oxidase, promoting cellular energy production.
  - **Tissue Heating**: NIR light, especially wavelengths approaching and above 2,000 nm, is absorbed by water in the skin, leading to dermal heating. This can be used for therapeutic heating applications but can also cause discomfort or burns if not properly managed.

Comparison: LED vs. Laser

- **LEDs**
  - **Wavelength Range**: LEDs offer a broader range of wavelengths, providing flexibility in targeting different tissue depths and types.
  - **Light Emission**: LEDs emit incoherent light, which means the light waves are not in phase and spread out more, covering a larger area.
  - **Cost and Efficiency**: LEDs are economical and efficient, making them suitable for various applications including general lighting, displays, and therapeutic uses.
- **Lasers**:
  - **Wavelength Range**: Lasers emit light within a narrow wavelength range, providing high precision.
  - **Light Emission**: Lasers emit coherent light, with waves that are in phase, allowing for a focused and intense beam. This makes lasers suitable for applications requiring high precision, such as surgery and targeted therapies.

Lower Power and Intensity: LED vs. Laser

- LEDs generally have lower power output compared to lasers, making them suitable for superficial treatments or applications that require covering larger areas.
- While less powerful than lasers, LEDs can still be highly effective for treatments that target the surface of the skin or larger areas. Examples include skin rejuvenation, wound healing, and general phototherapy. [11]

Role of LEDs in Prosthodontics

LEDs (Light Emitting Diodes) have found various applications in prosthodontics due to their versatility, efficiency, and specific properties. Here are some key roles that LEDs play in this dental speciality:

1. **Polymerization of Dental Materials**:
   - **Curing Light**: LEDs are commonly used in curing lights to polymerize resin-based composites and other light-cured dental materials. The blue light (around 440-490 nm) emitted by LEDs is particularly effective in initiating the polymerization process.
   - **Efficiency**: Compared to traditional halogen lamps, LED curing lights are more energy-efficient, generate less heat, and have a longer lifespan [12,13].
2. **Shade Matching and Color Evaluation**:
   - **LED Shade Matching Lights**: LEDs are used in devices designed for shade matching, ensuring that the color of prosthetic teeth matches the

patient's natural teeth. These devices often use LEDs to provide consistent, natural-looking illumination that enhances color accuracy.

- **Consistency**: LEDs provide a stable light source that does not fluctuate, improving the reliability of color matching processes [13-15].

3. **Oral Diagnostics**:

- **Illumination**: LEDs are used in various diagnostic devices, such as intraoral cameras and diagnostic lamps, to provide clear, bright, and focused illumination of the oral cavity. This enhances visibility for the dentist during examinations and procedures.
- **Detection**: Certain LEDs emit specific wavelengths that can be used to detect caries or other abnormalities through fluorescence or other light-based diagnostic techniques.

4. **Photodynamic Therapy (PDT)**:

- **Antimicrobial Treatment**: LEDs are used in PDT for their ability to activate photosensitizing agents. This technique can target and destroy bacteria and other pathogens in the oral cavity, providing an effective treatment for infections and aiding in the healing process of tissues around prosthetic devices. [16]

5. **Photobiomodulation (PBM)**:

- **Tissue Healing and Pain Management**: Low-level laser therapy (LLLT) or photobiomodulation using LEDs can promote healing of tissues, reduce inflammation, and manage pain. This is beneficial post-operatively in prosthodontics, particularly after implant placement or other surgical procedures.

6. **Educational and Demonstrative Tools**:

- **Patient Education**: LEDs are used in educational tools and devices to demonstrate procedures and outcomes to patients. For instance, LED-powered models can simulate different lighting conditions to show how prosthetic restorations will look in various environments.
- **Simulation**: LED-powered simulation tools can mimic various lighting conditions to show how the final restoration will appear, aiding in aesthetic planning.

7. **Portable and Handheld Devices**

- **Portable Diagnostic Devices**: Handheld LED devices are used for quick and effective examination and diagnostics in the operatory, providing flexibility and convenience.
- **Sterilization**: UV LED devices are used for the sterilization of implant components and surgical tools, ensuring a sterile environment and reducing the risk of contamination. [17]

Role of LED Photobiomodulation Therapy (PBMT) in Implantology

Photobiomodulation Therapy (PBMT), also known as Low-Level Light Therapy (LLLT), uses light at specific wavelengths to promote tissue repair, reduce inflammation, and relieve pain. In implantology, PBMT with LEDs plays a crucial role in enhancing various aspects of dental implant procedures. Here's an in-depth look at its roles and benefits:

1. **Enhancement of Osseointegration**

- **Stimulation of Osteoblast Activity**: PBMT has been shown to stimulate the proliferation and differentiation of osteoblasts, the cells responsible for bone formation. This enhances the integration of the implant with the surrounding bone tissue.

- **Bone Healing**: LEDs at specific wavelengths (e.g., red and near-infrared) can accelerate bone healing processes, ensuring quicker stabilization and integration of the implant.
- Khadra, M et al [18] discussed how laser therapy, including LED PBMT, enhances the activity of osteoblasts on titanium surfaces, improving bone-implant integration.

2. Reduction of Post-Operative Pain and Inflammation

- **Anti-Inflammatory Effects**: PBMT helps reduce inflammation around the implant site by modulating inflammatory mediators. This results in decreased swelling and discomfort post-surgery.
- Aoki, A et al [19] highlighted the application of PBMT in periodontal and peri-implant therapy, focusing on its benefits in reducing inflammation and promoting healing.
- **Pain Relief**: The analgesic effects of PBMT help manage post-operative pain, improving patient comfort and reducing the need for analgesic medications.
- Yousefi-Nooraie et al [22] provided the evidence of PBMT's effectiveness in pain management, which can be extrapolated to managing post-implant surgery pain.

3. Promotion of Soft Tissue Healing

- **Enhanced Soft Tissue Repair**: PBMT stimulates fibroblast activity and collagen production, promoting the healing of soft tissues around the implant. This is crucial for the health of gingival tissues and the overall success of the implant.
- **Wound Healing**: Faster wound healing reduces the risk of complications such as infections or dehiscence, contributing to better outcomes.
- Hopkins, J. T., & McLoda, T. A [21] supports the use of PBMT for wound healing, relevant to post-implant surgical sites.

4. Management of Peri-Implantitis Conclusion

- **Antibacterial Properties**: PBMT can reduce bacterial load and biofilm formation around implants, helping to manage and prevent peri-implantitis, an inflammatory condition that affects the tissues around dental implants.
- **Tissue Regeneration**: In cases of peri-implantitis, PBMT promotes the regeneration of affected tissues, aiding in the recovery and maintenance of implant health.
- Romanos, G. E & Nentwig, G. H [20] demonstrated the effectiveness of laser and light therapies, including LEDs, in treating peri-implantitis and promoting tissue regeneration.

5. Improvement of Overall Implant Success Rates

- **Higher Success Rates**: Studies have indicated that the application of PBMT can lead to higher success rates of dental implants by improving both hard and soft tissue responses to the implant.
- **Reduced Failure Rates**: By enhancing healing and reducing inflammation, PBMT reduces the likelihood of implant failure due to poor osseointegration or infection.

CONCLUSION

In conclusion, the role of Light Emitting Diode (LED) as Photobiomodulation Therapy (PBMT) in prosthodontics is highly promising and multifaceted. LED-based PBMT has demonstrated significant potential in enhancing various aspects of dental care, particularly in the field of prosthodontics. Its applications range from promoting wound healing and

reducing inflammation to alleviating pain and accelerating the integration of dental implants.

Key benefits include:

1. **Enhanced Healing**: LED PBMT has been shown to stimulate cellular processes that accelerate tissue repair and regeneration, making it beneficial for patients recovering from surgical procedures or implant placements.
2. **Pain Management**: The anti-inflammatory and analgesic effects of LED PBMT can significantly reduce post-operative pain, improving patient comfort and satisfaction.
3. **Improved Outcomes**: By promoting better healing and reducing complications, LED PBMT contributes to more predictable and successful prosthodontic outcomes.
4. **Non-Invasive**: As a non-invasive treatment modality, LED PBMT offers a safer alternative to traditional pain and inflammation management techniques, with minimal side effects.

Overall, the integration of LED PBMT into prosthodontic practice enhances clinical outcomes, patient comfort, and recovery times, making it a valuable adjunctive therapy in modern dental care. Continued research and clinical trials will further elucidate its benefits and optimize its protocols for broader adoption in prosthodontics.

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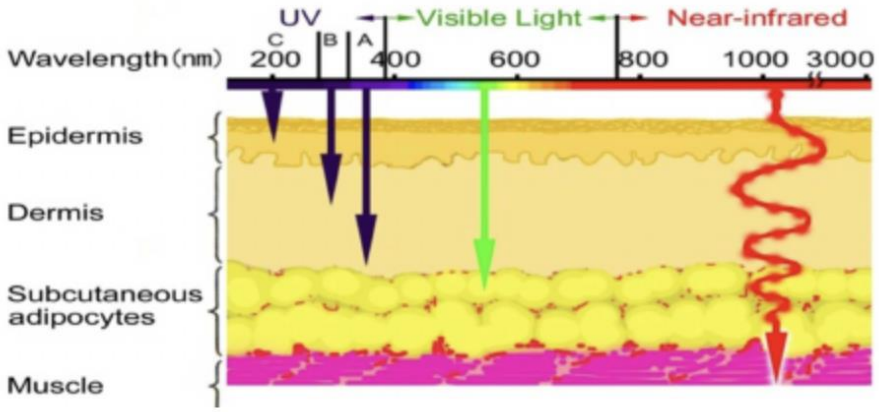

Figure 1: Light Penetration in Biological Tissues - a Schematic of penetration depth in each wavelength