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Review Article

Cold lasers for photobiomodulation in pulpotomy of primary molars: A short review

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ABSTRACT

Photobiomodulation with diode lasers of 660 and 810 - 980 nm is used for the proliferation of fibroblasts and to enhance the healing of oral lesions or surgical wounds. It has the potential to stimulate the formation of reparative dentin and preserve pulp vitality. Photobiomodulation uses low-level laser therapy (LLLT) which works on the principle of supplying direct bio-stimulative light energy to the cells. Based on these characteristics, numerous studies are conducted on photobiomodulation with a diode laser for pulpotomy in primary molars. This review article aims to provide data to clinicians regarding varying parameters used for photobiomodulation in pulpotomy and their clinical outcomes in primary molars.

1. Introduction

Photobiomodulation, as the name suggests is the modulation of biological tissues using photons (light energy). This light energy is usually produced by laser devices which are used for the therapeutic purposes such as wound healing, for analgesic effect, and repair and regeneration of the tissues.[1] Laser devices used for photobomodulation are known as non-surgical lasers, soft lasers, therapeutic lasers, or cold lasers. Due to its repair and regenerative properties, this therapy has been widely used in dentistry to prevent gagging, to alleviate post endodontic pain, to increase the speed of tooth movement in orthodontics, to enhance gingival and periodontal wound healing, or in pulpotomy.[2]

Dental pulp stem cells are indispensable for pulp regeneration[3] and hence photobiomodulation has been gaining popularity in pulpotomy procedure. Commonly used pulpotomy medicaments based on their treatment objectives are depicted in Figure 1. The progressive development towards a better understanding of biological mechanisms has led to a shift towards preservation and tissue regeneration in pulpotomy.[4] An ideal pulpotomy technique or medicament is extremely crucial to obtain maximum benefit for good clinical performance.[5] Photobiomodulation in combination with effective capping materials like Mineral Trioxide Aggregate (MTA) have shown to stimulate dental tissue repair.[6] The varying parameters associated with the use of photobiomodulation in pulpotomy poses a challenge for the clinician to use it effectively. Hence, this review article aims to provide different parameters used for photobiomodulation for pulpotomy in primary molars with its clinical performance.

2. Discussion

2.1. History

The first laser was created by physicist Theodore Maiman in Los Angeles in 1960. Since then they have been introduced to medicine and dentistry.

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Mester used low-power ruby laser irradiation on shaved mouse skin and observed that the hair started to grow faster on the irradiated skin area compared to the non-irradiated skin. When the dose was increased, the hair did not grow at all which was in contrast to the non-irradiated area where normal hair growth was seen. This experiment showed that the low-power had a stimulatory effect as opposed to high-power lasers which had an inhibitory effect.[7,8]

Since then he conducted various studies and proved that non-healing wounds could be easily treated by low-power lasers. Endre Mester is known as the father of photobiomodulation.[7]

2.2. Types of lasers

Different lasers are used in pediatric dentistry. These lasers include diode lasers of 655 nm wavelength for diagnosis of caries, argon lasers for composite curing, CO_2 lasers with a wavelength of 10600 nm for soft tissue surgeries, Nd: YAG lasers of 1064 nm wavelength and diode lasers with a wavelength of 810-980 nm for soft tissue cutting. The Erbium laser family includes Er: YAG (2940 nm) and Er,Cr: YSGG (2780 nm) which are used in hard tissues, cavity preparation, and also in soft tissue surgery. The low-power lasers are used in the stimulatory and inhibitory biologic processes.

2.3. Low-power lasers for photobiomodulation

A Diode laser of 660 nm and 810 - 980 nm is used for photobiomodulation (PBM) which helps in the proliferation of fibroblasts and enhances the healing of oral lesions or surgical wounds. It has also shown its potential to stimulate dentinogenesis and preserve dental pulp vitality. It is most frequently used due to its reliability, versatility, and convenience, together with its handiness and simple set-up.[9]

Early experiments confirmed that the dosage follows the so-called Arndt-Schultz law: "Too small a dose gives no effect, there is a therapeutic window within a certain dose range, and doses over that range are inhibitory."[9]

2.4. Equipment for photobiomodulation

Photobiomodulation benefits can be obtained with various wavelengths and units with different outputs. Usually, the therapeutic window for sub-thermal tissue interaction is 1 to 500 mW or 0.5 W (Class III/ low-level lasers), but surgical lasers (Class IV) can be defocused and used as a low-level laser.[10] The power of the GaAlAs lasers (diode laser) should not be less than 100 mW to obtain the desired biological effect in a reasonable time.

2.5. How to calculate the dose?

Although there is a wide therapeutic window in laser therapy, it is essential to apply a reasonable dose. To calculate the dose (energy density), the given energy is calculated as power into time (mW x seconds) (eg, 500 mW x 10 seconds = 5000 mJ = 5 J). Once the energy is calculated it is then divided by the irradiated area to obtain the optimum dose. If this area is 2 cm^2, the calculation is 5/2 = 2.5 J/ cm^2 or if it is 0.5 cm^2, it is calculated as 5/0.5 = 10 J/cm^2. An optimal power density is essential to generate biological effects and thus a low output cannot be fully compensated by longer exposure. Along with this depth of the target site must be considered.[9]

The amount of tissue between the laser probe and the target tissue and the type of tissue must be considered. A laser can easily transmit through mucosa and fat as opposed to muscle. Chromogenic pigments like hemoglobin and others are strong absorbers of laser light and therefore there is a need to increase the dosage. Contact mode is needed when it is involved in a cutting procedure. Treating an open wound requires a 2-4 mm distance between the laser and the target tissue. Various treatment dosages have been suggested where 2 to 3 J/cm^2 two or three times per week on gingival tissues, 4 to 6 J/cm^2 two or three times a week on muscles, 6 to 10 J/cm^2 once or twice a week on the temporomandibular joint, and 2 to 4 J/cm^2 directly on the tooth or osseous structure or indirectly over the apex.[9]

2.6. Regenerative pulpotomy with photobiomodulation (cold lasers)

A wide variety of studies with varying parameters have been conducted to evaluate the clinical, radiological, and histopathological outcomes of photobiomodulation for pulpotomy in primary molars. Most of the studies have used diode lasers of 660 nm or 810 nm wavelength. The energy density directed toward the pulpal tissue was from 2 J/cm^2-6.7 J/cm^2. All the studies have varying time periods of irradiation ranging from 10 seconds to 4 minutes. (Table 1) In spite of the varying parameters, most of the studies have shown a good clinical and radiographic success rate.[6,11–16] With these observations, it is essential to understand that the maximum effect of photobiomodulation therapy can be obtained by low energy density. This is in accordance with an in-vitro study conducted by Nawam et al.,[17] who suggested that 1 J/cm^2 enhances the angiogenic markers whereas 3 J/cm^2increases the expression of odontogenic genes.

Table 1: Laser parameters used for photobiomodulation in pulpotomy.

Author name (Year)	Type of study	Laser parameters	Outcome
Tadahiko Utsunomiya (1998)	Animal study	Type- Diode laser Wavelength- 830 nm Mode- Continuous, in-contact Time period- 3 minutes. Energy Density-105.9 J/Cm2 Delivery tip- 0.5 mm optical fibre	On histopathological analysis, Although accelerated wound healing was present, no difference in the expression of collagen type was observed.
Golpayegani et al. (2010)	In-vivo human clinical trial	Type- Diode laser Wavelength - 632 nm Mode- Continuous, non-contact Time period- 2 minutes 31 seconds Energy density- 4 J/cm2 Delivery tip- 0.6 mm optical fibre	Overall success rate- 83.33% at 12 months follow-up.
Durmus (2014)	In-vivo human clinical trial	Type- Diode laser Wavelength - 810 nm Mode- Continuous, non-contact Time period- 10 seconds Energy density- not mentioned Delivery tip- not mentioned	At 12 month follow-up, 100% clinical success rate and 75% radiographic success rate were present.
Fernandes et al. (2015)	In-vivo human clinical trial	Type- Diode laser Wavelength - 660 nm Mode- Continuous, non-contact Time period- 10 second Energy density- 2.5 J/cm2 Delivery tip- 0.3 mm optical fiber	On histopathological analysis, PBM+ZOE= Mild to moderate inflammatory infiltration, no odontoblastic layer. PBM+Ca(OH)2 = dense conjunctive tissue, and hard tissue barrier over the odontoblastic layer was present.
Uloopi et al. (2016)	In-vivo human clinical trial	Type- Diode laser Wavelength - 810 nm Mode- Continuous, non-contact Time period- 10 seconds Energy density- 2 J/cm2 Tip- not mentioned	At 12 months follow-up, an overall success rate of 80% was observed.
Alamoudi et al. (2020)	In-vivo human clinical trial	Type- Diode laser Wavelength - 810 nm Mode- Continuous, non-contact Time period- 40 seconds Energy density- 6.7 J/cm2 Tip-0.2 mm optical fibre	At 12 months, 100% radiographic success rate and 96.1% clinical success rate were observed.

Description: Note: PBM- Photobiomodulation,ZOE- Zinc Oxide Eugenol, $Ca(OH)_2$- calcium hydroxide, nm- nanometre,mm- millimetre, J/cm^2- joule per centimetre squared.

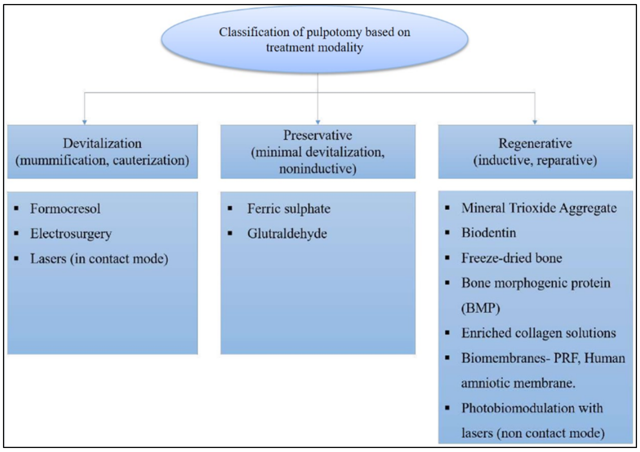

Fig. 1: Description as classification of pulpotomy based on treatment modality

2.7. *Mode of action of photobiomodulation*

1. Increased ATP production: Cellular photoreceptors can absorb low-level laser light and pass it on to mitochondria, which promptly produce the cells fuel, ATP.
2. Enhanced wound healing: Electron microscope examination has shown evidence of accumulated collagen fibrils and electron-dense vesicles in the cytoplasm within the laser-stimulated fibroblasts as compared with untreated areas. Increased microcirculation and neoangiogenesis can be seen with increased erythema around the wound area; during the initial phase of the treatment, the patient can feel the transient pin-prickling sensation, which is thought to be evidence the accelerated wound healing.
   The presence of oxidants and antioxidants is directly

related to the time and quality of the wound healing process. Photobiomodulation regulates the hemostatic process and thus promotes healing.[18]

3. Analgesic effect: Neuropharmacologic effects on the synthesis, release, and metabolism of a range of neurochemicals, including serotonin and acetylcholine at the central level and histamine and prostaglandin at the peripheral level.

2.8. *Various other applications of photobiomodulation in dentistry:*[2,9,19–21]

1. TMJ disorders.
2. To prevent gagging.
3. To increase the speed of orthodontic tooth movement.
4. To prevent post-endodontic pain.
5. Hypersensitive dentin.
6. Post extraction and bone healing therapy.
7. Herpes labialis
8. Aphthous ulcers.
9. Mucositis.
10. Trigeminal neuralgia
11. Vital pulp therapy

3. Conclusion

Regarding the use of photobiomodulation for pulpotomy in primary teeth, there is inconsistency in information about the optimum dosage to be used on pulpal tissue to provide biological repair and formation of tertiary dentin. However, based on the available evidence, it can be stated that the varying range of energy density from 2 J/cm^2- 6.7 J/cm^{2}can be beneficial. The time of irradiation as low as 10 seconds has shown a good clinical and radiographic success rate following an appropriate coronal seal and hence further clinical trials should be conducted to evaluate the success rate with low energy density and less irradiation time. It is essential to note that, thermal injury to the pulp depends on the duration of laser irradiation instead of the power output of the device. Hence, it becomes essential to be careful while using the laser to avoid any untoward outcome.

4. Conflicts of Interests

The authors have no financial interests or conflicts of interests.

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None.

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