Photoactivated Disinfection of Dentinal Tubules in Pediatric Dentistry: An Alternative Regime

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ABSTRACT
Pediatric dentistry faces a significant therapeutic challenge when it comes to conserving deciduous teeth with pulp alterations caused by caries or trauma. In an effort to eradicate bacteria that are still present following chemo-mechanical preparation, endodontic treatment using antimicrobial photodynamic therapy (PDT) combines a photosensitizer (PS) with a light source that is non-toxic . The molecular oxygen reacts with the excited photosensitizer present in the cells and activated by light. This reaction with the molecules results in the creation of singlet oxygen and the transfer of electrons or hydrogen between the molecules. The goal of this review article is to offer the paediatric dentist an alternate mode for disinfection of dentinal tubules utilizing photodynamic therapy.
Keywords- Endodontics, photodynamic therapy, photosensitizer, root canal

INTRODUCTION

The eventual purpose of endodontic therapy continues to be the complete eradication of harmful microorganisms from the root canal system. Although different fungi, viruses, and bacteria contribute to the microbial variety in endodontic infections, bacteria are by far the most frequent microorganism to be found there.[1] Despite efforts in this regard and a recognition of the importance of maintaining the health of the deciduous dentition toddlers still have several deep carious sores where the disease is polarised and involves the pulp.[2]

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It is generally known that removing bacteria from root canals during endodontic therapy is challenging[3] because of the biological cycle of the pulp that is unique to primary teeth and their internal anatomy, maintaining primary teeth with pulp changes brought on by caries or trauma is a significant therapeutic difficulty in paediatric dentistry. As a result, there is a need for sanitizers that are highly effective at eliminating bacteria, since this results in success. The majority of endodontic treatment failures are caused by microorganisms that persisted after the chemo regulatory process, medicines, and dressing.[4]

In addition, numerous other cutting-edge disinfection techniques have been created and tried. These new anti-biofilm techniques' main goal was to get rid of biofilm bacteria from the parts that weren't instrumented and without having negative effects on healthy tissues. Recently, ozone, herbal/enzyme alternatives, antimicrobial photodynamic treatment (aPDT), bacterial repelling nanoparticles, laser-assisted root canal cleaning, and other sophisticated

therapeutic techniques for endodontic biofilms have been used.[5] PDT, which employs low levels of laser to target bacteria in the root canals, is developing as a unique antimicrobial technique.[6]

Photodynamic therapy is a technique which disinfect by application of a photosensitizing substance to hard tissue or soft tissue, and then illuminate it with laser at a wavelength which is absorbed by the photosensitizers to kill germs there. Other names for it include photodynamic antimicrobial chemotherapy, light activated disinfection (LAD), photo-activated disinfection, and antimicrobial PDT (APDT). Three things are needed for PDT: a light source, a PS, and oxygen. The idea behind PS molecules bind to the bacterial membrane, which is how it works. When a bacterium is exposed to light at a wavelength that coincides with its peak PS absorption, singlet oxygen is produced. This causes the cell wall of bacteria to shatter and kills the bacterium.[7]

Based on the most recent endodontic literature, this review paper provides summary of Photodynamic therapy, which includes a full discussion of the process, numerous Photosensitizers utilised and their features, and different light sources. It also discusses the function of PDT in root canal sterilization.

PHOTOSENSITIZER

When exposed to light of a certain wavelength, a photosensitizer is a chemical substance that reacts with molecular oxygen which is present in the surrounding to form extremely reactive oxygen. Many photoactive substances, both organic and inorganic, have the ability to photosensitize. These consist of quinones (cercosporin), anthraquinones (fagopyrin, hypericin), polyacetylenes, thiophenes, chlorophyll degradation products, and 9-methoxypsoralen.[8]

The ability to absorb light in the central red region of the visible spectrum, which absorb readily in dentin and along with this it may permeate blood that may be present, is a crucial characteristic of photosensitizers to be employed in the root canal environment.[9] Although the impact of the photosensitizers on bacteria can alter, their positive or negative charge appears to be crucial in determining how well they attach to the cell wall of bacteria.[10]

The following Photosensitizers are frequently utilised for root canal cleaning in numerous studies:

1. Toluidine blue ‘O’
2. Methylene blue
3. Radachlorin
4. Rose Bengal
5. Titanium dioxide

Among all these toluidine blue and methylene blue are widely used.

Toluidine Blue ‘O’

A blue colouring agent is TBO, also referred to as tolonium chloride. The essential stain, TBO, is available in this pharmaceutical grade. Many gram-positive and gram-negative bacteria have been demonstrated to be resistant to it. Methylene blue (MB) does not attach to Enterococcus faecalis as tightly as tolonium chloride does, hence when employed in the root canal environment, tolonium chloride exhibits more consistent death.[9] When used at their final concentration, it is employed in minimal concentrations of 0.001-0.01%. The relatively modest dye concentration prevents irritation to soft tissue and coronal or radicular dentin discoloration from happening. When this substance is exposed to low intensity visible red light of 635 nm, single molecular oxygen is released, rupturing the cell wall of the bacteria.

Methylene Blue

Methylene blue is an aromatic heterocyclic chemical substance. It seem as a rigid, fragrance free, powder of dark green colour at room temperature, and when liquefy in water, it turns into a blue solution. Each Methylene blue molecule in the hydrated state contains three molecules of water. The

largest amount of light that the cationic dye MB can absorb is at a wavelength of 670 nm. Even after only brief exposure to light, it still exhibits significant toxicity towards some species of streptococci, including Streptococcus mutans. Although MB is a very potent sensitizer in and of itself, it is also exceedingly water soluble. It is known that MB can photoinactivate a numerous variety of microorganisms.

The DNA and outer membrane of the target species are both phototoxicly affected by phenothiazine dyes.[10] The favourable effects of MB's hydrophilicity, low molecular weight, and the outer membrane of gram-negative bacteria's porin-protein channels can be crossed by charge. A major interaction between MB and the anionic macromolecule lipopolysaccharide (LPS) produces MB dimers, which take part in the photosensitization process.

LIGHT SOURCES

PDT needs a light source that emits low-power visible light at a particular wavelength in order to activate the PS. Red light penetrates human tissue deeply thanks to the PS's greater activation wavelength and excellent red light transmission. As a result, red light between 630- 700 nm, which penetrates at a depth between 0.5 cm and 1.5 cm at 630 nm and 700 nm respectively, is what most PSs are activated by.[11] The three types of diode lasers that are most frequently employed for PDT in endodontic disinfection are GaAS lasers of 630 to 690nm, 830 nm or 906nm as well as LED light.[12]

In recent years, LED has become a viable replacement for laser in PDT. While being less powerful than lasers, LEDs have a number of advantages, including ease of use, its size, fine weight, cost effectiveness, and broad spectrum output, which allows for higher adaptability when exposed to radiation. Given that it is not merely a radiation in monochromatic form, which is unique compared to lasers, it seems to be a potential light source for photodynamic therapy. Non-collimated light can effectively kill endodontic germs by being applied for 30 seconds, spreading into the dentinal tubules to some extent .[13]

Several investigations that looked at the red light emitting diode as a light source for activating various photosensitizers helped to produce antimicrobial PDT. While using a powerful red LED and a small amount of either MB or TBO, two periodontopathic bacteria were effectively killed.[14] Staphylococcus aureus' growth was inhibited by more than 93.05% when MB was exposed to red LEDs.[15]

MECHANISM OF ACTION

PDT, which involves PS, a light source, and oxygen, is the non-thermal inactivation of cells, bacteria, or molecules by light. A photodynamic reaction is the result of these elements interacting.

A PS changes from a low energy state to high energy state when exposed to light of a specified wavelength. The light's wavelength needs to be precisely aligned with the PS's wavelength of absorption. The single state molecule can return to its unexcited state either by fluorescing or by producing a photon as light energy. Alternately, the molecule may undergo intersystem crossover, which calls for a shift in one electron's spin, to transform into an excited triplet state (T) molecule. The T state of molecules can either revert to their initial state and emit light (phosphorescence) or can continue to react in one of two ways (referred to as the type one and type two photo processes), and require oxygen.[16]

Type 1 Reaction

The PS reacts with a substrate in either its singlet or triplet state in different ways one is through transfer of electrons, second is abstraction of hydrogen to produce free radicals, that easily combine with oxygen to generate highly reactive oxides and peroxides, which harm biological targets like proteins, membrane or the DNA.

Type 2 Reaction

process include the shift of energy from the PS excited state to ground state to create excited state singlet oxygen, that has the ability to oxidise numerous biological components, including nucleic acids, proteins and lipids, and causes toxicity.

CLINICAL PEROCEDURE TO USE PDT

PDT treatment has no harmful thermal effects and has no chemical or thermal side effects that harm nearby tissues. It is well known that the typical PS stolonium Chloride and Methylene Blue are non-toxic in substantially greater amount than what is necessary for PDT to effectively destroy pathogens. Light microscopy and confocal scanning laser microscopy have both demonstrated the infiltration of dentinal tubules by methylene blue, and there is substantial proof that light travel through dentin in which dentinal tubules serving as the primary scatterers.[17, 18]

As a result, the photodynamic effect's reactive free radicals are capable to completely permeate the tubules of dentin, even previously inaccessible regions, and get rid of any remaining germs. There aren't many in vivo research examining PDT's antibacterial effectiveness. There isn't a solid clinical protocol for its application in endodontics, as a result. The clinical recommendations offered here are taken from the scant number of published in vivo investigations.[19, 20]

It is necessary to apply the PS solution directly to the location for a brief amount of time (such as 30 s) in order for the bacteria to bond with or absorb some of the photosensitizer and then become sensitive to the laser.[19] A 0.5 mL endodontic needle was used to inject the PS solution into the root canal in a research by Garcez et al. for two minutes as pre-irradiation and incubation period inside the root canal.[20] It is important to gently agitate the sensitizer in the canals to remove any air vesicle that can prevent the bacteria from making contact with the PS. In a properly prepared setting, such as a root canal which is free from saliva and blood, the PS should be applied. Due to the presence of molecules like catalase and lactoperoxidase, which scavenge reactive oxygen species, either of these fluids can hinder the deadly photosensitization process.[21-24]

Photosensitizers have been evaluated at doses ranging from 6.25 to 25 g/mL for MB[25-26] and 10 to 100 g/mL for TB'O' for endodontic disinfection.[27-29] PDT conditions for effective microbe killing typically range from 60 to 240 seconds using a red light laser with an output power of up to 100 megawatts.[6, 30]

The laser light should be provided using a photodynamic diffuser nozzle with a diameter between 200 to 300 m that produces a cylindrical emission pattern (360°), matching the curvature of the root canal system.[31,32] Such diffuser nozzles minimise the effective power density when the root canal is evenly illuminated, thereby lowering the risk of laser-induced visual injury.

To achieve even light diffusion inside the canal lumen, the fibre should be manually moved in spiral movements from the apex to the cervical region of the canal at a position where reluctance to the fibre can just be observed (about 1 mm from the apical region or apex).

CONCLUSION

PDT may be used in predictable single-visit treatment of canal because it has been recommended as a viable alternative to maximise root canal sterilization. It is still necessary to design a PDT protocol that can be employed as an efficient antipathogenic addition to chemomechanical therapy. When creating a PDT protocol, a number of factors must be considered, including light sources, photosensitizers and light delivery methods.

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