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Biophotonics: Enlightening the Future of Periodontics

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Abstract:- Biophotonics deals with the interaction between light and biological matter, by integrating the knowledge of physics, chemistry, engineering, biology, and medicine to solve specific biomedical or life science issues. Its innate ability to provide non-invasive, highly sensitive tissue information and induce specific localized tissue ablation renders biophotonics to be a vital aspect in enhancing dental healthcare. This article aims to provide an overview of contemporary biophotonics-based technologies and their applications in dental research and clinical practice.

I. INTRODUCTION

Today, technological revolutions continually impact our lives and constantly redefine our society.

Photonics is an optical technology, regarded as important for the new era.[1]

Photonics, by utilizing photons rather than electrons for transmitting, processing and storing information serves to provide excellent capacity and speed in information technology.[2] Over these last few decades, the role of photonics in medical and biomedical applications has significantly increased, while also evolving as a crucial application in optics and optoelectronic devices.[3]

Medical applications include sensing, diagnostic imaging, therapy, drug delivery and laser surgery, and optics and electronics applications include high-quality single photon sources, semiconductor technologies and fibre optics telecommunications. In dentistry, laser and light amplification by stimulated emission of radiation (LASER) is vital in soft tissue and periodontal applications.[3]

II. BIOPHOTONICS

A new extension of photonics is 'BIOPHOTONICS'. The term comprises of two Greek words: "bios" meaning life and "phos" meaning light. This multidisciplinary type comprises fusion blend of photonics and biomedical sciences.[2]

'BIOPHOTONICS' – is the science of generating, in order to detect and manipulate biological materials.[1]

Nature has used biophotonics as a basic principle of life, even from time immemorial.[5]It combines optical methods for studying and manipulating biological specimens at the subcellular, cellular, tissue, and organ levels, while spanning biomedical diagnosis, research, and therapy.

Biophotonics in dentistry enables early detection of diseases, for an efficient, minimally- invasive specific therapy coupled with the restoration of diseased tissues, functionally & aesthetically.[1] It integrates 4 major technologies: Lasers, Photonics, Nanotechnology & Biotechnology.[2]

III. SIGNIFICANCE OF BIOPHOTONICS

It aids early detection of maladies and helps for diagnosis and treatment, when applied in medicine and dentistry.

This is employed for studying biological tissues and processes at varied scales, ranging from micro levels to nano levels.[1]

The soft lasers effectively contribute in faster healing, improved remodelling and bone repair, restoring of normal neural function after injury, normalizing abnormal hormonal functions and modulating the immune systems.[4]

IV. CLASSIFICATION OF BIOPHOTONICS

A. CLINICAL APPLICATIONS
a) DIAGNOSTIC
b) THERAPEUTIC
- Thermal interaction
- Photo bio-stimulation
- PDT
- Bioimaging

B. RESEARCH
a) PHOTOMECHANICS
b) SPECTROSCOPY
c) FIBER OPTIC SENSORS

V. FUNDAMENTAL BASICS OF BIOPHOTONICS

The total energy can be divided into 4 parts: electrical, vibrational, rotational and translational. Only electronic and vibrational energy levels are of significance to biophotonics, as they form an integral part of spectroscopy, bioimaging, biosensing, flow cytometry, photodynamic therapy and biomaterials for photonics.

Properties of light and matter form the fundamental basis for creating an insight into biological systems.

Light waves exhibit properties such as interference and diffraction and light photons carry energy.[2]

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The biological application of spectroscopy and fluorescence microscopy utilize the photons while the interference feature of the wave is used for varied biophotonics purposes like phase contrast microscopy, optical coherence tomography and biosensing. In this article, we hereby discuss the two major applications of light in biophotonics i.e.

A. LASER

Lasers, first developed by Maiman (1960) are devices that produce a highly directional, monochromatic and intense beam of light.

B. BASIC STRUCTURE

An optical cavity lies in the middle and its core, called Active medium comprises of chemical elements, molecules or compounds.

Lasers are generally named for the material of Active medium. The 2 gaseous active medium lasers utilized in dentistry are Argon and CO2.

Two mirrors are placed parallel, at each end of the optical cavity. Surrounding this core is the excitation source, which could be a flash lamp device or an electrical coil, to infuse energy into this active medium. As a little heat is generated in the ensuing process, the cavity requires cooling. Other mechanical parts include a cooling system, focusing lens and some controls.

The parallelism of mirrors ensures that light is collimated. The mirror that is selectively transmissive allows light of sufficient energy to exit from the optical cavity.

VI. USES OF LASER IN PERIODONTICS

- **Mobility Assessment:** Laser Doppler Vibrometry is used to assess even small amount of tooth mobility.
- **In Prevention of plaque**: Laser toothbrush is designed to provide an antibacterial effect in oral cavity. It does not need toothpaste but directly radiates laser on teeth. The Er: YAG laser has the ability to remove lipopolysaccharides, smear layer & calculus from the root surface.
- **In Hypersensitivity:** Low level laser therapy (LLLT) has anti-inflammatory, analgesic and cellular effects in hyperemia and inflammation of dental pulp. Effects of laser therapy on hypersensitive teeth are:
  - Primary or immediate effect: remission of painful symptoms;
  - Secondary or late effect: intense cellular metabolic activity; proliferation of odontoblasts; and production of dentine. LLLT causes sealing of dentinal tubules by coagulation of hydroxyapatite crystals as well as formation of reparative dentine.
- **In Non- Surgical Pocket therapy:** It is a used to eliminate or reduce viable bacteria in the gingival sulcus.

VII. PHOTODYNAMIC THERAPY (PDT)

HISTORY:

Usage of light as a therapy dates back to ancient Times. This term 'Photodynamic Therapy' was first coined by Von Tappeiner (1904) for describing the phenomenon of oxygen-dependent photosensitization.[7] In 1978, Daughtery et al applied this novel technique and successfully treated various cancers[7] and Wilson proposed the usage of lethal photosensitization for treating periodontal diseases.[8]

VIII. MECHANISM OF ACTION

PDT involves 3 aspects**:** Photosensitizers, light and oxygen.[7] This mechanism is based on the dye- sensitized photooxidation of biological matter in target tissue. This entails the presence of a dye (sensitizer) in tissue to be treated.[8]

By irradiation with light in the visible range of the spectrum, the dye (photosensitizer) is excited to its triplet state, and this energy is transferred to molecular oxygen. The product formed is the highly reactive singlet oxygen capable of reacting with biological systems and destroying them. However, only the first excited state with energy of 94 KJ/mol (22Kcal/mol) above the ground state is important and the second excited state does not react.[9]

IX. PHOTOCHEMICAL REACTIONS

All photochemical reactions first begin with the generation of high energy triplet state photosensitizers (PS). Photoexcitation chemistry can potentially travel one of the three pathways and are classified as – Type I, Type II, & Type III reactions.

- **TYPE I**: Photooxidation by radicals wherein the substrate generates radicals and reactive oxygen species (ROS) like hydrogen peroxide & superoxide anions.
- **TYPE II**: Photooxidation by singlet oxygen which involves the transfer of energy of the triplet state PS to ground triplet state oxygen ($^3O_2$), generating singlet oxygen ($^1O_2$).
- **TYPE III**: Photoreaction not involving oxygen requires either high concentration of the PS or a de-aerated system, in order to bypass the reaction with oxygen.

X. APPLICATIONS OF PHOTODYNAMIC THERAPY IN PERIODONTICS

It is an emerging field for the treatment of periodontitis. Applications of photodynamic therapy in Periodontics are:

A. In periodontitis

- An effective approach of periodontal therapy is to change the local environment to suppress the growth of periodontal pathogens.
- There are 2 basic mechanisms that have been proposed to account for the lethal damage caused to bacteria by PDT
  - DNA damage
  - Damage to cytoplasmic membrane, allowing leakage of cellular contents or inactivation of membrane transport systems & enzymes.[7]

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B. In periodontal bone loss and furcations

- The use of PDT in furcation involvement in periodontitis shows advantages over the use of conventional antimicrobials such as the reduced need for flap procedures and shorter treatment time.9

C. In implantology

- PDT can be used in implantology to promote osseointegration and prevent peri-implantitis.
- PDT can preserve tissue, with almost no adverse effects at the light microscopic level. Intra-operatively used PDT with the CO2 laser seems to be more of value than the conventional method.10

D. In wound healing

- PDT has a bio-stimulatory effect on human osteoblast like cells during the first 72 hours after irradiation. It can enhance collagen fibre deposition and organized bone trabeculae after 30 days of induced bone defect healing, by affecting calcium transport during new bone formation.10
- Hence, it may prove beneficial in periodontal healing after gingivectomy, scaling, root planning, and intra-bony defect surgery.10

XI. BIO-NANOPHOTONICS

- Bio-nanophotonics is the science dealing with the interface between biomedical science and technology and nanophotonics.4
- Nanotechnology exploits specific phenomena and direct manipulation of materials on the nanoscale.4
- 'Nano' is derived from the Greek word "dwarf" and Nanotechnology is the science of manipulating matter measured in the nanometer, roughly the size of 2 or 3 atoms.11
- It can be defined thus – " the science and technology of diagnosing, treating and preventing disease and traumatic injury of relieving pain, and of preserving and improving human health, through the use of nanoscale structured materials, biotechnology and genetic engineering and eventually complex molecular machine systems and nanorobots."
- Nanomaterials are those materials with components less than 100 nm in at least one dimension, including clusters of atom, grains less than 100 nm diameter, films less than 100 nm in thickness & nanoholes.5

XII. TYPES OF NANOTECHNOLOGY

Broadly, nano technologies consist of three mutually overlapping and progressively more powerful molecular technologies:

- Nanoscale: This includes structured materials and devices that can be fabricated for advanced diagnostics and biosensors, targeted drug delivery and smart drugs.
- Molecular Medicine: via– genomics, proteomics, artificial biobotics (microbial robots)
- Molecular Machine Systems and Medical Nanorobots: These allow instant pathogen diagnosis and extermination and efficient augmentation and improvement of natural physiological function.[12]

XIII. NANOTECHNOLOGY IN PERIODONTICS

Functions may be controlled by an on-board nanocomputer executing programmed instructions in response to local sensor stimuli. Alternatively, the dentists may issue strategic instructions by transmitting orders directly to invivo nanorobots via acoustic signals (eg. ultrasound) or by other means.[11]

XIV. APPLICATIONS

Uses of nanotechnology in Periodontics are:

- **Perioprotect**: It is a comprehensive and customized method, for managing biofilms, that grow in the spaces or pockets between teeth and gums tissues. The ultimate goal is to manage oral biofilm with minimally invasive dentistry for oral health that lasts.[11]
- **Local Anesthesia:** A colloidal suspension comprising millions of active analgesics, micron- size dental robots will be instilled on the patients gingival, resulting in anesthesia.[12]
- **Photosensitizers and carriers**: c "Quantum dot" nanocrystals are tiny particles of only a few nanometers and the size of a protein molecule or a short sequence DNA. Quantum dots can be used as photosensitizers and carriers.[12]
- **Nanorobotics Dentifrice (Dentifrobots)**: Subocclusal dwelling nano-robotics dentifrice provided by mouthwash or toothpaste could patrol any supragingival & subgingival surface at organic matter into harmless, odourless vapours to perform continuous calculus debridement.

XV. CURRENT TRENDS IN PERIODONTICS:[13]

A few current researches in the field of Periodontics are:

A. DIAGNOSIS

a) Advances in traditional diagnostics
- Controlled- force, electronic probes.
- Computer- assisted, digitalized
- substraction radiography.
- Mobility measuring devices

b) Detection of periodontopathic organisms
- Bacteriologic DNA analysis
- Immunologic tests for putative
- pathogens.
- Microbiologic enzymes assay
- PCR

c) Indicators of local physical/ metabolic changes
- Subgingival temperature
- Nuclear medicine techniques (bone scanning)

B. THERAPEUTIC

- Waterlace-Combination of laser energy and water by Hydrophotonics.[11]
- Laser Periodontal Therapy (LPT)[14]

XVI. FUTURE TRENDS[4]

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Researches are on-going in the respective field for use in the treatment of Periodontics in future.

- Nanorobots.
- Dentifrobots.
- DETEC Tar.
- 4. Nanocoated implant surfaces . .
- 5.Second harmonic generation (SHG) microscopy.
- 6. Bone replacement materials .

XVII. CONCLUSION

In this review paper, we broadly discussed the application of biophotonics in dentistry. Considering the constant efforts to accomplish prevention and early diagnosis of oral diseases, as well as non-invasive treatment measures in modern dental practice, biophotonics should be the leading scientific discipline to provide advancements in dental medicine and technology.

REFERENCES

[1.] Kishan A. Fundamental and Application of Biophotonics in dentistry. 1st edi. Singapore: Imperial College Press; 2007. 1-8.
[2.] Prasad PN. Introduction to biophotonics. 1st edi. Hoboken (New Jersy): John Wiley & Sons; 2004. Pg. 1568.
[3.] hsaneh Daghigh Ahmadi,Saudah Hafeji , Zohaib Khurshid , Eisha Imran, Muhammad Sohail Zafar, Morvarid Saeinasab and Farshid Sefat. Biophotonics in Dentistry. Appl. Sci;2022, 12, 4254.
[4.] Singh S, Gupta I, Amarnath J, Gupta R, Pandey A, Gupta S. Biophotonics: A Magical ray of hope in Periodontic. Rama Univ J Dent Sci 2016 Dec;3(4):11-18.
[5.] Kong LX, Peng Z, Li SD, Bartold PM. Nanotechnology and its role in the management of periodontal diseases. Periodontol 2000 2006; 40: 184-196.
[6.] Bathla S. Periodontal Revisited. 1st edi. New Delhi: Jaypee Brothers Medical Publishers; 2011. 489-94.
[7.] Raghavendra M, Koregol A, Bhola S. Photodynamic therapy: A targeted therapy in periodontics. Aust Dent J 2009;54(1):102-109
[8.] Almeida Issa MC, Azulay MM. Photodynamic Therapy – A review of the literature and image documentation. An Bras Dermatol. 2010; 85(4): 501-11.
[9.] Malik R, Manocha A, Suresh DK. Photodynamic therapy – A strategic review. Indian J Dent Res; 2010; 21(2): 285-91.
[10.] Shivkumar V, Shanmugam M, Sudhir G, Pavitra PS. Scope of photodynamic therapy in periodontics and other fields of dentistry J Interdiscip Dent 2012; 2(2): 78-83.
[11.] Kiran KN, Ramesh BM, Srikanth C, Arpita PR. New trends in Periodontics. J Evol Med Dent Sciences 2012; 1(4): 550-557
[12.] Kanaparthy R, Kanaparthy A. The changing face of dentistry: Nanotechnology. Int. J Nanomedicine 2011; 6: 2799-2804.
[13.] De Dios NV. Current trends in periodontal diagnosis, disease recognition and management. Bartold PM, Ishikawa I, editors. Asian Pacific Society of Periodontology; 2004.
[14.] Mali S. Nanotechnology for surgeons. Ind J Surg 2013;75(6): 485–492.
[15.] Jurgens P. Hand book of biophotonics: 1st edi. Jena: John wiley & sons; 2012; 1-38.