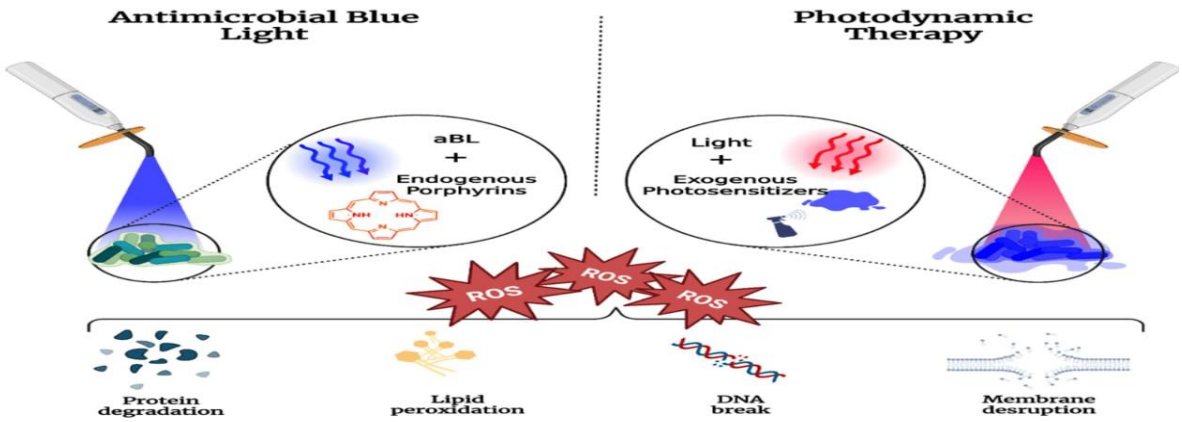
Biophotonics and Light-Activated Disinfection in Dentistry

Biophotonics, the science of using light-based technologies to study and manipulate biological materials, has emerged as a cutting-edge field in modern dentistry. Among its various applications, *light-activated disinfection (LAD)*—also known as *photodynamic therapy (PDT)*—has gained significant attention in endodontics, periodontics, and restorative dentistry. This technique uses a combination of a photosensitizing agent and a specific wavelength of light to produce reactive oxygen species (ROS) that selectively destroy microorganisms without damaging surrounding tissues. In endodontics, LAD offers an effective adjunct to conventional irrigation by targeting bacteria entrenched deep within dentinal tubules and biofilms, including resistant species such as *Enterococcus faecalis*.

The procedure typically involves applying a photosensitizer, such as methylene blue, toluidine blue O, or indocyanine green, into the prepared canal or infected area. When exposed to a diode or laser light source at the appropriate wavelength, the activated photosensitizer generates singlet oxygen and free radicals, which oxidize bacterial cell walls and nucleic acids, leading to microbial death. Unlike conventional chemical irrigants, LAD achieves disinfection through a physical mechanism, reducing the risk of tissue irritation, resistance development, or weakening of dentin structure.

Recent advances in biophotonics have introduced nanotechnology-enhanced photosensitizers that improve light absorption and tissue penetration, expanding antimicrobial efficacy. Fiber-optic delivery systems and miniaturized LED-based handpieces now allow better access to complex root canal anatomy. Furthermore, low-level laser therapy (LLLT), another branch of biophotonics, is being explored for promoting pulpal healing, dentin regeneration, and postoperative pain reduction. Dual-wavelength systems and oxygen-enhanced PDT represent new frontiers aimed at maximizing ROS generation while minimizing treatment time.



Biophotonics thus represents a paradigm shift in dental disinfection from chemical to photonic precision. As research continues, integrating light-activated therapies into everyday endodontic and restorative protocols could significantly enhance clinical outcomes, ensuring safer, faster, and more biologically compatible treatment modalities for patients.