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Review Article

Beyond the drill: laser-assisted advancements in endodontic care- review

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ABSTRACT:
The advent of laser technology has brought a paradigm shift in modern dentistry, particularly within the field of endodontics. This review aims to provide a comprehensive overview of the current applications, benefits, and limitations of laser use in endodontic procedures. Various types of lasers, including diode, erbium, neodymium-doped yttrium aluminum garnet (Nd\:YAG), and erbium-doped yttrium aluminum garnet (Er\:YAG), are explored with respect to their wavelengths, modes of action, and suitability for specific clinical tasks. The primary areas of focus include laser-assisted root canal disinfection, smear layer removal, apical surgery, pulp capping, and pain management. The review highlights how lasers enhance microbial decontamination and improve the outcomes of endodontic treatments compared to conventional methods. Moreover, it discusses the mechanisms by which lasers interact with dental tissues and irrigants to achieve superior cleaning and shaping of the root canal system. This review underscores the growing relevance of laser technology as a valuable adjunct in the endodontist's armamentarium, necessitating ongoing research and training for optimized outcomes.

Keywords: Laser dentistry, Root canal disinfection, Nd\:YAG laser, Er\:YAG laser, Diode laser, Apical surgery, Laser-assisted irrigation, Smear layer removal, Dental lasers

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INTRODUCTION

"Light Amplification by Stimulated Emission of Radiation" is what the acronym laser stands for. Since Albert Einstein first proposed the notion of stimulated emission in 1917, laser technology has advanced significantly[1].

One

In 1953, American doctors Hard Townes and Arthur L. Schawlow proposed the laser as a method. Their accomplishment was the creation of a "Maser Optic," a gadget that could output visible light instead of microwaves for the first time.[2]

The Institute for Advanced Dental Technologies estimates that in the United States, dental lasers have a 6% market share.[3]

According to the law of conservation of energy, energy is simply moved from one condition to another; it is neither created nor destroyed. Since laser and light technologies only perform two functions—heating the target or eliciting a reaction in it—the fundamental ideas behind their operation are rather straightforward. A curing light is a basic illustration of this. The light causes a chemical process that cures the material as it is absorbed by the composite.[4] Heat is produced as a byproduct of the conversion of light or photon energy into chemical energy. The wavelength of the light energy being emitted is one of the most crucial aspects of laser and light-based technology. Today, a multitude of wavelengths are available for procedures in the oral environment.[5]

A technological advancement in dentistry is causing an incredible paradigm shift by enabling dentists to perform a variety of hard-and-soft tissue procedures with better patient outcomes, less trauma, fewer post-operative complications, and, in the majority of cases, without the need for injections.[6] The range of procedures a dentist can perform for their patients is significantly increased by this new technology. With the most extensive indications for usage of any laser in medicine and dentistry, dentists are now effectively incorporating the Er, Cr: YSGG laser technology (Waterlase® MD laser, BIOLASE Technology, Inc.) into their operations.[7]

Lasers can be used to treat patients in the following aspects:

- Reduced anxiety or fear of the drill
- Reduced noise from the drill
- Needle-free or ‘‘no anesthesia’’ dentistry
- Restorative dentistry without the numbness or ‘‘fat lip’’ from the shot
- Desensitization of teeth
- Less chair time for many procedures
- Faster and better treatment of gum disease
- Reduced need for sutures
- New approaches for dental infections, requiring less antibiotics and pain medications
- Regenerative techniques enabling fewer extractions
- Faster and more comfortable healing
- Less pain associated with laser dentistry compared with more traditional treatments
- Less bleeding
- Less discomfort.[8]

All areas of dentistry, including orthodontics, endodontics, periodontal, surgical, and oral and maxillofacial surgery, use lasers. In order to cure pathologic problems and for aesthetic purposes, lasers are utilized for both soft and hard tissue operations.[9]

A computer-controlled semiconductor laser serves as the power source for a new generation of diode technology known as thermo-optically powered (TOP). It is a contact laser, like all diode devices. Fibers of quartz glass combined with sintered carbon make up the tip. Constant tip temperature is ensured via a controlling device. Speed control has no bearing on energy application, in contrast to conventional diodes.[10]

PULP DIAGNOSIS

Because the vitality tests used today are inadequate markers, diagnosing pulp vitality can occasionally be challenging. A erroneous diagnosis could result in the pulp tissue being removed needlessly. [14] Gazelius et al. were the first to describe the successful use of LDF in human teeth (1986). [15]

In addition to being used to diagnose blood flow in the tooth pulp, laser Doppler flowmetry (LDF) was created to evaluate blood flow in microvascular systems. This method makes use of low-power (1 or 2 mW) helium-neon and diode lasers. [16]

The application of an excimer laser system emitting at 308 nm for residual tissue detection within the canals was the other usage of lasers for endodontic diagnostics.[8].

The laser beam is focused onto the pulp's blood vessels via the tooth's crown. The laser beam's frequency is Doppler altered by moving red blood cells, which results in some light being backscattered out of the tooth. [17]

A photocell on the surface of the tooth detects the reflected light, and the output of this cell is related to the quantity and speed of the blood cells. 142 This method's primary benefit over electric pulp testing or other vitality tests is that it assesses a tooth's vitality without waiting for a painful sensation to occur. Furthermore, while pulp viability and an intact blood supply are preserved, teeth that have recently been traumatized or that are situated in a region of the jaw that may be impacted after orthognathic surgery may lose their sensitivity. [17] Endodontic therapy would have been unnecessary if the vitality of these pulps had been diagnosed primarily using electric pulp testing.

There are certain restrictions on laser Doppler flowmetry. Some teeth may be challenging to get laser reflection from. The anterior teeth, which have weak dentin and enamel, often don't cause any issues. Pulpal blood flow may fluctuate in molars due to their stronger dentin and enamel as well as the pulp's fluctuating location within the tooth.[8] Additionally, the use of many probes for correct assessment may be required due to variations in sensor output and poor manufacturer calibration. [16] Pulpal vitality can be measured objectively thanks to laser Doppler flowmetry. This technology could be utilized for patients who have trouble communicating or for young children whose responses might not be trustworthy if equipment costs come down and clinical application improves. [17]

Laser Doppler flowmetry has been used in PBF measurements for: (laser doppler flowmetry)

1. Estimation of pulpal vitality: When developing a differential diagnosis of dental pain, it's critical to evaluate each tooth's pulpal condition during treatment planning.
2. Pulp testing in children: Due to their subjectivity and dependence on the patient's response, sensitivity tests are unreliable in youngsters. Perhaps LDF is a better option.
3. The use of vitality tests, such LDF, can aid in the differential diagnosis of peripical radiolucencies because they may have nonendodontic causes.
4. Age-related changes in PBF can be tracked with Laser Doppler flowmetry. This technique has been used to demonstrate how the human pulp's hemodynamics deteriorates with aging.
5. Another sign that LDF is being used is tracking how exercise affects PBF.

6. LDF may be used to monitor responses to systemic and local pharmacological treatments, including local anesthetic solutions.
7. Reactions to thermal or electrical pulp stimulation can be tracked using laser Doppler flowmetry.
8. Tracking pulpal responses to orthodontic treatments.
9. Following orthognathic surgery, PBF can be measured using laser Doppler flowmetry.
10. PBF measurement following catastrophic injury.
11. Tracking the revascularization of teeth that have been replaced.

PULPOTOMY AND PULP CAPPING

"A dental material is placed over an exposed or nearly exposed pulp to encourage the formation of irritation dentin at the site of injury," according to the American Association of Endodontists, which defines pulp capping. To preserve the remaining coronal and radicular pulp tissues, a tiny amount of essential pulp must be surgically removed during a pulpotomy.

Pulpotomy is advised when the young pulp is already exposed to caries and the roots are not yet fully developed (open apices); pulp capping is advised when the exposure is extremely minimal, 1.0 mm or less, and the patients are young.

Calcium hydroxide is the conventional pulp-capping agent; however, when it is administered to pulp tissue, a dentin bridge is established and a necrotic layer is created. When the pulpotomy procedure is used, the same thing could happen. Applying mineral trioxide aggregate, a freshly developed substance, to exposed pulp yields positive outcomes. Although it requires three to four hours for the mineral trioxide aggregate to fully set, it results in more dentinal bridging in a shorter amount of time with noticeably less irritation. Whether pulp capping is done directly or indirectly, the success percentage varies from 44% to 97%. The same substances are used during pulpotomy until root development is finished. Whether to start full root canal therapy at that point is up for debate.

LASER THERAPY

Numerous research have examined the effects of various laser devices on dentin and pulpal tissue since lasers were first used in dentistry. Despite the pulpal damage induced by ruby lasers, [16] Melcer et al. demonstrated that an indirect CO2 laser-induced odontoblastic activation could be the cause of dentinal novo development. [18] When applied to the pulp or dentin, the C02 laser beam both sterilizes and cures dental decay while allowing the preservation of the vital tooth under specific energy density conditions. With further study, this technique should enable the examination of cellular activity into the initial, activation, and blocking phases. 19

Cavity preparation and carious removal using the erbium and erbium chromium lasers offer many advantages as follows

- Anaesthesia is usually unnecessary.
- The amount of heat generated in pulp chamber is not harmful for the pulp tissue.
- Laser preparation is selective for the carious tissues with the highest content of water (chromophore for erbium laser), and unlikely, it will result in overtreatment or mechanical exposure of the pulp.
- The irradiated dentinal surface becomes highly decontaminated and cleansed, with no smear layer.

As lasers can stimulate reparative dentin, clean the exposure site, and generate an analgesic effect that reduces pain and suffering, laser-assisted pulp capping techniques are helpful in pulpal exposures caused by mechanical exposure.

Using a 600 μm tip and air 6/10, water 5/10, the Er:YAG laser is used to remove dental cavities at settings of 100 mJ, 12 Hz, 1.2 W, and 100 μs. The laser is used to decontaminate deep dentinal cavities following carious removal operation.

Currently, indirect pulp capping may be carried out using both CO2 lasers and erbium family lasers:

Er:YAG (2940 nm) is employed with air 5/10, water 4/10 for 30 s, at 12 Hz, 50 mJ, 0.6 W, and 100 μs pulse duration. The parameters of a novel CO2 laser (9300 nm) include 250 μm spot size, water 40%, and 51 μs pulse duration.

The exposed pulp can be coagulated at 15 Hz, 10 mJ, and 600 microseconds for a few seconds in the event of a minor or unintentional exposure; the handpiece water feature is employed at 3/10 air and no water. A light-cured, resin-modified calcium silicate liner (Thera Cal LC, produced by Bisco, Inc.) is used to cover the pulpal area. Other pulp capping compounds, including calcium hydroxide, MTA, or Biodentine, can also be utilized for this purpose.

PULPOTOMY

This technique is defined by the American Academy of Pediatric Dentistry as the amputation of the pulp chamber while maintaining the radicular pulp's vitality, which will thereafter be treated with a medication.[20] When the pulp is cariously exposed and the tooth looks to be clinically and radiographically free of infection, pulpotomies are the most often performed procedure on primary teeth.

9300 nm is a new wavelength of CO2 laser that was just released onto the market. Because it is possible to vary the pulse duration and control the thermal contact with a water spray, this specific laser can be used for both soft and hard tissue therapy.

The following conditions can be treated with this 9300 nm CO2 laser (Solea by Convergent Dental, Natick, MA) for pulpotomy and coagulation in important primary teeth: 50 pulses, with a spot size of 0.25 mm, at power regulated by a variable power foot pedal from 1 to 50% for roughly 20 seconds each canal in the coronal section (water at 100%). ZOE can then be used to fill the tooth.

Current clinical procedures for use of lasers in direct pulp capping: treatment steps including advantages and disadvantages of lasers.

1. A rubber dam and local anesthetic are applied to the tooth if the diagnosis calls for direct pulp capping treatment. Using a high- and low-speed handpiece and/or hand tools, the dentin surrounding the exposed pulp is then prepared, and all softened, carious dentin is completely removed. To prevent undue harm to the exposed pulp tissue, this procedure needs to be done carefully. Because Er:YAG or Er,Cr:YSGG lasers can ablate carious dentin without direct touch, they may be useful for hard-tissue preparation in conjunction with mechanical treatment, depending on the circumstances. As a result, laser treatment reduces the exposed pulp tissue's mechanical damage.
2. After the surrounding dentin has been prepared, the exposed pulp tissue is hemostased and decontaminated, and this is when the majority of the laser is used. If the bleeding is small, traditional hemostasis and decontamination techniques include topical administration of Ca(OH)2 and extensive irrigation with NaOCl; if the bleeding is large, topical application of ferric sulfate. The area of bleeding 3 is then treated with a compressed application of a cotton pellet medicated with formocresol.
3. The CO2 laser can close tiny blood arteries by thermally coagulating soft tissue, hence it can readily stop blood flow during hemostasis in the non-contact mode.[21]
4. Sterilization and scarring in the irradiated area due to heat effects appear to be the most significant consequences of laser irradiation, which may help protect the pulp from bacterial invasion. Direct stimulation of dentin production may be another consequence of laser treatment.[22] 5. The diode laser's hemostatic effect is caused by hemoglobin and melanin's strong absorption of laser light, which guarantees that the treated region dries as quickly as possible. It offers deeper penetration as well. This laser creates a narrow area of hemostasis that includes a thin layer of necrosis. Below that, there is an area where the injury can be reversed, allowing fibroblasts and inflammatory cells that help form the dentinal bridge to migrate. 157
5. A filling material is applied after laser application and establishment of hemostasis.

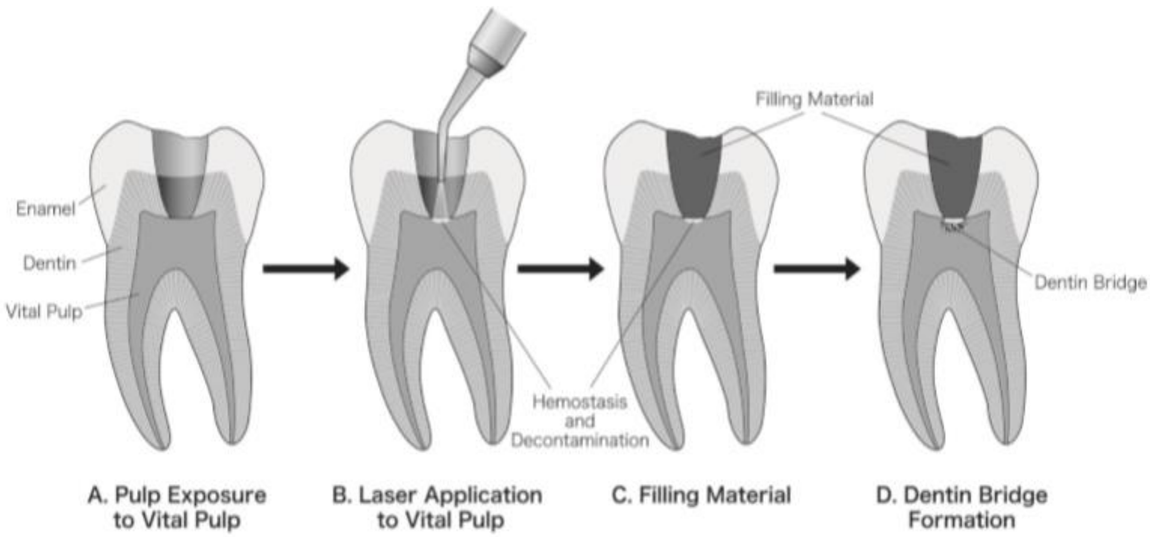

Figure 52: Treatment steps of direct pulp capping using lasers. (A) Exposure of vital pulp. (B) Hemostasis and decontamination of the exposed pulp tissue using lasers. (C) After laser application and hemostasis establishment, filling material will be applied. (D) Dentin bridge formation

Laser-assisted pulp capping has considerable advantages compared to traditional methods:[157]

1. Decontaminant effect
2. Haemostatic and coagulant effect
3. Reduced rise in pulp temperature
4. Reduction of intracavitary pressure
5. Dentinal melting
6. Biostimulating effect

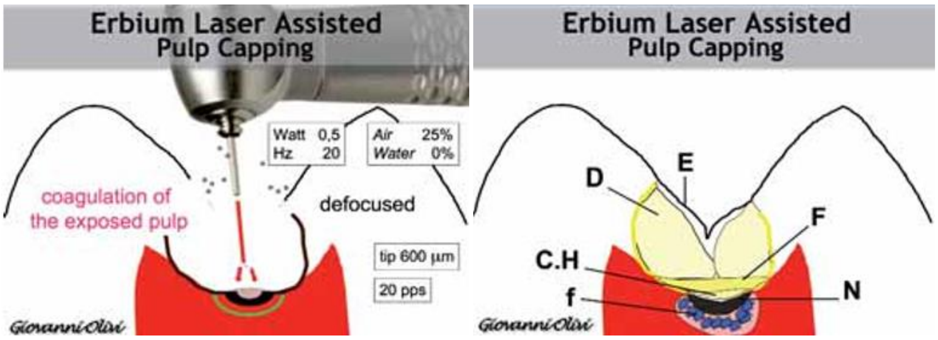

Figure 54
a.Laser procedure: defocused laser irradiation and coagulation of the exposed pulp, with air cooling and no water (25mJ Energy output).
b.Pulp capping and composite restoration: healing mechanism.
c.LEGEND f: migrating fibroblasts N: necrosis layer CH: calcium hydroxide capping material F: flowable composite DS: dentin and enamel composite filling.

CLEANING AND SHAPING

After pulp necrosis, bacteria and their byproducts from the root canal system develop periradicular periodontitis. Biomechanical instrumentation of the root canal is used to achieve successful endodontic therapy, which primarily relies on the removal of bacteria from the root canal system. However, studies have revealed that it is nearly impossible to completely eradicate bacteria from the root canal system, and a smear layer forms over the instrumented walls of the root canal.[16]

A thin optical fiber (Nd:YAG, erbium, chromium:yttrium-scandium-gallium-garnet [Er, Cr:YSGG], argon, and diode) or a hollow tube (CO2 and Er:YAG) can transmit the energy released by various laser systems used in dentistry into the root canal system.

Therefore, after biomechanical instrumentation, the potential bactericidal impact of laser irradiation can be employed successfully for further root canal system cleaning. Numerous lasers, including CO2, Nd:YAG, Excimer, diode, and Er:YAG, were used to study this effect. There seems to be general agreement that microbes could be killed by laser irradiation from dental laser systems. The effect is often directly proportional to the energy level and quantity of irradiation.[16]

A thorough analysis of O. 1 J/cm 2's effects on agar plates reveals that the excimer laser may suppress bacteria without leaving an agar indentation, even at very low energy levels. The excimer laser's bactericidal results on S. mutans suggest that using this laser could potentially kill other bacteria. 166 Because of their photo-thermal impact, all wavelengths damage the cell wall using various outputs. Gram-negative bacteria are more readily eliminated with less energy and radiation than gram-positive bacteria due to the structural differences in their cell walls.[11]

When used at standard parameters for laser-assisted endodontic procedures, the 808-nm and 1,064-nm lasers have a moderate direct bactericidal effect on black-pigmented P. gingivalis and a very limited direct bactericidal effect on unpigmented bacteria, including Gram-positive and Gram-negative bacteria, regardless of their cell wall structure.[25]

It is impossible to ignore a number of potential restrictions on the intracanal application of lasers. The laser energy emitted from the laser guide or the tip of the optical fiber travels along the root canal rather than necessarily laterally to the walls of the canal. As a result, employing a laser to achieve consistent coverage of the canal surface is nearly difficult.

The procedure's safety because there is a chance that the periapical tissues could sustain heat injury. When a laser beam is directly emitted from the optical fiber tip near a tooth's apical foramen, the radiation may be transmitted outside of the foramen. In turn, this radiation transfer may have a negative impact on the tooth's supporting tissues and pose a risk to teeth that are close to the mandibular nerve or the mental foramen.[16] "Removal of smear layer and debris by laser is possible, but it is difficult to clean all root canal walls, because the laser is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls," Matsumoto and colleagues wrote in their evaluation.

Laser uses in endodontics will grow as thinner, more flexible, and long-lasting laser fibers are developed. 8. The invention of a novel endodontic tip that works with an Er:YAG laser system was recently described by Stabholz and associates. Since the Food and Drug Administration approved the Er:YAG laser for use on hard tooth tissues, doctors have been using it more and more. In order to create an endodontic tip that permits lateral emission of the irradiation (side-firing) as opposed to direct emission through a single hole at its far end, the Er:YAG laser beam is given through a hollow tube. The volume and shape of root canals made with nickel-titanium rotary instruments were taken into consideration when designing this novel endodontic side-firing spiral tip.[13]

It uses a spiral slit all the way along the tip to emit the Er: YAG laser irradiation laterally to the root canal walls. Because the tip is shut at the far end, radiation cannot enter the tooth through the apical foramen.[14]

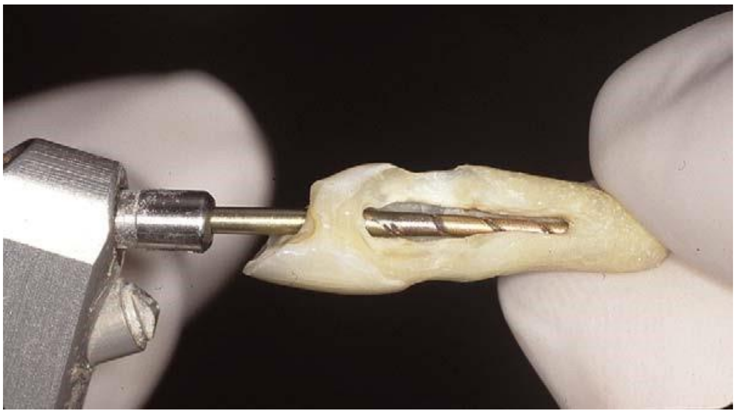

Figure 55: The prototype of the RCLase Side-Firing Spiral Tip is shown in the root canal of an extracted maxillary canine in which the side wall of the root was removed to enable visualization of the tip.

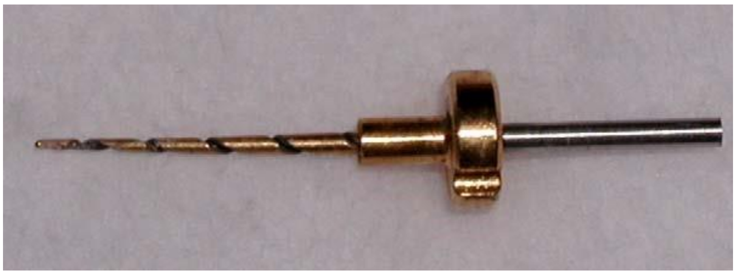

Figure 56: The RCLase Side-Firing Spiral Tip.

Unlike the dentinal tubules in the tooth crown, which usually have S-shaped curves, the tubules in the root run a rather straight course between the pulp and the periphery.[25] According to studies, bacteria and their byproducts from infected root canals have the potential to infiltrate the dentinal tubules. It was also found that bacteria were present in the dentinal tubules of diseased teeth, which are located about half the distance between the cementodentinal junction and the root canal walls. These results support the need and justification for creating efficient methods for smear layer removal from root canal walls after biomechanical instrumentation.

Disinfectants and laser radiation could access and eliminate germs in the dentinal tubules as a result of this removal.

The diameter of a root canal just prior to its apical constriction is known as its working width (WW). One of the few taperless NiTi instruments that can clean to the WW is the Light Speed LSX (Discus Dental) file. The instrument size that completes WW preparation is known as the final apical size, and it is established when the LSX file binds 4mm or more from the working length (WL) and needs to be pushed firmly to reach WL.[26]

Er, Cr: YSGG laser irradiation appears to be successful in straight root canal preparation and in clearing debris and smear layer from root canal walls; however, the success rate in curved root canals is low; the laser device may cause ledge or zipped formation, perforation, or over-instrumentation during canal preparations; therefore, more advancements in laser device and technique are needed to ensure curve root canal preparation is successful.[27]

LASER ASSISTED IRRIGATION

Since the root of a tooth is surrounded by bone and periodontal ligament, the canal functions as a closed-end system. When an irrigation needle is inserted into a closed-end canal, an empty space forms below the solution due to air entrapment, creating an airlock effect during the irrigation process. Therefore, the irrigation technique must be improved to achieve better debridement, particularly in the apical third of the root, where laser power of 1 W for 1 minute can drive the irrigation solution all the way to the tip of the canal. The laser group's method was statistically significantly more successful than the PUI group in removing the airlock from the apical third.[20]

When the apical foramen is bigger, pulsed erbium lasers can more easily produce pressure waves strong enough to push aqueous irrigant microdroplets beyond the apical constriction. Therefore, employing such lasers in conjunction with irrigants like hydrogen peroxide and sodium hypochlorite should be done with caution. Three elements make up 175 PDT: oxygen, light, and a photosensitizer. The patient is given a photosensitizer or its metabolic precursor. The photosensitizer changes from a low-energy ground state to an excited singlet state when exposed to light with a particular wavelength. The photosensitizer may then either transition to a higher-energy triplet state or decay back to its ground state, emitting fluorescence.[21]

The triplet state can quickly and selectively destroy the target tissue by reacting with endogenous oxygen to form singlet oxygen and other radical species. There are 2 mechanisms through which triplet biomolecules react - Type I includes the direct transfer of electrons and hydrogen from the photosensitizer, the creation of ions, or the extraction of electrons and hydrogen from a substrate molecule to create free radicals. Superoxide, hydroxyl radicals, and hydrogen peroxide are examples of highly reactive oxygen species that are produced when these radicals react quickly with oxygen. Singlet oxygen is the extremely reactive and electrically excited state of oxygen produced by type II reactions. It is challenging to discern between the two response processes in PDT. The fact that both Type I and Type II processes contribute suggests that the mechanism of damage depends on the concentration of photosensitizer and oxygen tension.

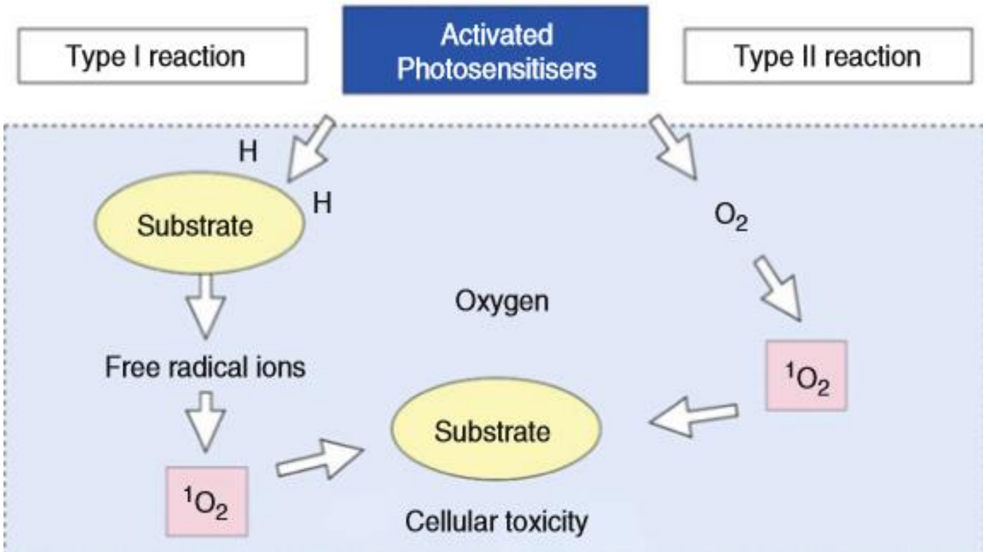

Figure 57: Photo activated Disinfection

Although PDT is thought to be a good way to get rid of oral germs, not many clinical research have evaluated how well it works in root canal therapy.[29] PDT is another innovative therapy strategy for treating oral biofilms. Plaque structure disruption has significant effects on the biofilm's homeostasis.[28] Endodontic PDT can be performed using a variety of light sources, including diode, metal-vapor, argon, and helium-neon lasers. Because light and exogenous photosensitizers are associated, they have an antibacterial impact when employed at low power, initiating a series of processes that ultimately result in cell death. Because low-power lasers enable quick periapical tissue repair and less post-instrumentation discomfort, they are utilized in endodontics.

The Erbium laser uses relatively little energy (less than 50mJ) to produce peak power, and its pulse duration is very short (less than 150µs). While the peak power offers the benefit of water molecule excitation (target chromophore) and the subsequent creation of the photomechanical and photoacoustic effects (shock waves) of the irrigant solutions introduced in the root canal on the dentinal walls, the use of minimally ablative energy minimizes the undesirable ablative and thermal effects on dentinal walls. These results are quite effective in decontaminating the canal, eliminating the bacterial biofilm, and cleaning the smear layer from the dentinal walls.[11]

The foundation of photoactivated disinfection (PAD) is the idea that certain chemicals attach to target cells and are activated by light with the right wavelength. Bacteria are poisoned by the free radicals that are created. Photo-activatable compounds include, for example, methylene blue and toluidine blue. The majority of the current microorganisms can be killed by tolonium chloride. According to in vitro research, PAD effectively combats photosensitive bacteria such Actinomycetemcomitans, Peptostreptococcus micros, E. faecalis, Fusobacterium nucleatum, and Prevotella intermedia. However, while assessing PAD's antibacterial properties as an adjunct to irrigation and instrumentation in E. faecalis-infected canals, Souza et al. (2010) found no discernible impact on intra-canal disinfection.[30]

It has been demonstrated that PAD eliminates bacteria like S. mutons that are frequently present in root canals. S. rntermedius E. foecolis Interrnedio prevotello. microorganisms of Peptostreptococcus. Nucleotum Fusobacterium. Actinomyccs and Porphyromonos species. In order for the bacteria to bind or absorb some of the photosensitizer and become sensitive to the laser light, the photosensitizer solution must be briefly in direct contact with the location when employing PAD clinically. Similar to endodontic irrigants, the dye solution must be carefully shaken inside the root canal to remove any air bubbles that would prevent bacteria from making contact. Additionally, the photosensitizer dye must be applied in a properly prepared environment, specifically a root canal region devoid of saliva or blood.

Due to the presence of ROS scavenger molecules like catalase and lactoperoxidase, both of these fluids have the potential to hinder the deadly photosensitization process. Typically, a visible red diode laser with an output power of up to I00 mW is used to deliver PAD parameters for effective microbe killing, which are in the range of I5 Jkm* over 60–I20 seconds. Delivering the laser energy with a photodynamic diffuser tip that produces a cylindrical emission pattern that matches the root canal system's form will have the most impact. Such diffuser tips not only evenly irradiate the root canal but also lower the effective power density, which significantly lowers the possibility of laser-induced visual damage.[31]

PIPS

The swelling and contracting cavitational bubbles at the PIPS tip are thought to generate pressure waves that spread outward and create fluid motion. The Er:YAG laser's parameters and tip shape determine the bubble's size, shape, and dynamic behavior. The cavitational bubble in this investigation was created using sub-ablative settings. In other words, rather than removing material directly from the canal's edge, the high peak power from the brief pulse (50 µs) and the high absorption of the Er:YAG wavelength by water caused a vapour bubble to form, expand, and then collapse quickly at the tip.

The PIPS effect is brought on by the fluid's quick movement around the tip, which spreads to the surrounding fluid. According to the study's results, PIPS activates a model canal's fluid at a considerable distance from the instrument and causes higher average speeds than ultrasonic activation. It is believed that a mix of chemistry and fluid dynamic or mechanical forces is responsible for effective clinical irrigation.[33] In comparison to traditional irrigation and sonic irrigation methods, it may be inferred that the application of laser-activated irrigation with a unique tip design (PIPS) and PUI can result in a stronger binding between the resin sealer and the root dentin.[34]

PIPS and Endo Activator groups can be regarded as alternatives to diode laser groups in the removal of microorganisms from diseased root canals because they demonstrated promising antibacterial activity and less live bacteria than standard needle irrigation. In minimally instrumented, experimentally instrumented root canals, the diode laser group demonstrated superior antibacterial efficacy and the fewest live bacteria in comparison to the standard needle irrigation, PIPS, and Endo Activator groups. When compared to passive ultrasonic, sonic, or simple needle irrigation,[35] laser-activated irrigation with the photon-induced photoacoustic streaming approach of 6% sodium hypochlorite greatly enhanced the cleansing of biofilm-infected dentine.

OBTURATION

Two main presumptions underlie the justification for using laser technology to help obturate the root canal system:

- The capacity to use laser irradiation as a heat source to soften gutta-percha for use as an obturating material
- To condition the dentinal walls prior to applying an obturating bonding material.
  The first laser-assisted root canal filling method made use of the Argon 488 nm laser. This wavelength, which can penetrate dentin, was used to polymerize a resin that was placed into the main root canal.
  It was demonstrated that the resin in the lateral canals was easily polymerized at low energy levels (30m W) when the biomaterial's ability to enter accessory root canals was evaluated. This wavelength's unsuitability for other dental operations rendered its continued use moot. [37]
  When using warm gutta-percha compaction procedures, the importance of endodontic sealers has been amply shown. [14]

According to the study, lased groups' apical leakage was noticeably less than that of nonlased groups. This decreased apical leakage may have resulted from laser irradiation, which lowered the smear layer and removed debris from the canal wall, making it more suitable for canal obturation. [24]

The depth to which root canal sealers penetrated the dentinal tubules was not enhanced by the use of the Nd:YAG laser as part of the endodontic apparatus. Sealer tags were not consistently adapted to the entire circumference of the root canal walls in the tested sealer. Nonetheless, because it increases the superficial extension that the sealer has created close to the apex, the Nd:YAG laser might be a suitable addition to root canal therapy.[37]

ENDODONTIC RETREATMENT

Coronal microleakage from temporary or permanent coronal restorations that are insufficient, as well as potentially bacteria in dentinal tubules that can proliferate when coronal restorations are insufficient, appear to be the pathways of reinfection of the root canals during and after root canal therapy.[23] The necessity to eliminate foreign material from the root canal system that could be challenging to remove using traditional techniques may be the justification for employing laser irradiation in non-surgical retreatment. The effectiveness of the Nd-YAP laser (1340 nm) in root canal retreatment (200 mj and a frequency of 10 Hz) was investigated by Farge et al.[38]

Gutta-percha and zinc oxide-eugenol sealer were attempted to be removed. They also mentioned an attempt to remove broken instruments and silver

cones. They came to the conclusion that debris and obturating materials would not be entirely removed from the root canal by laser radiation alone. Yu et al.[39] removed fractured files and gutta-percha from root canals using a Nd-YAG laser set to three output strengths (1, 2, and 3 W).
Gutta percha can be softened with just the Nd YAG laser. Neither the amount of time needed for the process nor the amount of gutta percha that remained on the root canal walls improved with the addition of solvent.[41] The Nd:YAP laser fiberoptic with a 200/xm diameter can work in the apical third of the root, whereas the manual retrieval method is most successful when it comes to pieces that are broken in the coronal third. When a piece of the broken instrument is securely stuck inside the canal and cannot be removed using ultrasonic means, the Nd:YAP laser may also be utilized.
In a similar vein, a broken silver cone that is out of reach of peet splinter forceps may be evaluated for laser treatment. In contrast to traditional methods, a dry root canal is required for the Nd:YAP laser irradiation. Simultaneous consideration of chemical dissolution is not necessary. 200 Hand tools or drilling machines are also used in therapeutic dentistry to remove old filling materials, such as those from root canals: When dental materials are laser-ablated, the damage to dental tissues and pain experienced during various dental manipulations is reduced, and the manipulations are made easier, resulting in greater treatment quality. [12]
In order to remove broken stainless steel tools without harming healthy tooth material, a study was conducted to assess the effectiveness of Nd:YAG laser treatment. The study's objective was to determine whether using a brass tube charged with solder in conjunction with a Nd:YAG laser would be advantageous for the extraction and fixation of broken endodontic files.[43]

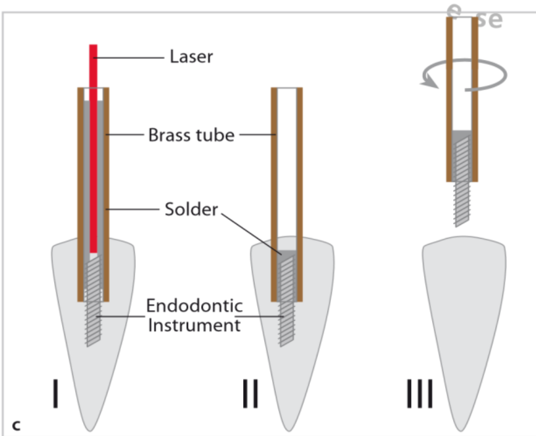

Figure 58:

1. Laser energy melts the solder.
2. After the laser is deactivated, the solder hardens and connects the brass tube to the fractured instrument.
3. Removal of the brass tube/ endodontic instrument complex.

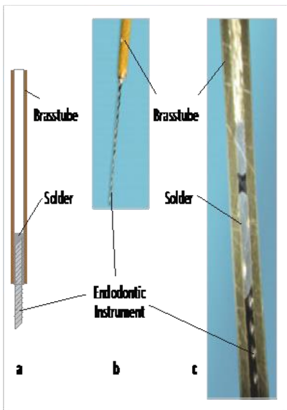

Figure 59:

(a and b) Details of the brass tube/endodontic instrument complex. (c) The complex has been cut away longitudinally to illustrate the connection between the endodontic instrument and the solder

Dental instruments have been successfully sterilized using lasers (Ar, CO2, Nd:YAG lasers) (Adrian & Gross 1979, Hooks et al. 1980, Powell & Whisenant 1991). According to the results, certain dental instruments can be sterilized by all three lasers (Ar, CO2, and Nd:YAG lasers); however, the argon laser was able to do so reliably for two minutes at the lowest energy level of 1 W. Appropriate irradiation systems must be created before applying this understanding to a clinical setting.

ENDODONTIC SURGERY

Dr. Weichman of the University of Southern California made the first attempt to using a laser in endodontic surgery. 138 When teeth cannot be properly treated nonsurgically or have not responded well to traditional treatment, surgical endodontic therapy is the preferred course of action. All endodontic surgery aims to eradicate the illness and stop it from coming back. Only when nonsurgical treatment is unable to produce a superior outcome should the surgical alternative be taken into consideration.

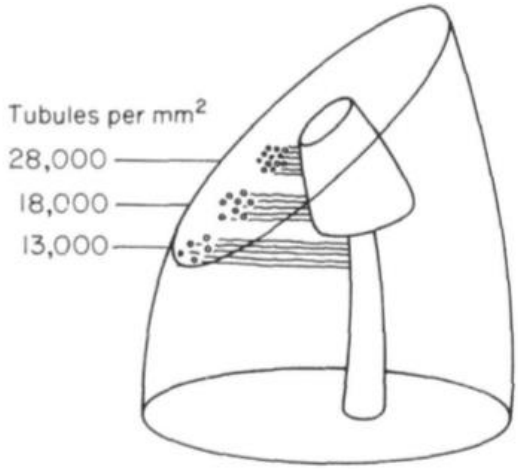

Figure 60: Tubule density at three locations on an apieected root face: top, close to the root canal; middle, mid-way between the canal and the dentinecementum junction; and bottom, close to the dentine-cementum junction. Potential for leakage exists if the angle of the cut face is steep and/or the retrograde filling extends for only a short distance into the canal.

Lasers were originally used in endodontics by Weichman and Johnson, who tried to seal the apical foramen of recently extracted teeth when the pulp had been removed from the root canal. The teeth's apices were exposed to high-power (CO2) laser radiation. Their aim was not accomplished, as evidenced by the cementum and dentin melting and eventually forming a "cap" that was easily removable.[16] Miserendino demonstrated the recrystallization and carbonization of the root dentin of the apical root dentin by applying CO2 laser energy to the apices of recently extracted human teeth. High-speed rotary turbines are not necessary for apicoectomy since surgical bone curets may easily remove the carbonized root material.

Therefore, enhanced hemostasis, possible disinfection of the infected root surface and apex, and a decreased risk of surgical site contamination due to the removal of aerosol-producing air turbine handpieces were the benefits of laser application in endodontic surgery.[42] 320 patients were assessed in a prospective research of two retrograde endodontic apical preparations using and not using a C02 laser. The results showed that the healing process was not aided by either procedure.[43] Studies conducted in vitro with the Nd:YAG laser have demonstrated a decrease in the amount of dye or bacteria that can pass through removed roots. It was proposed that structural alterations in the dentin after laser application were most likely the cause of the decreased permeability in the lased specimens.

SEM analysis revealed that the hard tissue had melted, solidified, and recrystallized; however, the structural alterations were not consistent, and the melted regions seemed to be connected by regions that resembled those in the nonlased specimens. A bloodless surgical field should be simpler to accomplish if a laser is utilized for the procedure because of its capacity to vaporize tissue and coagulate and shut tiny blood vessels. The sliced surface is sealed and sterilized if it is exposed to radiation. Furthermore, mechanical drills would no longer be necessary due to the Er:YAG laser's ability to cut strong dental tissues without causing significant thermal or structural damage.[43]

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