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LASERS IN PROSTHODONTICS – A REVIEW

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Abstract:

Since the development of ruby laser by Maiman in 1960, a variety of studies on the potential applications of lasers in dentistry have been conducted. Many applications like computer aided design and rapid prototyping technology, and study of occlusion in complete dentures using three-dimensional laser scanner have been developed. Its applications range from fixed Prosthodontics, treatment of dentinal hypersensitivity and to surface treatment of base metal alloys. Today it even extends to the fields of dental implantology and maxillofacial Prosthodontics. This article reviews and summarises various studies of laser applications in Prosthodontics.

Key words: LASER, Complete Denture, CAD/CAM, Impression, Crown Preparation, Welding, Dental Implants, Maxillofacial Prosthesis.

Introduction:

Light is an integral part of our life. The early 20th century saw one of the greatest inventions in science & technology, in that LASERS (Light Amplification by Stimulated Emission of Radiation) went on to became a gift to health sciences. A laser is an instrument that produces a very narrow, intense beam of light energy (electromagnetic radiation) through a process called stimulated emission. Albert Einstein is usually credited for the development of the laser theory. He was the first one to coin the term "Stimulated Emission" in his publication "Zur Quantentheorie der Strahlung", published in 1917 in the "Physikalische Zeitschrift"[1].

Their application range from a simple television remote to computer devices such as laser mouse, presentations, CD ROMs, DVD ROMs, Astronomy and communication application, war machines, guns and tanks, cutting and welding in metallurgy industries, Robotics and even in toys.

The use of lasers for treatment has become a common practice in the medical field. Theodore Harold Maiman is generally credited for building the first working ruby laser and operating it for the first time on May 16, 1960 at the Hughes Research Laboratory in Malibu, California. MASER a microwave amplifier by Charles H.Townes, P.Gordon et al became the basic principle for laser pumping. This set the stage for a "snowball effect" which would lead to the development of many laser systems, which we utilize in healthcare today. The application of laser to dental tissues was reported by Stern, Sognnaes and Goldman et al. in 1964, describing the effects of ruby laser on enamel and dentine with a disappointing result. However, with the recent advances and developments of wide range of laser wavelengths and different delivery systems, researchers suggest that lasers could be applied for the dental treatments too.[1]

Currently, numerous laser systems are available for dental use. Neodymium-doped: Yttrium-Aluminium-Garnet (Nd: YAG), carbon dioxide (CO2) and semiconductor diode lasers have already been approved by the United States Food and Drug Administration for soft tissue treatment in oral cavity. The Erbium doped: Yttrium-Aluminium-Garnet (Er: YAG) laser was approved in 1997 for hard tissue treatment in dentistry[2].

Background knowledge:

The basic components of a laser are straight forward and are always similar regardless of the type of equipment. They include an active lasing medium within an optical cavity (resonator) and a pumping source (energy source). The optical cavity consists of two mirrors placed on either side of the laser medium. Due to this arrangement, photons resulting from the stimulated emission will form a continuous avalanche process. As long as the pumping energy maintains the population inversion in the active medium, more stimulated photons are created thus producing energy. The energy is absorbed and emitted in the resonator and with the aid of mirrors, is reflected and resonates within this chamber, and ultimately produces laser light. Because one of the mirrors is partially transmissive, some of the laser energy escapes at one end of the device into a delivery system. Consequently; a laser is just a source to generate a high energetic beam of light, which is monochromatic, collimated and coherent (Fig 1).

In medical, the photo thermal effect is in the range of m sec to sec of irradiation time. The light energy is converted into thermal energy, which is locally cooled by water that irrigates the irradiated and surrounding tissue. As the temperature increases at the surgical site, the tissues can be warmed up to (37-50°C), coagulated (60-70°C), welded (70-90°C), and vaporized (100-150°C). If the laser energy continues to be absorbed by the tissue, carbonization occurs (>200°C) and with it the possibility of significant tissue damage. Consequently, both target and surrounding tissues can be subjected to these harmful effects.[3]

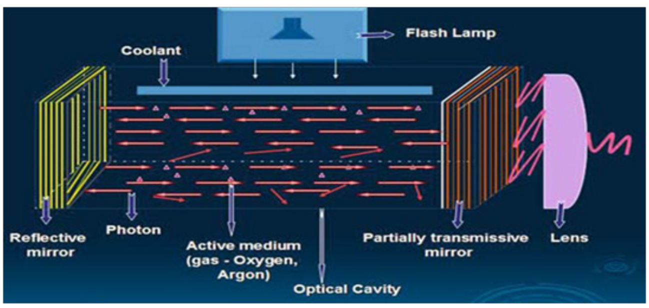

Fig 1 : Production of Laser

Classification of Lasers:[4]

I. According to the wavelength (nanometers)

1. UV (ultraviolet) range – 140 to 400 nm
2. VS (visible spectrum) – 400 to 700 nm
3. IR (infrared) range – more than 700 nm

- Most lasers operate in one or more of these wavelength regions.

II. Broad classification

1. Hard laser (for surgical work)

   i. CO2 lasers (CO2 gas)

   ii. Nd:YAG lasers (Yttrium-aluminium-garnet crystals dotted with neodymium)

   iii. Argon laser (Argon ions)

2. Soft laser (for biostimulation and analgesia)

   i. He-Ne laser

   ii. Diode lasers

III. According to the delivery system

   i. Articulated arm (mirror type)

   ii. Hollow waveguide

   iii. Fiber optic cable

IV. According to the type of active medium used :

Gas, solid, semi-conductor or dye lasers

V. According to type of lasing medium :

E.g. Erbium: Yttrium Aluminium Garnet

VI. According to pumping scheme

1. Optically pumped laser
2. Electrically pumped laser

VII. According to operation mode

1. Continuous wave lasers
2. Pulsed lasers

VIII. According to degree of hazard to skin or eyes following inadvertent exposure,

The laser classification system is based on the probability of damage occurring.

Class I- (< 39mw) Exempt; pose no threat of biological damage.

Class II- (< 1 mw) The output could harm a person if he were to stare into the beam for a long period of time. The normal aversion response or blinking should prevent you from staring into the beam. No damage can be done within the time it takes to blink.

Class IIIA - (<500mw) Can cause injury when the beam is collected by optical instruments and directed into the eye.

Class IIIB - (<500mw) Causes injury if viewed briefly, even before blinking can occur.

Class IV - (> 500mw) Direct viewing and specular and diffuse reflections can cause permanent damage including blindness.

Lasers used in Prosthodontics:

I) Complete denture Prosthodontics:

i. Prototyping and CAD/CAM (Computer Aided Design and Computer Aided Manufacturing) technology.

ii. Analysis of occlusion by CAD/CAM.

iii. Analysis of accuracy of impression by laser scanner.

II) FIXED PARTIAL DENTURE:

i. Tissue management.

ii. Crown preparation

III) REMOVABLE PARTIAL DENTURE:

i. Laser welding.

IV) IMPLANT DENTISTRY:

i. Soft tissue surgery.

ii. Implant surface debridement.

iii. Implant surface treatment.

V) MAXILLOFACIAL PROSTHODONTICS:

i. Sintering with CAD/CAM technology.

I) COMPLETE DENTURE PROSTHODONTICS:

PROTOTYPING AND CAD/CAM TECHNOLOGY: The term rapid prototyping (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data. These "three dimensional printers" allow designers to quickly create tangible prototypes of their designs, rather than just two-dimensional pictures. Such models have numerous data.

In addition to prototypes, RP techniques can also be used to make tooling (referred to as rapid tooling) and even production-quality parts (rapid manufacturing).A software package slices the CAD model in to a number of thin (eg.0.1mm) layers, which are then built up one atop another. Rapid prototyping is an additive process, combining layers of paper, wax, or plastic to create a solid object.

In contrast, most machining processes (milling, drilling, grinding, etc.) are "subtractive"processes that remove material from a solid block. RP's additive nature allows it to create objects with complicated internal features that cannot be manufactured by other means.[5,6]

Laser Rapid Forming of A Complete Titanium Denture Base Plate:[7] This technique uses the combination of the CAD/CAM and LRF (Laser Rapid Forming) methods for forming the titanium plate of a complete denture. Laser scanner, reverse engineering software, and standard triangulation language (STL) formatted denture base plate and sliced into a sequence of numerical controlled codes.

The denture plate will be built layer-by-layer, on the LRF system. After the traditional finishing techniques, this denture plate will be acceptable for use in patients.

II) STUDY OF COMPLETE DENTURE OCCLUSION USING BY THREE-DIMENSIONAL TECHNIQUE:[8]

After fabrication of new dentures the occlusion can be examined and studied with the help of laser scanner technique and three-dimensional reconstruction. The laser scanner scans the occlusion of the dentures fabricated, then the scanned image is used to fabricate the three dimensional structure by three-dimensional reconstruction. The relationship between the parameters of balanced occlusion can also be analyzed.

III) ANALYSIS OF ACCURACY OF IMPRESSION BY LASER SCANNER:[3]

Several studies have made comparisons in the dimensional accuracy of different elastomeric impression materials. Most have used two dimensional measuring devices, which neglect to account for the dimensional changes that exist along a three-dimensional surface.

The scanning laser three-dimensional (3D) digitizer can delineate x, y, and z coordinates from a specimen without actually contacting the surface. The digitizer automatically tracks and coordinates with precision and stores data as the number of points on a surface with a resolution of 130 mm at 100 mm. These exacting features suggest that the laser digitizer might accurately and reliably measure the dimensions of dental impression materials while avoiding subjective errors.

The image is built up and landmarks identified which allow superimposition of the images and enable the differences between two similar images to be calculated. The 3D laser captures complex 3D texture-mapped models and they are exported into a 3D (Scan Surf) software application where it is built and triangulated into a 3D meshwork image of the object. The scanning process is accomplished within a minute whereas the software analysis takes much longer. The software superimposes the two objects by either registering landmarks or by registering as iterative closest point (ICP). This finds an optimal fit between the two surfaces and in effect acts as a reference area. Once superimposed, the difference of the two surfaces is calculated as the shortest distance of each point on one object surface from a second object surface, within a range of 0.5 mm. Three-dimensional digitizers will eventually become less expensive, require less maintenance, track faster, and be available with more standardized software.

Fixed Partial Denture:

I) TISSUE MANAGEMENT:

Crown lengthening:[9] This is a procedure when inadequate crown height is present for crown restoration an adequate crown height is created by removing required gingival soft tissue. With the help of the lasers soft tissue crown lengthening can be done without raising a flap. By its thermal effect the laser seals vascular and lymphatic vessels at the same time it vaporize the excess gingival tissue. Since no flap was required for this surgery, sutures were not necessary and the wound healed by secondary intention.

Advantages:

- Increased coagulation that yields a dry surgical field and better visualization.

- Tissue surface sterilization and therefore, reduction in bacteremia.
- Decreased swelling, edema of target tissue.
- Decreased pain, and in some cases no need of anesthesia while surgery.
- Faster healing response and increased patient acceptance.
- Less chair-side time.

II) CROWN PREPARATION:[10]

Crown preparation with lasers a debated topic still. There are no conclusive studies yet showed the use of lasers for crown preparation purposes. But still some commercial companies say that they can be used. The following is the details what these companies say:

Er, Cr: YSGG laser is used most commonly now. It uses hydrokinetic technology (laser-energized water to cut or ablate soft and hard tissue).Because of this mechanism local anesthesia is not required in many cases, making this more comfortable procedure for the patient, and of course, saving time and anesthetic use by the patient.

The laser hand piece resembles a high-speed hand piece but with fiber-optic tips instead of a bur, which directs the laser energy at a focal point approximately 1-2 mm from the tissue surface.

The crown preparation should be started on maximum setting for cutting enamel (6W,90% air,75% water),started with a defocused mode for 30 seconds to 1 min for anesthesia of tooth.

While placing the gingival margin setting will be reduced 1.25 W, 50% air, 40% water to control the cutting tip, for the purpose of accuracy.

To finish with the interproximal, buccal, lingual/ palatal reduction cuts will be performed with the dentin settings 4W, 65% air, 55% water. The laser has to be reset at 2.25 W, 65% air, 55% water to finish the buccal cusp overlay, and the final margination of the proximal and lingual surfaces.

Advantages:

- For vital crown preparation no need of local anesthesia, as laser causes temporary paraesthasia of nerve endings.
- Procedure is accurate and faster than the conventional method.

Disadvantages:

- Trained dentist required the particular use.

III. REMOVABLE PARTIAL DENTURES:8

LASER WELDING:

The removable partial dentures defect can be repaired by the use of pulsed laser with relative low average out power. This is known as a precise and rapid joining method, but its success depends on the control of many parameters.

Eg: For Co-Cr alloy frameworks:

The welding parameters were determined for each defect type and working step (fixing, joining, filling, planning). Adequate combination of pulse energy (6-14 J), pulse duration (10-20ms) and peak power (600- 900 W) depending on the working stage improves the success of the welding procedure.

IV. IMPLANT DENTISTRY:[11,12]

FOR STERILIZATION OF SOCKET:

In immediate implant dentistry after extraction of tooth,sockets can be sterilized immediately without inducing pain and any infection.

IN CASE OF PERI- IMPLANTITIS:

Since the laser does not transmit damaging heat, it can be utilized to vaporize any granulation tissue as well as clean the implant surface in periimplantitis cases. This procedure eliminated the acute state of peri-implantitis, resulting in positive GTR, and allowing the patient extended use of the implant.

TO DEBRIDE THE IMPLANT SURFACE:

Miller Robert has shown that treatment of the contaminated implant surface by mechanical and chemotherapeutic means has met with mixed success. Development of a laser system operating at 2780 nm and using an ablative hydrokinetic process offers the possibility for more efficient decontamination and debridement. Laser ablation using the Er: Cr: YSGG laser is highly efficient at removing potential contaminants on the roughened implant surface while demonstrating no effects on the titanium substrate.

V. IN MAXILLOFACIAL PROSTHESIS:[13]

New advances in rapid prototyping technologies have demonstrated significant advantages compared to more conventional techniques for fabricating facial prosthesis. The use of selective laser sintering technology is an alternative approach for fabricating a wax pattern of maxillofacial prosthesis. This new approach can generate directly by prototyping and reduce labor-intensive laboratory procedures.

SLS (SELECTIVE LASER SINTERING):

The SLS (Selective Laser Sintering) is a method of computer aided designing using mainly the laser. In this method models are generated directly from 3-D computer data then converted to STL files, which are then sliced in to thin layers (typically about 0.1 mm/0.004 inches) using the associated computer software. The laser sintering machine produces the models on a removable platform by applying incremental layers of the pattern material. For each layer, the machine lays down a film of powdered material with an accurate required thickness, again a fresh film of powder is laid down, and the next layer is melted with exposure to the laser source. This process continues, layer by layer, until the pattern is completed.

ADVANTAGES:

- Manufacturer time is reduced.
- More precision can be achieved.

LIMITATIONS OF LASERS:[14]

- It requires additional training and education for various clinical applications and types of lasers.
- High cost required to purchase equipment, implement technology and invest in required education.
- More than one laser may be needed since different wave lengths are required for various procedures.

Conclusion

The laser technology has been widely used in dentistry on both hard and soft tissues in various treatment modalities. However, lasers have got their own limitations specifically being technique sensitive. It has never been the "magic wand" in the field of medicine or dentistry but been beneficiary as an adjunct with other procedures used for the treatment. In the future laser dentistry can be more brighter with going on further research. Even now Lasers are blessing in disguise if used efficaciously and ethically. As Aaron Rose Says, "In right light at right time everything is extraordinary."

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