Review Article

LASERS: NOVEL APPROACH TO DENTISTRY

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ABSTRACT

Lasers were introduced into the field of clinical dentistry with the hope of overcoming some of the drawbacks posed by the conventional methods of dental procedures. Since its first experiment for dental application in the 1960s, the use of laser has increased rapidly in the last couple of decades. Initially it was used for ablating the hard tissues for acid etch treatment. Later Lasers were used for cutting, coagulation & cauterization of the soft tissues. Advancement in the medical use for surgery has helped clinicians to overcome several complications and patients' discomfort. The idea was to be able to treat both soft tissues and hard tissues, including bone, without direct contact, vibrations and pain. Potential hazards can be encountered while using lasers like ocular hazards, tissue injury, inhaling the vapour emitted by the laser procedure, fire and explosion hazards etc. Laser fluorescence is an effective method for detecting and quantifying incipient occlusal and cervical carious lesions.

Key Words: Laser, Dentistry, Pulsed, Diode, Soft tissue

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INTRODUCTION

In 1960, the first laser was established into the fields of medicine and dentistry. Then, this science has proceeded quickly. Due to many advantages, lasers are essential for an extensive variety of procedures.[1]

In 1917, lasers have come down a long way, when Albert Einstein reported the theory of stimulated emission. In 1960, Theodore Maiman was indicated Laser function making use of a Ruby laser. In 1964, Stern and Sognnaes were used the Ruby laser to vaporize enamel and dentin in dentistry.[2]

Laser is a type of electromagnetic wave generator. The emitted laser has three elements.

1. Monochromatic
2. Coherent
3. Collimated[3] The fundamental research introducing the first uses of laser in medicine in the field of biology is the major applications in this field. Low-energy lasers are used in biology enabling high-finesse studies in spectroscopy, measuring the speed of movement of bacteria, determining the vitality and speed of movement of spermatozoa.[4] The main feature is wavelength, which refer to the position of the laser in the electromagnetic spectrum.[5] The safe use of laser is important examined in the laser therapy. With the availability, utilization and future development of different laser wavelengths and methods of pulsing, much interest is developing in this growing field.[6] In hard tissues, the laser stimulate diagnosis of caries and enhance the resistance of dental enamel to caries, laser etching of enamel, cavity preparations, photo polymerization of composite resin and sterilization of the root canal system.[7] The risks for hard tissue treatment could be reduced and the quality of prepared dentine cavities or cuts in bone increased by placing observations on pulse durations, pulse energies and intensity distributions within the beam.[8]

The mechanism of laser therapy allows us to distinguish the primary and secondary mechanisms. The primary mechanisms associate with the interaction between photons and molecules in the tissue, while the secondary mechanisms associate with the effect of the chemical changes produced by primary effects.[9] A pulsed Erbium laser, the Er:YSGG laser was preferred for treatment of dental hard tissue in the recent years. Only few investigations about the application of this laser in dental treatment are printed.[10]

Children and adolescents are the best candidates for laser use because they are commonly concerned by pain, bleeding, incapacitation and office visits for extensive postoperative care.[12]

Modern paediatric dentistry takes advantage of new approach to enhance the standard of care of children and adolescents. The use of laser in medicine that enhance the standard treatment in many fields such as ophthalmology and dermatology for routine procedure.[13]

Today lasers technology has changing our life in many ways and improvement in the field of medicine and dentistry are playing a main role in patient care and wellbeing.[14]

Soft tissue NIR lasers are identified by a high absorption in chromophores found in soft tissue, e.g. haemoglobin, occurring in excellent soft tissue incision, ablation and coagulation performance as well as antimicrobial effectiveness, due to deep highly localized tissue heating.[17] In Australia, lasers have been used in dental practice since 1990, and the currently systems constitute a high state of technical refinement in terms of both performance and user features.[18] Dentists and patients should recognize that laser-induced tissue trauma to the surgical site can add some days to the healing process.[21]

HISTORICAL DEVELOPMENT

In dentistry, the first experiment with lasers was described in a study about the effects of a pulsed Ruby laser on human caries (Goldman *et al*, 1964). The results of that study indicated that the effects varied from small 2-mm deep holes to complete disappear of the carious tissue, with some whitening of the surrounding rim of enamel, appearing extensive destruction of carious areas along with crater formation and melting of dentine. Initially researchers found that CO2 lasers created cracking and disruption of enamel rods, incineration of dentinal tubule contents, and excessive loss of tooth structure, carbonisation and fissuring and increased mineralization caused by the removal of organic contents.[1]

Especially in paediatric dentistry, lasers are very safe differentiated with rotating instruments, when used in the treatment of very young children due to the lowered risk of accidental damage to soft tissues and pulp tissue. It is mainly to observe the rules of safety such as the use of specific protective glasses according to the wavelength used, as well as choosing the appropriate size glasses for the face of the child.[11]

For the first time treated a vital tooth to laser energy by Goldman *et al*., the paint has capable no pain and superficial damage to the crown in 1965. In 1964, the Nd:YAG laser was developed by Bell Telephone Laboratories. The current immediate development of lasers, with different wavelengths and may continue to have major impact on the scope and practice of dentistry.[14]

LASER FUNDAMENTALS

The word *laser* is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Light is a form of energy that travels in a wave and exists as a particle. This particle is called a photon. Photons are the smallest units of energy and considered having zero mass or charge.

Amplification by stimulated emission of radiation is a process that occurs inside the device, and was proposed by Albert Einstein in 1916.The chemical elements, molecules, or compounds in the core of the laser contain the active medium, which is a solid, liquid, gas, or semiconductor in dental lasers.[16]

LASER BASICS

Dental lasers are named determined by the active medium that is aroused. The active medium can be a gas (e.g. argon, carbon dioxide), a liquid (dyes) or a solid state crystal rod e.g. Neodymium yttrium aluminium garnet (Nd:YAG), Erbium yttrium aluminium garnet (Er: YAG) or a semiconductor (diode lasers).These highly directional and monochromatic laser lights can be provided on to target tissue as a continuous wave, Gated-pulse mode or free running pulse mode.

LASER DEVICE COMPONENTS

All laser devices have the following chief constituent;

1) A laser medium can be a solid, liquid or gas. This lasing medium decides thewavelength of emitted light from the laser and the laser is named after the lasing medium. E.g.CO2 laser.

2) An optical cavity or laser tube having two mirrors, one fully reflective and the other partially transmissive which are located at either end of the optical cavity.

3) An external mechanical, chemical or optical and power source which excites or 'pumps' the atoms in the laser medium to higher energy levels.

LASER DELIVERY

In clinical practice, a laser must be able to effectively deliver laser energy to the target site. Early delivery systems use in the oral cavity was enormous. Today fibre optic delivery systems are the system of lasers as they can deliver laser energy to most parts of the oral cavity and within the complex root canal system.[2]Theexisting range of laser delivery systems involves:

1. Articulated arms
2. Hollow waveguides
3. Fibre optics

MECHANISM OF LASER ACTION

The concept of mechanism of action of laser energy on tissue is photo thermal, other mechanisms may be peripheral to this process [Rapid heating of water molecules within enamel causes rapid vaporization of the water and build up of steam which causes an expansion that ultimately over comes the crystal strength of the dental structures, and the material breaks by exploding, this process is called ablation]. For a laser, the energy must be occupied for biological effect. The degree of absorption in tissue will alter as a function of the wavelength and optical characteristics of the target tissue.[2] The following are the possible mechanisms of laser action:

1. Photo-thermal ablation: This occurs with high powered lasers, when used to vaporization or coagulate tissue through absorption in a major tissue component
2. Photo-mechanical ablation: Disruption of tissue due to a range of phenomena, including such a Shock wave formation, Cavitations etc.
3. Photo-chemical effects (Using light sensitive substances to treat conditions suchas cancer).[14]

CLASSIFICATION

Lasers are arranged into various groups: class I (inherently safe); class II and IIIa (where the eye is protected by the blink reflex); class IIIb (where direct viewing is hazardous); and class IV (where the laser power is above 0.5 Watts, and the laser is classed as extremely hazardous). Most dental and medical lasers are class IV, and safety standards is required to secure the dentist, patient and support staff.[2]

CLASSIFICATION OF LASERS: Lasers can be arranged according its spectrum of light, material used, and hardness etc. Lasers are also arranged as soft lasers and hard lasers.

Soft lasers are of cold (athermic) energy released as wavelengths and encourage cellular activity. Clinical application involves healing of localized osteitis, healing of apthous ulcers, reduction of pain, and treatment of gingivitis. The current soft lasers in clinical use are the:

- Helium-neon (He-N) at 632.8 nm (red, visible).
- Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible).

Hard lasers (surgical) can cut both soft and hard tissues. Newer variety can transfer their energy via a flexible fibre optic cable. More usual type clinically used, under this category the medical lasers are:

- Argon lasers (Ar) at 488 to 514 nm
- Carbon-dioxide lasers (CO2) at 10.6 micro-meter
- Neodymium-doped yttrium aluminium garnet (Nd:YAG) at 1.064 micrometer.
- Holmiumyttrium-aluminium-garnet (Ho:YAG) at 2.1 micro-meter.
- Erbium,chromiummyttrium-slenium-gallium-garnet (Er, Cr:YSGG) at 2.78 micro-meter.
- Neodymiummyttrium-aluminum-perovskite (Nd:YAP) at 1,340 nm.[3]

USES OF LASERS IN DENTISTRY

The development in laser technology has been organized into various fields of dentistry. Some of the present applications of laser in dentistry are,

A. Diagnosis

a) Detection of pulp vitality
1. Doppler flowmetry
2. Low level laser therapy (LLLT)
b) Laser fluorescence - detection of caries, bacteria and dysplastic changes in the diagnosis of cancer

B. Hard tissue applications

a) Caries removal & cavity preparation
b) Recontouring of bone (Crown lengthening)
c) Endodontics Root canal preparation, sterilization and apicoectomy.
d) Laser etching
e) Root canal preparation for retrofill amalgam or composite

C. Soft tissue applications

a) Laser assisted soft tissue curettage and periapical surgery
b) Bacterial decontamination
c) Gingivectomy and gingivoplasty
d) Aesthetic contouring, frenectomy
e) Gingival retraction for impressions
f) Implant exposure
g) Biopsy incision and excision
h) Treatment of aphthous ulcers
i) Haemostasis
j) Tissue fusion - replacing sutures
k) Laser assisted flap surgery
l) Removal of granulation tissue
m) Pulp capping, pulpotomy and pulpectomy
n) Operculectomy and vestibuloplasty
o) Incisions and draining of abscesses
p) Removal of hyperplastic tissues and fibroma

D. Laser induced analgesia

E. Laser activation

a) Bleaching agents
b) Restorations (composite resins)

F. Others

a) Removal of root canal filling material and fractured instrument.

b) Softening of gutta percha.
c) Removal of moisture/ drying of canal

IN SURGERY

- Lasers obtain good haemostasis with the decreased need for sutures and surgical packing in case of soft tissue procedures.
- The healing tissue mix well with surrounding structures when the laser incision is more broad and irregular than that of a scalpel.
- There is significantly enhanced visualization of the surgical field when good control of bleeding.
- Early post-operative discomfort and swelling are decreased because of the sealing of nerves and lymphatics.

LIMITATIONS OF LASER

- Erbium family of Laser is inadequate to eliminate gold and vitreous porcelain and only interaction with amalgam.
- The laser is not as fast as a rotary bur for enamel removal.
- All units operate at line voltage and the Erbium lasers need an additional air supply.
- Unsafe to human eye sight[2]

DIAGNOSTIC APPLICATIONS

Laser fluorescence (**LF**) can be used as an integrated with standard methods for detection of occlusal caries. The portable diode laser-based system explain the emitted fluorescence on the occlusal surface agree with the extent of demineralization in the tooth.[19]

SOFT TISSUE APPLICATIONS

By Goldman et al. reports of lasers in oral and maxilofacial surgery in 1968.They described the use of the CO2 laser in preliminary investigative surgery. There was discussion of early investigators about injury to the underlying bone around teeth. Clayman et al. at the obstruction caused by the CO2 laser to assess the effect of this laser on bone in both the short and long term.

HARD TISSUES APPLICATIONS

It is the most evident applications of lasers are for elimination of dental enamel, dentin, bone, or cementum. Researchers has obtained significant observation by using lasers to ablate hard dental tissue for bonding pre-treatment, dental decay removal, and tooth preparation. This goal can be attained only after more information is accessible on tissue/laser interactions and technology.[4]

Laser effects of enamel: Initially, when lasers were first assessed in dentistry, it was thought for the drilling and cutting of enamel. The problems of preventive dentistry to create enamel surface alteration that may increase resistance to dental caries without pulp alterations by the effect of low laser energy densities. It processed tissue changes due to high energy pulses placed at an incident surface modify enamel solubility and resistance to subsurface demineralization.

Effects of laser on dentine: The specificity of this tissue is stated by the dentinal tubules that interface with pulpal surface, cementum, and enamel. The process of dehydration of dentin will modify not only the hard tissue but also the first layer of odontoblasts. As an effect of thermal stresses during laser, dentin evolves multiple micro cracks and severe carbonization. Dentine contains of 70% inorganic mineral substance and 30% organic substance and water.

Laser application in restorative dentistry: The enamel and dentin contain water; laser energy occupied by water would cause volumetric expansion resulting in ablation suggested by Wolbarst. The ablation mechanism is decided by a localized plasma formation, it is called “plasma-mediated” or “plasma-induced” ablation.[12]

ENDODONTICS

In endodontics, the use of lasers for elimination of germs in the root channel, especially in the lateral dentinal tubules (necrotic, gangrenous pulp in the corona and root). This involves a wavelength that appears high transmission through hydroxyapatite and water. Nd:YAG lasers indicate the best results in transmission and germ reduction measurements.

LASER-ASSISTED PERIODONTICS

In periodontics, there is differentiated between the closed curettage, with a probe depth of 5mm to 6mm, and the open curettage, with probe depths over 6mm.Lasers can be used for germ reduction after having fulfilled pre-treatment and concernment eliminate using conventional methods in cases where periodontal disease is present and it is favoured to perform a closed curettage. Pulsed Nd:YAG lasers attain both requirements and they eliminate germs that have collected on the hard tissue surface because Nd:YAG lasers interact with pigmented surfaces, decrease germs in periodontal pockets.

IMPLANTOLOGY

There are various wavelength options to exhibit implants. The first wavelength ever used to exhibit implants was the 10.6μm CO2-laser, while the tissue surface carbonization was drawback. As an alternative the 810nm and 980nm diode lasers can be used, while the thermally disrupt areas are larger than with CO2-lasers.

PERI-IMPLANTITIS

The treatment of peri-implantitis is similar to closed or open curettages in periodontics. Both Nd:YAG and diode lasers have their approach area in this field. Most studies on the treatment of peri-implantitis are found on 810nm diode lasers. The best procedure to treat a large peri-implantitis obstruct is exhibiting the implant that has been affected by inflammation.[5]

LASER HAZARD CLASSIFICATION

A risk is something with the potential to cause injury. There are a number of risks related with laser use in a clinical environment, the most used the laser light itself. There are several international laser standards and classifications. The Centre for Devices and Radiological Health (CDRH) of Food and Drug Administration (FDA) of USA sets forth the standards governing the manufacture of lasers in the Code of Federal Regulations (CFR). Another classification is set by the 'The International Electro technical Commission' (IEC), a global organization that produces and issues international standards for all electrical, electronic and related technologies.

1. Ocular Hazards

The eye abrasion occurs either by direct emission from laser or from the reflection from mirror likes surfaces. Dental instruments have ability to create reflections that may result in tissue injury to both the operator and the patient.

2. Tissue Damage

Thermal interaction of radiant energy with tissue proteins can result laser influence injury to the skin and other non target tissue (oral tissue).Temperature elevations of 21ºC above normal body temperature (37ºC) can create cell destruction by denaturation of cellular enzymes and structural proteins, which interrupt basic metabolic processes.

3. Respiratory/Environmental Hazards

It includes the potential inhalation of air borne biohazard: materials maybe delivered as a result of surgical application of lasers. These secondary hazards belong to a group of 'potential laser hazards' (also called as 'non beam hazards').

4. Combustion Hazards

Laser may cause other problem in the presence of flammable materials. The dental surgical setting can be easily erupted if exposed to the laser beam which is used by flammable solids, liquids and gases.

5. Electrical Hazards

Most laser systems include high potential, high current electrical supplies. The most serious accidents with lasers have been electrocutions. There are various associated hazards that may be potentially harmful.

Electrical hazards are grouped as:

- Shock hazards
- Fire hazards or explosion hazards

LASER HAZARD CONTROL MEASURES

According to OSHA guidelines and ANSI standards, for the safe use of lasers in dentistry, control measures are required to decrease the possibility of unwanted exposure of patient and personnel to laser radiation. Four categories of control measures are:

1. Engineering Controls: Engineering controls are planned and built into the laser equipment to give safety. Engineering controls involves enclosures, interlocks and beam stops are very constructive at removing hazards.

2. Personal protective equipment: All people within the dental treatment room must wear adequate eye protection, including the patient. When selecting the protective eyewear, various factors should be assessed.

3. Administrative and procedural controls: If general anaesthesia is managed during dental procedure, in place of the standard P.V.C intubation tube, a red rubber or silastic tube should be used.

4. Environmental controls: Analysis of environmental hazards includes an assessment of three primary aspects of the laser treatment area that should be assessed to initiate control measures for the particular approach.

ROLE OF LASER SAFETY OFFICER (LSO)

The Laser Safety Officer (LSO) is an individual selected to be responsible for a laser or system of lasers for the arrangement and implementation of a safety plan involving standard operating procedures for the safe operation of lasers. The LSO has power and control to observe and implement the control of laser hazards and to affect the knowledgeable estimation.[6]

LASER ADVANTAGES IN PAEDIATRIC DENTISTRY

Lasers and analgesia

Laser cavity design: micro-macro morphological aspects

Pulp Temperature

Erbium laser soft tissue use

Erbium laser conservative therapy of the pulp

CRITICAL EVALUATION OF DISADVANTAGES

Education, cost and investment return

Laser and Adhesive dentistry[11]

LASER – TISSUE INTERACTIONS

The photothermal conversion of energy enables soft tissue incisions and excisions to be capable with showing precision and haemostasis. Photo-activated disinfection (PAD) is an example of a photochemical effect, known in medicine as photodynamic theory.[15] Laser light is used to outcome managed and definite changes in target tissue through the transfer of electromagnetic energy in clinical dentistry. Light energy interacts with a target medium in one of four ways:

Transmission
Laser beam appears distally and invade the medium without interacting with the medium. The beam exits either unchanged or partially refracted.

Reflection
When the density of the medium or angle of incidence are less than the refractive angle then total reflection of the beam will appear. If the medium interface is non-homogenous or rough then the incident and emergence angles of the laser beam will be the same for true reflection or some scatter may appear.

Scatter
There is interaction between the laser beam and the medium. This interaction is not thorough adequate to cause proper attenuation of the beam. Result of light scattering reduces the laser energy with distance, together with a deformation in the beam.

Absorption
The incident energy of the laser beam is attenuated by the medium and converted into another form. The conversion of laser energy is into heat or, in the case of very low energy values, biomodulation of receptor tissue sites occur by the use of dental diode lasers.

FACTORS ASSOCIATED WITH ABSORPTION AND THERMAL RELAXATION

Some of the more important factors that alter the thermal relaxation of the target tissue and absorption of laser light by the target tissue are:

LASER WAVELENGTH AND TISSUE COMPOSITION

Parts of the tissue that absorb laser light energy are termed chromophores. Oral tissues contain various chromophores: hemoglobin, melanin and other pigmented proteins, (carbonated) hydroxyapatite and water. The absorption coefficients for the listed chromophores with regard to the wavelengths used in dental lasers. Basically, pigmented tissues will better absorb visible or NIR wavelengths, whereas non-pigmented tissues absorb longer wavelengths.

BEAM DIAMETER AND BEAM MOVEMENT

As laser light exits the optic fibre, divergence of the beam will occur. Therefore, the spot size of the beam (relative to the target tissue) will decide the amount of laser energy being distributed over an area. The spot size will increase with increasing distance (optic fibre – target tissue).

COOLANTS

Coolants can check the temperature rise of target and associated tissues. Coolants can be either endogenous (e.g. blood flow) or exogenous (e.g. air, water, pre-cooling of tissue).[17]

DIAGNOSTIC LASER APPLICATIONS

Low power laser energy has found several uses in diagnosis, both in clinical settings and in dental research. Low power lasers operate typically at powers of 100 milliwatts or less, and may produce energy in the visible spectrum (400-700nm wavelength), or in the ultraviolet (200-400nm), or near infrared regions (700-1500nm). There are few reason built low power lasers for the middle infrared (1500-4000nm) or far infrared regions (4000-15000nm).

PHOTOACTIVATED DYE DISINFECTION USING LASERS

Low power laser energy is not toxic to bacteria, but is useful for photochemical activation of oxygen-releasing dyes. Singlet oxygen liberated from the dyes causes membrane and DNA harm to micro-organisms. The photoactivated dye (PAD) technique can be managed with a range of visible red and near infrared lasers, and systems using low power (100 milliwatt) visible red semiconductor diode lasers and tolonium chloride (toluidine blue) dye are now available.[21]

PHOTODYNAMIC THERAPY

The advantage of PDT for early carcinomas in the oral cavity is capable to preserve normal tissues while effectively treating cancers up to 1 cm in depth. Clinical studies have indicated that PDT is a successful method for the treatment of dysplastic, microinvasive, and early forms of cancer.[20]
A more powerful laser-initiated photochemical reaction is photodynamic therapy (PDT), which has been engaged in the treatment of malignancies of the oral mucosa, especially multi-focal squamous cell carcinoma. These directly injury cells and the associated blood vascular network, stimulating both necrosis and apoptosis.

OTHER PHOTOCHEMICAL LASER EFFECTS

The argon laser creates high intensity visible bluelight (488nm) which is able to beginphotopolymerization of light-cured dental restorative materials which use camphoroquinone as the photoinitiator.

LASER WAVELENGTHS USED IN DENTISTRY

Argon lasers: Argon is laser with an active medium of argon gas that is excited by a high-current electrical discharge. It is fibre optically distributed in continuous wave and gated pulsed modes and only surgical laser device whose light is scattered in the visible spectrum.

Diode lasers: Diode is a solid active medium laser produced from semiconductor crystals using some combination of aluminium or indium, gallium, and arsenic. The available wavelengths for dental use range from about 800 nm for the active medium containing aluminium to 980 nm for the active medium composed of indium.

Nd-YAG lasers: It can be used to fulfill a number of soft-tissue applications, involving the following: gingival troughing; esthetic contouring of gingiva; treatment of oral ulcers. During soft-tissue procedures, the Nd:YAG laser provide good hemostasis which promotes a clear operating field.

CO_2 laser: It is a gas active medium laser that integrates a sealed tube containing a gaseous mixture with CO2 molecules pumped via electrical discharge current. The light energy, whose wavelength is 10,600 nm. It can easily pierce and coagulate soft tissue providing the dentist a clear operating field and it has a shallow depth of perforation into tissue.[21]

LASER APPLICATIONS IN THE DENTAL LABORATORY

Laser holographic imaging is a common method for keeping topographic information, such as crown preparations, occlusal tables, and facial forms. The use of two laser beams enable more complex surface characteristic to be mapped using interferometry, while conventional diffraction gratings and interference patterns are used to create holograms and contour profiles.[18]

CLINICAL LASER APPLICATIONS

Conventional dentistry includes using rigid metal or diamond instruments to drill, cut, or corrode hard and soft tissues. Traditional dental treatment is allowing as the process of eliminating infected or pathologic tissue by either drilling or cutting. Dental lasers can be used to cut, incise, and ablate hard and soft tissues. The basic properties of laser light—such as selective absorption, coagulation, sterilization, and stimulatory effects on vital structures.[20]

CONCLUSION

The Er: YAG laser has been found to have approach in areas such as cavity preparation, removal of caries and restorations, and etching of enamel. It has decreased the treatment time and accelerated healing, when sharp instruments are used and it relieves patient from pain of needle prick or pain from trauma. In the future, with the exposure of laser, patients will enjoy a better oral health. Currently, CO_2 lasers have been used in dentistry for soft tissue procedures. Clinical research involving randomized trials are required to impart parameter settings, delivery mode, and other guidelines for hard tissue procedures. When considering the versatility of the system, research has shown that the 810 nm is the premier wavelength used in dental diode laser systems. It can be used for a variety of methods which are carried out in a modern dental practice, involving a multitude of soft tissue procedures, such as soft tissue surgery, periodontal therapy as well as efficient tool for use in implantology, endodontics and tooth whitening.

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