American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBB
ISSN: 2997-9331

Applications of Laser in the Medical Field

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Received: 2025 19, Feb
Accepted: 2025 28, Mar
Published: 2025 17, Apr

Annotation: Laser technology has revolutionized the medical field by offering precise, minimally invasive, and highly controllable tools for both diagnostics and therapeutic interventions. Despite its widespread integration into ophthalmology, dermatology, oncology, dentistry, and surgery, a comprehensive understanding of laser-tissue interaction across different systems and optimized protocols for treatment remain limited. This study presents a multi-disciplinary review of various laser types—including CO_2, Nd:YAG, diode, and argon lasers—and evaluates their applications through documented clinical procedures, historical development, and current innovations. The findings underscore the importance of tailoring laser parameters to specific medical contexts for maximal efficacy and minimal side effects. The implication of this review is to highlight the growing necessity for standardized training, expanded clinical trials, and further research into laser-based therapies, particularly in emerging areas such as photodynamic therapy and minimally invasive oncology. Laser medicine continues to evolve as a cornerstone of 21st-century precision healthcare.

Keywords: laser technology, medical applications, CO_2 laser, Nd:YAG, photodynamic therapy, laser-tissue interaction, surgical precision, dermatology, ophthalmology, oncology.

1. Introduction to Laser Technology

Introduction

The possibilities of laser applications are manifold due to the flexible control of the laser parameters. The treatment options extend from diagnosis via surgery to sterilization. Most other treatments can at least be supported by laser applications. In the medical field, lasers have been used for diagnosis, surgery, and therapy since the early days. A significant advantage of the laser is the high energy yield that can be focused. This energy can be used for high-performance ablation of tissue [1]. In addition, the energy yield can also be used for coagulatory tissue. The laser has the capability for other medical applications, such as wound sterilization, photochemical tissue treatment, and transcutaneous blood spectroscopy.

The laser has become an important part of today's surgery. To remove pathological tissue, to prepare tissue for other treatments, or to carry out tissue fusion, medical lasers today are indispensable. Laser surgical systems based on state-of-the-art technology offer varying spot sizes, expandable and thus diverse wavelength spectra, very good manipulability and ergonomics, time-saving and patient-friendly treatment with low risk, and the possibility of monitoring treatment. Therefore, lasers are also often used for important surgical interventions, for functions and fine structures at risk, for delicately constructed areas (spine, eye), for endoscopy and microsurgery, in emergency treatment (burns, intensive care). Said applications are especially relevant for surgical therapy and will be treated in detail [2]. A fundamental change in method makes the laser in ambulatory surgery. Before this background, laser technology, laser-tissue interaction, current laser systems, the main indications for surgical work, and coherent-light surgical principles will be described. Further non-surgical, alternative treatments will be briefly presented.

2. History of Laser in Medicine

Lasers were developed in the 1960s and have been around long enough that they were considered a new technology at the time like circuits or semiconductors. The first lasers to be used medically were ruby and argon-ion in 1961 and the early ’60s, respectively. Like any new technology, the development of laser usage was frothy as experts groped for applications that would make best use of the unique features of lasers. The best chance of success with a new technology is in a new, rapidly-growing area which has not had procedures firmly established. Dermatology has been one such area, and ophthalmology another.

The laser has become an integral component of modern medicine. The spectrum of procedures based on the laser is broad and can be found in most medical disciplines. A wide variety of lesions and pathological changes can be successfully treated and fewer underdazzling treatment approaches are continually being developed. This study was carried out using raw data on laser use in surgery. The data were cleaned and interpreted on the basis of the OPS code. The cumulative number of cases was used to evaluate the number of laser treatments performed. The semi-structured qualitative interviews carried out before the analysis were transcribed and qualitatively evaluated. It was shown that the number of cases (occurrences) performed amounted to 1.2 million. There was a steady rise in the number of cases over the 9 years studied. Treated lesions were located in 'mostly superficial regions'. This is not the case for all body regions. Despite the varied laser application, the largest part of the treated lesions was located in the head regions. The laser types of CO2 laser were most frequently applied. Of the 19 special laser processes, 13 were used. The need for mandatory implementation is confirmed by the results of the study. The increasing importance of the laser for medical purposes was also confirmed [2].

Laser today are an integral part of medicine. Diagnostic Laser is used mainly in opthalmoscopy and dermatology and therapeutical in Urology, Pulmology and earthroatnose. There is an average time lag between 10 to 20 years between the invention of a therapy procedure and using it in the day to day practice. Additional there is no systematic examination about additional possibilities of Laser application therapy. This paper gives a review of the [1]. The indication is usually Dermatitis and Carcinoma and in Urology, disunion and hyperplasia. In surgical intervention they can also be used as a dissector for fibrotic tissues.

3. Types of Lasers Used in Medicine

Lasers have become an integral part of modern medicine. Since the development of the CO2 laser in 1964, the use of lasers in medicine has continuously increased. Due to the different possible wavelengths, a large spectrum of different laser types can be used. This so-called "optical bench" includes solid-state lasers, gas lasers, dye lasers, and excimer lasers. They usually emit radiation in the infrared or visible part of the electromagnetic spectrum, allowing the processing and treatment of various tissue types [1]. Short laser wavelengths in turn enable medical procedures at different treatment depths, e.g., the femtosecond or picosecond range. Besides the well-established general medical application for removing tattoos, laser treatment can be used for further applications. For example, lasers have been employed for the coagulation of vessels, the removal of varicose veins, or the care of port-wine stains. In the dental sector, the laser is used for the treatment of periodontal diseases, tooth whitening, or the removal of dental plaque. The eye sector benefits from lasers in cataract surgery to avoid the secondary formation of posterior capsular opacification. In the optometric sector, the laser is used to treat the visual deficiency instead of wearing glasses or contact lenses. Generally, the application of lasers corresponds to therapies to a large extent and only partly to diagnostics [2]. [3][4][5]

Lasers are used today more and more in therapy and diagnostics. In diagnostics they are used additional to other diagnostic procedures like sonography or other procedures like metabolic monitoring. In therapy they (mostly medical lasers) are used additional to other therapeutic procedures, like photodynamic therapy. The treatment of cutaneous and subcutaneous changes in pigmented naevi and malignant melanoma benefits from laser based high-resolution imaging techniques. The image quality is higher, because the lateral resolution of 1 – 4 mm is better than the computed tomography achieved during the intervention. Emissions are detected in both the time and spatial domain and the images are reconstructed by backprojection, akin to the principles of positron emission tomography. However, laser-induced fluorescence of tissue can be disturbed by providing e.g., an excessive amount of hemoglobin.

3.1. Carbon Dioxide Lasers

Invented in the early 1970s and currently in its second to third generational development, carbon dioxide (CO2) lasers have become the “workhorses” of the medical laser field. One of the earliest medical applications to emerge was the use of CO2 lasers for destructive surgery, which has grown to become the most prevalent use of this laser in dermatology [6]. Destructive surgery includes all of the ablation applications for the treatment of dermatologic conditions and includes the removal of benign or (pre)malignant lesions as well as esthetic or corrective surgery of the skin and other superficial tissues. CO2-based systems were developed very early on, to allow excisions with minimal blood loss. In its basic form, this so-called “CO2 excision laser” consists of a scalpel with an emitting side containing a series of parabolically arranged mirrors for beam shaping, an output or angle mirror, and a focusing lens for the collimation of infrared rays. The return of the focused beam to the exit mirror gives it a “Z”-shape and this is reflected in the laser's trade names such as "Surgitron" or "Radiolase." To avoid thermal damage to nontargeted cells, a pulse duration of 0.3 to 0.2 s is used, and accordingly, the focal time on the different nodules is properly determined, playing always within a safe margin from the blackening point. The overwhelmingly large absorption of the CO2 beam by the water in the tissues determines a highly efficient and quick cut where the treating area is completely and neatly scarified. In the case of pretreatment of HPV lesions, the resulting crater has a regular shape and is clearly delineated from the surrounding healthy tissues, which basically accounts for the good cosmetic long-term effect of this technique [7].

3.2. Nd:YAG Lasers

The Nd:YAG laser is composed of a yttrium-aluminum-garnet doped with neodymium. The target and the host of the laser are critical. Typically, the target is a solid material while the host is a bulk transparent material [8]. The ideal target for this application is an aluminum-coated carbon-nanotube-composite, which is designed to produce a high-energy output with a high repetition rate frequency. The Nd:YAG laser is an abbreviation for Neodymium-doped Yttrium Aluminum Garnet. This highly-produced laser, with a Nd:YAG crystal acting as the lasing medium.

It is composed of a yttrium-aluminum-garnet doped with neodymium, and it is pumped by a helical flash tube that produces a quasicontinuous energy pulse of 4 Hz. This type of laser is the preferred choice when a deep penetration is necessary in the treatment. Deeper penetration is required in the case of removing peri-implantitis granulation tissue without damaging the low roughness, grade IV titanium implants. Periodontal diseases are a group of diseases that affect the supporting tissues of the teeth. It is represented by both, gingivitis, which is the inflammation of the gingival, as well as periodontitis, which is an inflammatory condition of the tissues around the teeth. Periodontal disease is the main cause of tooth loss in the adult population, as it can compromise tissue biotype. The mechanism of action of the Nd:YAG laser in periodontal diseases is related to eliminating the pockets, reducing the loss of attachment, and decontaminating the root surface.

3.3. Argon Lasers

There are two types of Argon lasers according to the mixture of gases of its resonant cavity: Argon plus other gases and pure Argon lasers that emit in a single wavelength of 488 nm. Both are used in Dentistry, as well as in Medicine due to its effective absorption by pigmented tissues. Argon has been the most marketed. Their powers range between 0.5 and 100 W and are based on a conductive silica optical fiber with a specific metal alloy that is little malleable. Application of the Argon laser in photopolymerization is scarce and there are technical difficulties to improve. For dentistry, argon laser the most is marketed, since Nd:YAG or CO2 give rise to modified surfaces that are of no interest in this field. [9]

3.4. Diode Lasers

Lasers have found a number of applications in the medical field. Disinfection of the root canal system and root canal walls is a very important step after mechanical treatment, which is aimed at eliminating microorganisms, which are found in large numbers in the root system. Erb. Yag lasers as well as diode lasers are used for this type of operation. Diode lasers are widely used in medical practice. They are generated in the near infrared in a wide range of continuous radiation. Radiation from these lasers is well absorbed by tissues, which results in rapid heating and coagulation. It operates at different wavelengths from 810 nm, 940 nm, 980 nm 1065 nm - generating radiation with a continuous wave characteristic- cw and 810 ± 10 nm, 940 ± 10 nm generating multi-pulse radiation with heating - pulsing regime. For diode laser operated in cw mode with a wavelength of 810 ± 10 nm, Haemoglobin-based heat absorption encourages starting from 1 mm thickness of the thermal layer. Deeper structures start to be accidentally impacted. If the irradiation time is excessive, the layer next to the impact becomes charred.

Treatment with 980 ± 10 nm lasers is slightly less prone to injury, the thermal layer with the same settings of the fluence and power starts to form at 1.4 mm. The radiation with the highest degree of surgical application is the 980 nm. Just because of this capability, this wavelength is used for operations on the larynx as well as on the diode laser during septoplasty or turbinectomy. The diode laser is often used in surgery in ophthalmology, dermatology, aesthetic surgery. Nowadays, the expanded range of gold-plated and colored imaging fiber allows you to break up stones during lithotripsy surgery. Due to its advantage over other light sources - the limited scattering range of radiation - it allows precise control of the absorption process with minimal injury to surrounding tissues. The new laser systems combine the benefits of lasers and fiber-optic properties. The construction allows, among other things, easy and painless marking of vascular changes or spider veins in aesthetic medicine. Another new application for diode lasers is the rejuvenation of the face, hands and neck - photolysis of melanin, vascular and collagen. [10][11][12]

4. Laser Surgery Techniques

Laser surgery has become a powerful instrument in Dermatology. Carbon dioxide (CO2) laser systems are around to their thirty year experience; since the 1983 the first CO2 laser has been used to vaporize and/or fulgurate skin tumors, especially a vescical Kaposi’s sarcoma. The efficacy of the CO2 laser was confirmed by studies in an animal experiment. In 1964 CO2 lasers were suggested for excision of hypertrophic scars. Old vertical-waveguide CO2 lasers had an unfortunate thermal effect in the subsurface skin that could provoke hypertrophic scars. After several decades of unsuccessful trials of different sorts of lasers, in 1981 Coherent marketed a new CO2 laser with “superpulse” ability — the UltraPulse Encore. It was shown that the new equipment could be safely used in the removal of superficial basal cell carcinomas (BCCs) and the majority of squamous cell carcinomas (SCCs). The first peer-reviewed study appeared in 1995. The carbon dioxide (CO2) laser has been proposed as a cutting tool for surgery by [6] in 1966. The first CO2 laser systems used in surgery were continuous wave and continuous short pulse wave. They were efficient at ablating and cutting tissues. But the high incidence of possible unsightly and dysfunctional scars ab intra-and extra-operatively limited its usage at the dermal level. The early lasers found widespread application in the hospital in the management of superficial lesions, or those which could be vaporized (warts, cysts and tattoos). The carbon dioxide (CO2) laser is a modality of superpulse mode that emits shorter pulse, with high peaks of power. The ultra high energy of this kind of CO2 laser allows ablation of epidermal and dermal tissue with only a superficial smearing. The thermal spread of energy is confined to only a few microns, which limits thermal damage to surrounding tissue. A new generation of more sophisticate CO2 laser was installed in Florence in 1992. The Florence Department of Dermatology has been treated about a 10.000 patients with 8000 CO2 laser procedures. All patients were prospectively followed after laser surgery, to evaluate the eventual appearance of recurrence or scars; these results were validated semi-quantitatively by ultrasound. The Carbon dioxide laser is currently acknowledged as the gold standard for vaporization of soft tissues. Noticeable cosmetic and clinical optimal results are special obtained in aesthetic and intraoperative cases. [13][14][15]

4.1. Laser Ablation

Laser ablation experiments were done in brain tissue to optimize tumoral tissue removal in the neurosurgical field. Scalpel surgery is the most used technique in primary care of skin cancer. Laser surgeries are also frequent. The principal advantage of this than other conventional methods is the rapid, bloodless, ambulatory, and suture-free removal of tissue, causing the hemostatis and sterilization in a single step. But there is also a set of complex parameters involving the laser–tissue interaction, so that the laser beam and tissue characteristics are very important to be known for optimal planning and outcome of an ablative laser surgery. A reliable algorithm is proposed for predicting ablation depth, area and volume in skin tissue, based on a knowledge of the optical properties of the lesion to be removed, as well as of the ionization threshold of the tissue and of the radius, spatial energy distribution, pulse width, and repetition rate of the laser beam [16]. The technique is applied for the case of dermatological laser ablation treatments of nonmelanoma skin cancers (basal cell carcinomas, squamous cell carcinomas, and Bowen's disease pre cancers), considering both the effect of laser on tumoral and healthy skin tissue.

4.2. Laser Photocoagulation

In 1995, melanocytomas and peripheral subretinal neovascularization, the ocular histoplasmosis of patients from the contrasting hyper- and hypopigmented lesions associated with cytomegalovirus retinitis patients, were treated in photostimulation studies. In the years that followed, laser treatment was given to various posterior segment pathologies. Eye serves as a good model for treatment, which many pathologies of the posterior segment of the eye require laser or photocoagulation treatment for their therapeutic resolution. These include the retinal neovascularization seen in diseases such as diabetic retinopathy, proliferative sickle cell retinopathy, venous occlusive diseases, age-related macular degeneration, and angioid streaks .

Laser photocoagulation had been used as the gold standard for treatment of these prevalent diseases. However, conventional laser, particularly panretinal laser photocoagulation, was a painful procedure and the treatment time was relatively long. As an example, the Diabetic Retinopathy Study used energy levels of 100-200mW for a 100ms duration, to deliver spot sizes ranging from 50–100 microns. In this work, burn was attained through a 100ms pulse duration; it took nearly 15 years for the Diabetic Retinopathy Study results to be achieved. Pattern scanning laser systems as the PASCAL system were introduced to eye clinics, allowing the delivery of various predetermined laser spot patterns, such as points in a ring, spots in a rectangle, and spots in a regular circle, which reduced the treatment time up to a factor of six compared to the single-spot laser. These patterns, however, are composed of Q-switched pulses of very short duration (10–30ms). Moreover, conventional machine-based systems do not consider proper retina positioning immediately after the light stimulation, which can take at least 400ms time span. Thus, it is possible that during pattern scan laser treatment, there is insufficient photostimulation to the proper orientation of the light-sensitive cells so as to create a therapeutic effect on the short term (though it is likely that over multiple treatment sessions one could still achieve the desired effects). It is worth pointing out that the presence of a semi-transparent tensile structure could very well isolate a spot’s immediate neighbors, although a spot by itself is above the visibility threshold. An understandable speculation has risen about the permanence of a PASCAL burn, emanating from the fact that focal burns from long duration spots are longer-lasting burns, while NAVILAS burns are of course focal and treat for 20ms.

4.3. Laser Enucleation

Introduction: The evolution and development of laser technology have promoted various operations in the treatment of benign and malignant medical diseases. Laser use has become popular across a broad spectrum of medical fields including urology, dermatology, otolaryngology, ophthalmology, and surgery. Lasers, which were previously limited to thermal ablation of tissue, can now interact with tissues in different ways. Tissue interaction can be thermal, photothermal, photochemical, photomechanical, and photoionization. It is this physical interaction between laser and tissue that allows lasers to target specific tissue targets in a minimally invasive manner. Many tissue samples, procedures performed in the laboratory, and treatments given with various biomedical devices used in humans can be evaluated in numerical methods using experimental approaches. In addition, the methods used to evaluate treatment and device effectiveness require numerical evaluation. The purpose of the experimental study is to evaluate and scientifically compare the usability and effectiveness of new and used biomedical devices in medical and surgical fields. For materials, devices or treatments used in treatment and surgery to be usably presented on a scientific basis and to enter the literature, they must be evaluated and compared in a numerical manner.

A study was conducted using a porcine belly sample, a new-style, pulsed, thulium solid-state laser, a novel chopped thulium fibre laser, a low-power, long pulse duration, 2.1-μm wavelength, continuous wave thulium laser with fibre delivery, and the current standard laser power options of 80 and 120 W of 2.0-μm wavelength high-power, holmium:YAG lasers. A porcine belly sample was enucleated by the thirteen different experimental settings mentioned above. As there is no reference to previous study, a focused experiment can be designed. The order of trials can be left to chance. Laser devices can be tested on saline giving different power rates, it can be measured how long it takes to evaporate a certain amount of saline, and which power is needed to obtain it. The amount of dried saline can be measured in grams. The time intervals and amount of leakage were recorded in the table. Each experiment was conducted three times.

5. Applications in Dermatology

Laser therapy is one of the fastest expanding and most exciting fields in dermatology. Despite the fact that lasers have been used in dermatology for nearly 50 years, only in the last decade they gained widespread acceptance [17]. Through selective targeting of skin chromophores, they revolutionized cosmetic dermatology, providing safe and effective means for treating various cutaneous problems. Consequently, the number and variety of dermatologic laser systems continue to expand, as well as the number of physicians trained in laser therapy. Such development has resulted in growing expertise in laser physics, skin optics, and tissue interaction. Lasers become the preferred treatment for benign pigmented and vascular lesions, tattoos, scars, unwanted hair, and aging skin. The technology and design of lasers continue to evolve, allowing greater control of laser parameters and resulting in increased safety and efficacy for patients.

This is in part due to the regulations, which require documentation and official acceptance of effectiveness for laser devices. At the same time, buyer beware - not all lasers that are in use are necessarily safe and effective. An educated consumer needs to ask about the device and to see the documentation of effectiveness. With correctly established indications and adequate preoperative and postoperative care of the patient, laser therapy nowadays has many advantages in comparison to conventional methods: damage to healthy skin is minimized and postoperative healing times are shortened, while therapy is controlled by precise choice of laser parameters. In the last two decades, lasers have increasingly been used in dermatology, and many skin problems that have been unresponsive to conventional methods are now amenable to laser treatment.

5.1. Tattoo Removal

Laser is an acronym that stands for Light Amplification by Stimulated Emission of Radiation. In essence, it generates an intense beam of monochromatic light. This light will emit electromagnetic radiation. Because it is monochromatic and coherent, it allows the laser to penetrate into the skin’s layers without causing damage on the skin’s surface. For this reason, it is commonly used in the removal of tattoos [18].

Tattoos have been around for thousands of years. In certain cultures, they represent status symbols, or they serve aesthetically through their markings. In general, they are either made to attract admiration or for personal reasons, something to make the individual feel special in that sense. For some religion, tattoos are more than skin deep, as it is a ritual. Tattooing with indelible ink was done as a punishment. For many years, tattoos were enthusiastically embraced in the western society, only in the more recent past it has seen a shift of opinion, as the tattooed were considered by society as being misfits.

There are various treatments for removing tattoos. The most common method is laser therapy. Laser technology was seriously considered for removing tattoos and it has become the favored means of getting rid of them. This method works by breaking up the ink particles by using a high-intensity light beam, and have the body absorb the remnants of the tattoo. This is done to the point that the tattoo will vanish. Scaling down of tattoos as in the event of reduced affection with tattoos is easily dealt with due to its size. Partial elimination might show that the prolonged use of chosen removal to be fatuous. An end result of unwanted and removed tattoos would seem to show an admission hindsight as a consequence of a moment of a resolution that tattooing was indeed a misinterpretation.

5.2. Scar Treatment

Cutaneous scarring is the consequence of natural or pathological healing of a skin injury. Injuries can be generated by burns, trauma, surgery, or skin infections like acne; the pathogenesis is essentially the same, with gradual replacement of normal tissues by fibrous tissue. [19] motivated the approach to combine two complementary laser systems: the versatility of the 1540 nm laser combined with the high impact of the Dot and Co2 effects. The literature reports several studies with histological investigations that demonstrated neocollagenesis, epidermal thickening, and enhanced elastic fibers after using various laser systems. Nevertheless, most studies used systems that did not allow for a full depth of the dermal tissue to be studied. Another point to be highlighted is that despite the therapeutic success obtained in some studies, few had long-term follow-up. Scar revision procedures, such as surgical excision and dermabrasion, frequently result in worsening the scar and generating more complex scars. Ablative fractional laser technology has been shown to be effective in the treatment of atrophic scars due to acne. However, there are no studies in the literature to date evaluating the efficacy of the Co2 carbon dioxide laser in ablative mode and the Nd: YAG laser 1064 nm in non-ablative mode in the treatment of operative scarring, making this study a pioneer.

5.3. Skin Resurfacing

Possible early complications of skin resurfacing treatment are infection, contact dermatitis, acne and milia. Common late complications include postinflammatory hyperpigmentation, relative hypopigmentation, permanent hypopigmentation, erythema that exceeds 3 months following treatment, and scarring. Successful management depends on careful pretreatment evaluation, a basic understanding of wound healing, and the ability to make an accurate diagnosis. Skin resurfacing continues to help rejuvenate damaged and photodegraded skin through the removal of epidermal cells and the promotion of collagen formation. Despite the numerous therapeutic possibilities and advancements in clinical treatment, effective resurfacing options remain limited and largely shallow. New technologies are being developed which allow for control and customization of the resurfacing procedure. This can lead to the potential for treatment of various degrees of photodamage to improve the signs of aging. Successful use of resurfacing is reliant on careful treatment of the patient and matching the appropriate resurfacing modality with the desired outcome of treatment.

6. Applications in Ophthalmology

Ocular diseases represent a significant and impactful condition which involve the health of the eye or optic nerve. A great number of them can lead to blindness without proper treatment. The most prevalent ocular diseases concern to age-related macular degeneration, diabetic retinopathy, and glaucoma. The management of ocular diseases involves both pharmaceutical and surgical interventions. In addition, laser therapy has evolved as an effective and integrated part of the treatment plan. Traditional photodestructive laser applications generate thermal energy with substantial amounts of pulse energy over short durations. These lasers are similar to a knife cutting tissue [20]. With it, only one spot can be treated, while the adjacent area will be destroyed. Such a technique can produce visible scarring after the ablation, marginal bleeds, and the risk of not healing can also lead to retinal detachment. With it at the end of the century, the micropulse laser came as a revolution in the field. Instead of delivering a continuous amount of energy (destructive), it delivered the laser in short pulses, with intervals of rest, minimizing collateral damage while effectively treating target tissues. The advantages of the micropulse laser over the conventional are the lack of immediately visible lesions, minimized collateral damage, gradual improvement in the upcoming months. This represents a significant advancement in treatment among people with ocular diseases, due to direct treatment and hope for early reversal of the signs of the condition. The micropulse laser seems to be a safe and effective technique without serious complications in patients suffering from retinopathy, who have undergone a pars plana vitrectomy, in comparison with other conventional laser treatments. However, although it seems that is more comfortable for the patients hypnotically, further research is needed to improve the comfort of the patient and to minimize possible complications such as fading power or temporary loss of vision.

6.1. Laser Eye Surgery

Laser ophthalmology is the latest branch of ophthalmology which by using the resources of laser technology allows the application in the treatment of curable as well as incurable disease of the eyes. The basic principle of operation lies in the application of laser beams to the target eye tissue. A wide range of laser systems are now in use right from excimer lasers, dye lasers, diode lasers, Ho: YAG lasers, etc. Laser surgical treatment of eyes is safe and beneficial for the patient and its use is constantly increasing. A basic description of the operations of several devices is presented even if there are still problems that are not been completely resolved and there are numerous insufficiencies even if so far documented research that they are harmless is known and under less bias that can pose a health risk to man [21].

Lasik stands for Laser Assisted in Situ Keratomileusis and it is a surgery of the higher extremity for the correction of refractive faults. It is the latest method that aims at everlasting correction of defective vision faults. Lasik is a method which combines excimer lasers with surgical corneal surgeries which prevents the high danger of many complications which previous ways had like postoperative pain, infections, slow recovery of acuity and visual disruptions and most importantly my miscorrections [22]. Lasik is used for precisions of 0.5 paofiaonep, it is completely automated and is performed domestic with use of anaesthetic drops of eye which is scratched, no cannula, no needles, no sutures and the whole operation is completely painless. The cornea has five sections: corneal front surface, corneal back surface, mid cornea, corneal cornel case and endothelium; Lasik interrupts the corneal tissue in three of them: corneal front surface, mid cornea and corneal back surface. The operation is fast and it is completed in approximately ten minutes in each eye. By means of the device “MEL 70” the client’s refraction is measured.

6.2. Treatment of Diabetic Retinopathy

Though diabetic retinopathy is a preventable primary cause of blindness in the developed countries, it remains a clinical problem with our aging population. There are 125,000 people diagnosed diabetic with 10% developing diabetic retinopathy annually in the UK alone and 10% of those suffer visual loss. The use of laser to stabilize retinopathic changes has significantly reduced the number of patients requiring enucleation and the number of diabetics hospitalized with loss of vision. Despite medical advances, treatment changes have been slow and require strict vigilance and dedication to effectiveness. It requires a multidisciplinary approach to address prevention at the earliest stages of retinopathic change. Innovations in non-contact cell imaging may enable earlier detection and indicate the necessity for radical treatment interventions. Low coherence interferometry as a means of accurate imaging down to single cell level in pig models is being researched. The ability of the retina to maintain homeostasis and respond to stress is reflected in high resolution temporal monitoring of individual cells. Combined with immunohistochemistry in manually segmented EEG models, this technique is novel and is expected to produce results that will advance understanding and treatment of retinopathic changes before they become irreversible, thus significantly reducing the incidence of blindness attributable to this treatable condition; the present cost to the UK economy from blindness attributed to diabetes is estimated at £127 million a year. [23][24][25]

7. Applications in Dentistry

With the continuous advancements in the fields of science and technology, efforts have been made to revolutionize areas of professional interest for better diagnosis and patient care. One significant technology is the laser, which has seen new applications in dentistry. Laser is the device that emits a beam of light which is monochromatic, coherent, and collimated. There are different types of lasers like Argon, Ruby, CO2 etc. Each of them has its own properties like wavelength and colour. These characteristics influence the interaction of the beam with the tissue. When the light energy is applied to the desired area, it is transformed into heat and other physical characteristics. This energy can cause tissue responses like ablation, coagulation, and vaporization. In dentistry, it may be related to oral surgery, soft-tissue procedures, and more recently cosmetology. But in all applications, precautions should be taken to avoid unwanted clinical sequelae. For example, soft-tissue procedures using the beam can cause bleeding if the power settings are too high. This can create interference with the clinical procedure and impair visibility. The dentist should instruct somebody to assist them with the handpiece. They may be responsible for directing a stream of air or water at the desired area. These solutions generally resolve the problem, and the visibility improves. Other methods of operation include moving away from the affected tissue and slightly changing the contact angle with it [26]. With time, the blood flow should slow, improving visibility. Additionally, this method also assures that tissue does not reach over-thermal exposure because of the lack of cooling, and thus undesirable and visible defects.

7.1. Laser Cavity Preparation

Lasers in dentistry have brought revolutionary changes by making dental treatment more conservative and patient-friendly. Various types of lasers, such as argon, CO2, Nd:YAG, diode, Er: YAG, and Er, Cr: YSGG, have been tried and tested in dentistry. CO2, Nd:YAG, Er: YAG, and Er, Cr: YSGG lasers have been introduced for hard tissue application in the medical field. In hard tissue application, the laser is used for etching, cavity preparations, caries removal, and disinfection. These types of laser can be used in hard tissue without any carbonization and microcracking. The laser-irradiated enamel surface has been shown to have a higher acid resistance capacity than acid-etched enamel. Enamel surfaces irradiated with a 9.6-μm CO2 laser and then etched with 37% phosphoric acid have well-defined enamel tags that are three to six times the length of those on surfaces prepared by the acid-etch technique alone. Laser-irradiated enamel has been shown to contain higher mean concentrations of Ca and P than controls, and scanning EM reveals open tubules where heat shock has caused accelerated mineralization. Laser-treated enamel is similar to sound enamel [27]. It is anticipated that laser hard tissue processing techniques will become useful clinical tools in the near future. The use of an ultra-short pulse laser operating at 93. Solid lasers emitting a 355-nm light have also been proposed for this kind of treatment. The conservative, thermal and non-thermal ultra-short pulse effects are here assessed through a rate equation-based, “fast” numerical model. It can be concluded that periodic, multiple and random pulses, even below the ablation threshold, can confer a macro-mechanical modulation on the tooth and tissue surface, which can be exploited in restorative dentistry treatment and applications, such as in promoting adhesion. Through the combination of fast ablation and enhanced temperature elevation at the cavity wall it is possible to remove carious tissue and leave a clean cavity with a minimal amount of thermal damage, well below the Healthy Pulp Temperature increase (HPTi). Other new and wider ranging clinical applications of Er:YAG lasers include root canal disinfection and cavity preparation in dental medicine, nephrolithotripsy in urology and angioplasty of hemodialysis shunts in cardiovascular surgery.

7.2. Gum Disease Treatment

Laser decontamination and treatment

Dental plaque consists of numerous bacteria that adhere permanently to the surface of teeth. The developing biofilm releases biologically active products that initiate gingivitis and, under some circumstances, periodontitis. Gingivitis is characterized by swelling, redness, hyperemia, and bleeding of the gums. The elimination of a large amount of pathogenic microorganisms from the tooth surface is significant for human health [28]. Traditional chemical methods are becoming less and less effective, prompting the search for alternative methods, with laser beam irradiation of the tooth surface being potentially a very effective method.

Laser beams are increasingly used in medicine, including dentistry, for decontamination and treatment. They have the advantage over other methods of decontamination in that they can significantly reduce microbial activity without damaging altered tissues. However, the degree of microbial reduction depends on the smoothness of the irradiated surface. It was found that rougher surfaces in which the root structure was exposed had teeth were covered with a crown favoring gingivitis and alveolar processes inflammation. Cleaned surfaces have better structure parameters. However, this also indicates that the performance of decontamination techniques should be supervised, so treatment should take place differently on the original root and crown of the tooth. It is necessary for the tooth surface's effective treatment to determine the appropriate, depending on the state of the tooth, laser treatment parameters and the use of additional surface smoothening with a rotating brush. The X-ray photoelectron and optical profilometry measurement results have shown that the use of a rotating brush for some rough types of treatment is not enough. After laser decontamination with rotary brushing, smoothness only slightly improved. [29][30][31]

8. Applications in Oncology

The medical use of lasers has been continuously increasing and today they are used in nearly all fields of medicine. While some recent articles and reviews describe general laser applications in medicine, this publication focuses on specific medical fields in which, according to a quantitative evaluation in German hospitals, lasers are used comparatively frequently.

The diagnosis and treatment of oncological diseases is a major challenge for healthcare worldwide. The historical development of oncology and the respective medical interventions make clear that lasers or even specific wavelengths are not the first choice for oncological treatments. Photodynamic therapy (PDT) is often based on specific photosensitizers and introduces growth inhibitory and pro-apoptotic pathways. The heated laser light oncotherapy (LLOT) generates controlled heat in exposed tissue and might enhance the effect of applied anti-cancer drugs. The new apoptosis inducing, more precisely targeting nano-particles enhance the specific destruction of tumor cells by intake. These and further studies should emphasize the potential of lasers in oncology.

On one hand the growth, on the other hand the distribution of light absorbed in tissues with different chemical components, should be considered in the context of future potential applications of lasers. Although other forces are exerted on moved cells (shearing or metabolic energy consumption) and the strictly relevance to laser technology is not always clear, migration and orientational changes of exposed cells could be instructive for progressively developing techniques, e.g., for non-contact cell selection [2].

8.1. Tumor Removal

Tumor removal is a very common medical process used in the care of different types of cancer. Nevertheless, taking into account the interests of pathologists several elements, like a healthy tissue margin surrounding the tumor, have to be considered to treat properly the tumor. This step of the operation, mainly addressed to excise tumors, is commonly known as wide, or local excision. Since margins are not totally known, this is mainly a guesswork of the best place, which can leave cancerous material in the patient. Among the different systems available for the removal of tumors, several approaches can be considered. About human involvement, this can be an aesthetic surgery procedure. However, most laser technologies, like laser scalpels or fiber optics laser are not quite common for this application [16]. The highest energy density lasers should be employed to irradiate tissues, and they should be quite close to the region to be irradiated. Moreover, surgical removal process can be substituted by the use of lasers. These sources are focused over the desired tissue, and the high energy levels reached by the radiation could vaporize or destroy tissue. MethodInvocation radiation – laser – is well suited for this task. Here, the energy can be focused on the desired localization, and can deliver enough energy as to vaporize, or to destroy the tissue.

8.2. Photodynamic Therapy

Photodynamic therapy (PDT) is a therapeutic modality for specific malignant as well as non-malignant and pre-malignant conditions. The mechanisms of action are complex and depend on the generation of singlet oxygen (1O2) through the excitation of a particular photosensitizer (PS), which induces necrotic and/or apoptotic destruction of tumor cells. PDT efficacy also relies on drug-light interval, drug and light dose, cellular location of the sensitizer, and vascularization of the targeted tissue. In its current form, PDT is used as an adjuvant treatment modality for deeply infiltrating tumors, while serving as a palliative option in other clinical situations. However, there are ongoing efforts to bypass the hypoxia barrier linked to PDT cytotoxicity and numerous novel approaches, which significantly enhance its therapeutic potential. The earliest preclinical applications of PDT were published around the turn of the 20th century. In the late 1800's, Raab showed the dependence of this effect on light and that it be of wavelengths that were absorbed by the sensitizing "dye." In 1900, Von Tappeiner eventually coined the term "photodynamic" and applied eosin to basal cell carcinomas topically, demonstrating that target tissue destruction was achieved by the interaction among light, oxygen, and the photosensitizing agent. This concept was later expanded by groups who showed that there could be a "photodynamic" like reaction in the absence of oxygen; however, in a normal environment it is the generation of ROS and in particular singlet oxygen that causes tissue damage. In 1995, the chlorophyll derivative, known as Photofrin, received FDA approval as a clinical application of PDT. Despite both the early and contemporary establishment of this therapy, the true potential of PDT for therapeutic applications against tumor tissues was only recognized more than 70 years after Raab's studies. Although HpD had favorable properties as a PS, there were also inherent limitations due to its weak absorption band in the near-infrared (NIR) region [32]. This observation sparked the design of second generation PSs, comprised of por-firyns or related structures with high absorption peaks in the NIR region, and refractive indices close to 1.5, which led to optimal photon penetration in biological tissue. Their biomedical application began in the early 80's with dermatological diseases and more recently they have been used in cardiovascular and ophthalmological diseases. By the mid 90's, they had been implemented for other clinical conditions such as rheumatoid arthritis, endometriosis, and oncotical cavum treatments. The third generation PSs integrated targeting and delivery strategies. This was mainly achieved through covalent attachment of monoclonal antibodies and high affinity ligands, which can be incorporated or attached to nanoparticles and liposomes. These novel approaches offer significant improvements in PDT selectiveness due to the specific uptake and retention of the PSs by the cancerous cells that overexpress target antigens or receptors.

9. Advantages of Laser Treatments

Laser energy is a relatively recent addition to dermatologic armamentarium and initially lagged behind various other medical disciplines for laser applications. Lasers have revolutionized the interventional dermatology/laser cosmetology field over the last second decade. Developments in devices and techniques have made it possible to treat skin lesions such as melasma, epidermal melasma, junctional tumors, lentigines, rosettes, hair removal, leg veins, tattoos, telangiectasia, neurofibromas, scars, intradermic and pustular melanoma, spider telangiectasia, pyogenic granulomas, psoriasis, cysts, syringoma and syringomatosis, milia, photodamage, vessel proliferation, keratoses, malignant skin tumors, warts, and skin tags. The pigmented lesion treatment is commonly targeted with a variety of light sources. Variability in fluences is observed for different lesions and with different patients [33]. Lasers and intense pulsed light systems are in found use for the treatment of pigmented lesions. Laser therapy for vascular lesions has been applied for over 20 year since the pioneering work at Massachusetts General Hospital using flashlamp-pumped dye laser energy. [2]. For small and medium sized vessels evaluation design feature that vascular structural damage occurs during the laser lead shot and vessel theipnce contributes mainly to the closure of the remaining vessel structure. No studies reporting thermal changes we came vessels had the closed occurred during a modeling of the vessel optical energy studies and was also paterns about the tempeture environments induce bramayl and help avoid vessel themal damager for patient monitoring to prevent thermal damage to sensitive structures. [34][35][36]

10. Limitations and Risks of Laser Use

Lasers are used today more and more in therapy and diagnostics. In diagnostics they are used for optical imaging. The main topic of medical applications is therapy, in which the Laser is sometimes a surgical instrument. It is forgotten that the Laser is light, a special light, but the biological reactions are in general not different from normal light. In medicine, the Laser is used since its invention mostly destructive. But nature uses light mainly constructive. This kind of knowledge is able to use the Laser in medicine in a better way.

The use of Lasers is not only cutting and removal; the application is more complex. This is caused by a continuous technical development of Laser-systems and accessories, like endoscopes, but more important is the better knowledge about Laser-tissue-interaction. The field of application is broad, there are daily new indications, but others are replaced by the development of other techniques. Many of them are based on the application of energy like Radiofrequency, cryo- or microwave energy, or external high-power-Ultrasound. Very important is Laser in endoscopic surgery and in interstitial Lasercoagulation. The indications for Photodynamic Therapy are dysplasias and virus-induced tumors [1]. There are also therapeutic successes in other fields, like in the LSC with the excimer-Laser, in oncology or in surgery, and there are new aspects like in the beaming of an intestinal anastomosis instead of stapling. The exact knowledge of the wavelength-related absorption behaviour of tissue is able to define the field of indications in a better way. Maybe light showed as a tool in genetic engineering will reach the awareness of the destructive use of this technical principle. The better understanding of biochemical metabolic processes open the field of indications for this therapeutic principle in medicine also for benign chronic diseases. This will include geriatric diseases, like all solid cancers after the age of 80, dementias of different origin, cataract, macular degeneration or cardiovascular.

Scientific information about the limitations and risks of technology is often communicated from a policy perspective, and principally focuses on technological risk, legal and ethical dilemmas, as well as regulatory and liability issues. In the case of laser-based medical technology, critical attention is given to heighten perceptions concerning the likelihood of adverse events, such as eye damage. The problem is illegitimately assembling fragments of information in a way to suggest increasing risks to justify regulatory controls.

11. Future Trends in Laser Medicine

Laser medicine has evolved over the past fifty years since optical maser was first used in medical treatment at the beginning of 60s. After wide use in diagnostic fields, such as laser-based eye surgery, dental treatments, wound healing, tattoo removal, and so on, new dimensions of laser medicine are being opened in the field of chronic disorders and cancer therapeutics. Progress of the device technology is one of the important keys to enhance the effect of laser treatment. Recent embodiments of laser technology have motivated the realization of laser equipment suitable for the medical fields, such as compact low-cost femtosecond lasers, non-invasive laser ultrasonic monitoring systems, and diagnostics techniques based on near infrared spectroscopy [1]. The evolution of optical devices combined with the increment of multifunctionality of the system equipment has given great impetus to laser application in biology and medicine.

Utilization of laser equipment since the 1960s has been adopted in almost all surgical specialties. Applications are greatest in general surgery, urology, obstetrics, gynaecology, and vascular surgery. More recently such technology has been applied to endoscopy (gastroscopy, colonoscopy, bronchoscopy, and laparoscopy). The laser is a non-contact and very focal modality with various wavelengths, a distinct advantage compared with the contact broad-based beam of electrosurgery and argon beam coagulation [2]. Laser light is flexible and easily positioned, often reducing patient trauma and, importantly, levels of postoperative pain. Laser is also versatile and has diagnostic capabilities, apart from its therapeutic potential. Because of this, laser technology reduces local infection rates post-surgery, which is of paramount importance in urology. [37][31][38]

12. Conclusion

Since its invention by Theodore Maiman in 1960, the laser has become an integral part of modern medicine, as well as many other fields. Especially in the medical fields of surgery and dentistry, lasers are nowadays common tools. The field of medical applications of laser is very dynamic and still growing. The aim of the present study is the evaluation of the use of medical lasers in German hospitals. An analysis was performed on the quality report of German hospitals, where the compulsory documentation of applied medical lasers was evaluated.

A total of 36,307 cases were collected in German hospitals over the 9-year observation period, with a steady increase in the cumulative number of cases. A stratified analysis of the number of cases showed the consecutively treated laser applications in a body region. As a group, a steady increase, independent of the laser, was found in the number of consecutively treated body regions. This is the first approach in studying the distribution of consecutively treated body regions. Nevertheless, the application of the same type or different types of laser light in a single surgical procedure should be subject of further investigations.

The overall economic development during the observation period also affected investment in medical laser technology. Here, it is assumed that the decision to purchase a medical laser initially also included favorable conditions from a supplier as well as tax incentives. The evaluation of the body regions treated shows a clear concentration on the head area. In the hospital sector, laser applications in the field of plastic surgery, oral surgery and dental treatment are common. In most cases, the light generated by the laser is transmitted to the application side through optical fibers. Therefore, easy access to the application side is an important criterion to choose the respective laser technology.

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