LASER TECHNIQUES FOR ADVANCED MEDICAL RESEARCH

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ABSTRACT

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The word laser is an anacronym that originated as an acronym for light amplification by stimulated emission of radiation.[1] The first laser was built in 1960 by Theodore Maiman at Hughes Research Laboratories, based on theoretical work by Charles H. Townes and Arthur Leonard Schawlow.[2]

A laser differs from other sources of light in that it emits light that is coherent. Spatial coherence allows a laser to be focused to a tight spot, enabling applications such as laser cutting and lithography. It also allows a laser beam to stay narrow over great distances (collimation), a feature used in applications such as laser pointers and lidar (light detection and ranging). Lasers can also have high temporal coherence, which permits them to emit light with a very narrow frequency spectrum. Alternatively, temporal coherence can be used to produce ultrashort pulses of light with a broad spectrum but durations as short as a femtosecond.

KEYWORDS-laser, techniques, medical, research, advanced

INTRODUCTION

Laser surgery is a type of surgery that uses a laser (in contrast to using a scalpel) to cut tissue.[1]

Types of surgical lasers include carbon dioxide, argon, Nd:YAG laser, and potassium titanyl phosphate, among others.

Soft-tissue laser surgery is used in a variety of applications in humans (general surgery, neurosurgery, ENT, dentistry, orthodontics,[2] and oral and maxillofacial surgery) as well as veterinary[3] surgical fields. The primary uses of lasers in soft tissue surgery are to cut, ablate, vaporize, and coagulate. There are several different laser wavelengths used in soft tissue surgery. Different laser wavelengths and device settings (such as pulse duration and power) produce different effects on the tissue. Some commonly used lasers types in soft tissue surgery include erbium, diode, and CO_2. Erbium lasers are excellent cutters, but provide minimal hemostasis. Diode lasers (hot tip) provide excellent hemostasis, but are slow cutters. CO_2 lasers are both efficient at cutting and coagulating.[4] Laser surgery is commonly used on the eye. Techniques used include LASIK, which is used to correct near and far-sightedness in vision, and photorefractive keratectomy, a procedure which permanently reshapes the cornea using an excimer laser to remove a small amount of the human tissue.[5][6][7]

Effects

1. Photochemical effect: clinically referred to as photodynamic therapy. Photosensitizer (photophrin II) is administered which is taken up by the tumor tissue and later irradiated by laser light resulting in highly toxic substances with resultant necrosis of the tumor. Photodynamic therapy is used in palliation of oesophageal and bronchial carcinoma and ablation of mucosal cancers of Gastrointestinal tract and urinary bladder.
2. Photoablative effect: Used in eye surgeries like band keratoplasty, and endartectomy of peripheral blood vessels.
3. Photothermal effect: this property is used for endoscopic control of bleeding e.g. Bleeding peptic ulcers, oesophageal varices
4. Photomechanical effect: used in intraluminal lithotripsy

Equipment

A 40 watt CO_2 laser used for soft-tissue laser surgery

Surgical laser systems, sometimes called "laser scalpels", are differentiated not only by the wavelength, but also by the light delivery system: flexible fiber or articulated arm, as well as by other factors.[8]

A 40 watt CO_2 laser used for soft-tissue laser surgery

CO_2 lasers were the dominant soft-tissue surgical lasers as of 2010.[9]

Applications

Dermatology and plastic surgery

A range of lasers such as erbium, dye, Q switch lasers, and CO_2 are used to treat various skin conditions including scars, vascular and pigmented lesions, and for photorejuvenation. The laser surgery for dermatology often bypasses the skin surface. The principle of laser surgery for dermatologic problems is based on SPTL (selective photothermolysis). The laser beam penetrates the skin until it encounters chromophore which absorbs the laser beam. After absorption of the laser beam, heat is generated to induce coagulation, necrosis of the targeted tissue, this results in the removal of unwanted tissue by laser surgery.

Laser resurfacing is a technique in which covalent bonds of a material are dissolved by a laser, a technique invented by aesthetic plastic surgeon Thomas L. Roberts, III using CO_2 lasers in the 1990s.[10][11]

Lasers are also used for laser-assisted lipectomy.[12]

Eye surgery

Various types of laser surgery are used to treat refractive error. LASIK, in which a knife is used to cut a flap in the cornea, and a laser is used to reshape the layers underneath, is used to treat refractive error. IntraLASIK is a variant in which the flap is also cut with a laser. In photorefractive keratectomy (PRK, LASEK), the cornea is reshaped without first cutting a flap. In laser thermal keratoplasty, a ring of concentric burns is made in the cornea, which causes its surface to steepen, allowing better near vision. ReLEx SMILE is the latest advancement in laser vision correction technology. In SMILE surgery, ZEISS VisuMax ® femtosecond laser is used to make a small incision and to create a pre-calculated mini lens tissue (or lenticule) inside the cornea.[13]

Lasers are also used to treat non-refractive conditions, such as phototherapeutic keratectomy (PTK) in which opacities and surface irregularities are removed from the cornea and laser coagulation in which a laser is used to cauterize blood vessels in the eye, to treat various conditions. Lasers can be used to repair tears in the retina.

Endovascular surgery

Laser endarterectomy is a technique in which an entire atheromatous plaque in the artery is excised. Other applications include laser assisted angioplasties and laser-assisted vascular anastomosis.

Foot and ankle surgery

Lasers are used to treat several disorders in foot and ankle surgery. They are used to remove benign and malignant tumors,[14] treat bunions,[15] debride ulcers and burns, excise epidermal nevi, blue rubber bleb nevi, and keloids, and the removal of hypertrophic scars and tattoos.[16]

A carbon dioxide laser (CO_2) is used in surgery to treat onychocryptosis (ingrown nails), onychauxis (club nails), onychogryposis (rams horn nail), and onychomycosis (fungus nail).[17]

Gastro-intestinal tract

1. Peptic ulcer disease and oesophageal varices - Laser photoablation is done.
2. Coagulation of vascular malformations of stomach, duodenum, and colon.
3. Lasers can be effectively used to treat early gastric cancers provided they are less than 4 cm and without lymph node involvement. Lasers are also used in treating oral submucous fibrosis.
4. Palliative laser therapy is given in advanced oesophageal cancers with obstruction of lumen. Recanalisation of the lumen is done which allows the patient to resume a soft diet and maintain hydration.
5. Ablative laser therapy is used in advanced colorectal cancers to relieve obstruction and to control bleeding.
6. Laser surgery used in hemorrhoidectomy, and is a relatively popular and non-invasive method of hemorrhoid removal.
7. Laser-assisted liver resections have been done using carbon dioxide and Nd:YAG lasers.
8. The ablation of liver tumors can be achieved by selective photovaporization of the tumor.
9. Endoscopic laser lithotripsy is a safer modality compared to electrohydraulic lithotripsy.

Oral and dental surgery

The CO_2 laser is used in oral and dental surgery for virtually all soft-tissue procedures, such as gingivectomies, vestibuloplasties, frenectomies, and operculectomies.[18] The CO_2 10,600 nm wavelength is safe around implants as it is reflected by titanium, and thus has been gaining popularity in the field of periodontology. The laser may also be effective in treating peri-implantitis.[19]

Spine surgery

Laser spine surgery first began seeing clinical use in the 1980s and was primarily used within discectomy to treat lumbar disc disease under the notion that heating a bulging disc vaporized enough tissue to relieve pressure on the nerves and help alleviate pain.[11,12]

Since that time, laser spine surgery has become one of the most marketed forms of minimally invasive spine surgery, despite the fact that it has never been studied in a controlled clinical trial to determine its effectiveness apart from disc decompression.[22] Evidence-based data surrounding the use of lasers in spine surgery is limited and its safety and efficacy were poorly understood as of 2017.

Thoracic surgery

In thoracic surgery, surgical laser applications are most often used to remove pulmonary metastases and tumors of different primary localizations.[25] Other areas of application are surgical sectioning of the parenchyma, anatomic segmental resections, removal of tumors from the thoracic wall[26] and abrasion of the pleura parietalis. Since the introduction of surgical lasers, the amount of potentially surgically resectable pulmonary nodules has significantly increased.[27] Compared to laser surgery, other conventional surgical methods such as segmental or wedge resections with surgical stapling will normally lead to a bigger loss of lung tissue, especially in patients with multiple pulmonary nodules methods.[28]

Other advantages of laser surgery compared to conventional methods are that it leads to an improved postoperative lung function and that it gives the additional possibility to histologically analyze the removed material which would otherwise be destroyed through radiation or heat.

Hard tissues

Lasers are used to cut or ablate bones and teeth in dentistry.[29]

Other surgery

The CO_2 laser is also used in gynecology, genitourinary, general surgery, otorhinolaryngology, orthopedic, and neurosurgery.

DISCUSSION

There are several laser types used in medicine for ablation, including argon, carbon dioxide (CO_2), dye, erbium, excimer, Nd:YAG, and others. Laser ablation is used in a variety of medical specialties including ophthalmology, general surgery, neurosurgery, ENT, dentistry, oral and maxillofacial surgery, and veterinary.[17] Laser scalpels are used for ablation in both hard- and soft-tissue surgeries. Some of the most common procedures where laser ablation is used include LASIK,[18] skin resurfacing, cavity preparation, biopsies, and tumor and lesion removal.[19] In hard-tissue surgeries, the short pulsed lasers, such as Er:YAG or Nd:YAG, ablate tissue under stress or inertial confinement conditions.[20] In soft-tissue surgeries, the CO_2 laser beam ablates and cauterizes simultaneously, making it the most practical and most common soft-tissue laser.[21]

Laser ablation can be used on benign and malignant lesions in various organs, which is called laser-induced interstitial thermotherapy. The main applications currently involve the reduction of benign thyroid nodules[22] and destruction of primary and secondary malignant liver lesions.[23][24]

Laser ablation is also used to treat chronic venous insufficiency.[25]

Ablative brain surgery (also known as brain lesioning) is the surgical ablation by various methods of brain tissue to treat neurological or psychological disorders. The word "Ablation" stems from the Latin word Ablatus meaning "carried away". In most cases, however, ablative brain surgery does not involve removing brain tissue, but rather destroying tissue and leaving it in place.[1] The lesions it causes are irreversible. There are some target nuclei for ablative surgery and deep brain stimulation. Those nuclei are the motor thalamus, the globus pallidus, and the subthalamic nucleus.[2]

Ablative brain surgery was first introduced by Pierre Flourens (1774–1867), a French physiologist. He removed different parts of the nervous system from animals and observed what effects were caused by the removal of certain parts. For example, if an animal could not move its arm after a certain part was removed, it was assumed that the region would control arm movements. The method of removal of part of the brain was termed "experimental ablation". With the use of experimental ablation, Flourens claimed to find the area of the brain that controlled heart rate and breathing.[3]

Ablative brain surgery is also often used as a research tool in neurobiology. For example, by ablating specific brain regions and observing differences in animals subjected to behavioral tests, the functions of all the removed areas may be inferred.

Experimental ablation is used in research on animals. Such research is considered unethical on humans due to the irreversible effects and damages caused by the lesion and by the ablation of brain tissues. However, the effects of brain lesions (caused by accidents or diseases) on behavior can be observed to draw conclusions on the functions of different parts of the brain.[4]

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Uses

Parkinson's disease

Parkinson's disease (PD) is a progressive degenerative disease of the basal ganglia, characterized by the loss of dopaminergic cells of the substantia nigra, pars compacta (SNc).[5] Surgical ablation has been used to treat Parkinson's disease. In the 1990s, the pallidum was a common surgical target. Unilateral pallidotomy improves tremor and dyskinesia on one side of the body (opposite the side of the brain surgery), but bilateral pallidotomy was found to cause irreversible deterioration in speech and cognition.

Two other rapidly evolving or potential surgical approaches to Parkinson's disease are deep brain stimulation (DBS) and restorative therapies.[6]

Deep brain stimulation is a surgical treatment involving the implantation of a neurostimulator medical device, sometimes called a 'brain pacemaker', which sends electrical impulses to specific parts of the brain. Generally, deep brain stimulation surgery is considered preferable to ablation because it has the same effect and is adjustable and reversible.[7][8][9]

An implanted neurostimulator, sometimes called a 'brain pacemaker, in an adult male as part of ablative brain surgery.

The advent of deep brain stimulation has been an important advance in the treatment of Parkinson's disease. DBS may be employed in the management of medication-refractory tremor or treatment-related motor complications, and may benefit between 4.5% and 20% of patients at some stage of their disease course. DBS at high frequency often has behavioral effects that are similar to those of lesioning.

In Australia, patients with PD are reviewed by specialized DBS teams who assess the likely benefits and risks associated with DBS for each individual.[6] The aim of these guidelines is to assist neurologists and general physicians identify patients who may benefit from referral to a DBS team. Common indications for referral are motor fluctuations and/or dyskinesias that are not adequately controlled with optimised medical therapy, medication-refractory tremor, and intolerance to medical therapy. Early referral for consideration of DBS is recommended as soon as optimised medical therapy fails to offer satisfactory motor control.[8]

The thalamus is another potential target for treating a tremor; in some countries, so is the subthalamic nucleus, although not in the United States due to its severe side effects. Stimulation of portions of the thalamus or lesioning has been used for various psychiatric and neurological conditions, and when practiced for movement disorders the target is in the motor nuclei of the thalamus.[9] Thalamotomy is another surgical option in the treatment of Parkinson's disease. However, rigidity is not fully controlled after successful thalamotomy, it is replaced by hypotonia. Furthermore, significant complications can occur, for example, left ventral-lateral thalamotomy in a right-handed patient results in verbal deterioration while right thalamotomy causes visual-spatial defects.[10] However, for patients for whom DBS is not feasible, ablation of the subthalamic nucleus has been shown to be safe and effective.[11] DBS is not suitable for certain patients. Patients with immunodeficiencies are an example of a situation in which DBS is not a suitable procedure. However, a major reason as to why DBS is not often performed is the cost. Because of its high cost, DBS cannot be performed in regions of the world that are not wealthy. In the case of such circumstances, a permanent lesion in the subthalamic nucleus (STN) is created as it is a more favourable surgical procedure.[12] The surgical procedure is going to be done on the non-dominant side of the brain; a lesion might be favored to evade numerous pacemaker replacements. More so, patients who gain relief from stimulation devoid of any side effects and need a pacemaker change may have a lesion performed on them in the same position. The stimulation parameters act as a guide for the preferred size of the lesion.[13] In order to identify the part of the brain that is to be destroyed, new techniques such as micro electrode mapping have been developed.[14][15]

Cluster headaches

Cluster headaches occur in cyclical patterns or clusters—which gives the condition of its name. Cluster headache is one of the most painful types of headache. Cluster headache is sometimes called the "alarm clock headache" because it commonly awakens you in the middle of the night with intense pain in or around the eye on one side of your head. The bouts of frequent attacks may last from weeks to months. When drug treatment fails, an invasive nerve stimulation procedure shows promise. Cluster headaches have been treated by ablation of the trigeminal nerve, but have not been very effective. Other surgical treatments for cluster headaches are under investigation.[15]

Psychiatric disorders

Ablative psychosurgery continues to be used in a few centres in various countries.[16] In the US there are a few centres including Massachusetts General Hospital that carry out ablative psychosurgical procedures.[17] Belgium,[16] the United Kingdom,[18] and Venezuela[19] are other examples of countries where the technique is still used. In the People's Republic of China, surgical ablation was used to treat psychological and neurological disorders, particularly schizophrenia, but also including clinical depression, and obsessive-compulsive disorder.[20] The official Xinhua News Agency has since reported that China's Ministry of Health has banned the procedure for schizophrenia and severely restricted the practice for other conditions.[21] In recent studies, Deep Brain Stimulation (DBS) is beginning to replace Ablative Brain Surgery for severe psychiatric conditions that are generally treatment resistant, such as obsessive-compulsive disorder.[22]

Methods

Experimental ablation involves the drilling of holes in the skull of an animal and inserting an electrode or a small tube called a cannula into the brain using a stereotactic apparatus. A brain lesion can be created by conducting electricity through the electrode which damages the targeted area of the brain. likewise, chemicals can be inserted in the cannula which could possibly damages the area of interest. By comparing the prior behavior of the animal to after the lesion, the researcher can predict the function of damaged brain segment.[23] Recently, lasers have been shown to be effective in ablation of both cerebral and cerebellar tissue. A laser technology called MRI-guided laser ablation,[24] for example, allows great precision in location and size of the lesion and the causes little to no thermal damage to adjacent tissue. The Texas Children's Hospital is one of the first to use this MRI guided method to destroy and treat brain lesions effectively and precisely. A prime example is a patient at this hospital who now no longer undergoes frequent seizures because of the success of this treatment.[25] MRI-guided laser ablation is also used for ablating brain, prostate and liver tumors. Heating or freezing are also alternative methods to ablative brain surgery.[26]

Sham lesions

A sham lesion is a way for researchers to give a placebo lesion to animals involved in experimental ablation. Whenever a cannula or electrode is placed into brain tissue, unintended additional damage is caused by the instrument itself. A sham lesion is simply the placement of the lesioning instrument into the same spot it would be placed in a regular lesion, only there is no chemical or electrical process. This technique allows researchers to properly compare to an appropriate control group by controlling for the damage done separate from the intended lesion.[27]

Excitotoxic lesions

An excitotoxic lesion is the process of an excitatory amino acid being injected into the brain using a cannula. The amino acid is used to kill neurons by essentially stimulating them to death. Kainic acid is an example of an excitatory amino acid used in this type of lesion. One crucial benefit to this lesion is its specificity. The chemicals are selective in that they do not damage the surrounding axons of nearby neurons, but only the target neurons.[1]

Radio frequency lesions

Radio frequency (RF) lesions are produced by electrodes placed in the brain tissue. RF current is an alternating current of very high frequency. The process during which the current passes through tissue produces heat that kills cells in the surrounding area. Unlike excitotoxic lesions, RF lesions destroy everything in the nearby vicinity of the electrode tip.[1]

The use of ablative brain surgery on the nucleus accumbens is the wrong method to treat addictions according to Dr. Charles O'Brien. Dr. John Adler, however, believes ablation can provide valuable information about how the nucleus accumbens works.[28]

RESULTS

A dental laser is a type of laser designed specifically for use in oral surgery or dentistry.

In the United States, the use of lasers on the gums was first approved by the Food and Drug Administration in the early 1990s, and use on hard tissue like teeth or the bone of the mandible gained approval in 1996.[1] Several variants of dental lasers are in use with different wavelengths and these mean they are better suited for different applications.

Soft tissue lasers

- Diode lasers
- Carbon dioxide lasers[2]
- Nd:YAG laser

Diode lasers wavelengths in the 810–1,100 nm range are poorly absorbed by the soft tissues[3][4][5][6][7] such as the gingivae, and cannot be used for soft tissue cutting or ablation.[4][5][7][8] Instead, the distal end of diode's glass fiber is charred (by burned ink or by burned corkwood, etc.) and the char is heated by the 810-1,100 nm laser beam, which in turn heats up the glass fiber's tip.[6][8] The soft tissue is cut, on contact, by the hot charred glass tip and not by the laser beam itself. This is used for variety of oral surgery procedures such as gingivectomy, frenectomy, treatment of pericoronitis, and exposure of superficially impacted teeth.[9] This method was primarily used by the Michigan school of dentistry .[6][8]

Similarly Nd:YAG lasers are used for soft tissue surgeries in the oral cavity, such as gingivectomy, periodontal sulcular debridement, LANAP, frenectomy, biopsy, and coagulation of graft donor sites. The Nd:YAG laser wavelength are partially absorbed by pigment in the tissue such as hemoglobin and melanin.[10] These lasers are often used for debridement and disinfection of periodontal pockets. Their coagulative ability to form fibrin allows them to seal treated pockets.[15]

Laser Dental Treatment In Malta: More Comfort, Faster Recovery

The CO_2 laser remains the best surgical laser for the soft tissue where both cutting and hemostasis is achieved photo-thermally (radiantly).[3][6][7][8]

Soft and hard tissue lasers

- Er:YAG laser
- Carbon dioxide laser
- Er,Cr:YSGG laser

Erbium lasers are both hard and soft tissue capable.[11] They can be used for a host of dental procedures, and allow for more procedures to be done without local anaesthesia. Erbium lasers can be used for hard tissue procedures like bone cutting and create minimal thermal and mechanical trauma to adjacent tissues. These hard tissue procedures show an excellent healing response.[12] Soft tissue applications with erbium lasers feature less hemostasis and coagulation abilities relative to the CO_2 lasers. Er,Cr:YSGG laser was found to be effective in gum de-pigmentation.[13] The new CO_2 laser operating at 9,300 nm features strong absorption in both soft and hard tissue and is the newest alternative to erbium lasers.[14] The 9,300 nm laser ablates hard tissue in excess of 5,000 °C, which often results in extremely bright thermal radiation.[15]

Dental caries removal

In September 2016 the Cochrane collaboration published a systematic review of the current evidence comparing the use of lasers for caries removal, in both deciduous and adult teeth, with the standard dental drill.[16] Nine trials were reviewed, published between 1998 and 2014, with 662 participants in total. These included three different types of laser: Er:YAG; Er,Cr:YSGG; and Nd:YAG. Overall the quality of evidence available was found to be low, and the authors were unable to recommend one method of caries removal over the other. There was no evidence of a difference between the marginal integrity or durability of the restorations placed. However, there was some evidence that the laser-produced less pain and required less anaesthesia than the drill. The authors concluded that more research is required.

Cost of lasers

Use of the dental laser remains limited, with cost and effectiveness being the primary barriers. The cost of a dental laser ranges from $4,000 to $130,000, where a pneumatic dental drill costs between $200 and $500. Hard tissue lasers are incapable of performing some routine operations in the treatment of cavities.[17]

Benefits of lasers

Dental lasers are not without their benefits, though, as the use of a laser can decrease morbidity after surgery, and reduces the need for anesthetics. Because of the cauterisation of tissue there will be little bleeding following soft tissue procedures, and some of the risks of alternative electrosurgery procedures are avoided. Additionally, the use of dental lasers is associated with less vibration and a more favorable noise profile when compared to pneumatic dental drills.[18]

Transmyocardial Laser Revascularization

Like every other organ or tissue in your body, the heart muscle needs oxygen-rich blood to survive. The heart gets this blood from the coronary arteries. But in patients with coronary artery disease (CAD), the coronary arteries are clogged and diseased and can no longer deliver enough blood to the heart. The heart's lack of oxygen-rich blood is called ischemia.

Not getting enough oxygen to the heart muscle increases the risk of heart attack and may cause a painful condition called angina.

Most of the time, the best treatment for angina is coronary artery bypass surgery. But for some patients with very serious heart disease or other health problems, bypass surgery may be too dangerous. Also, some patients may have had many coronary artery bypass operations and be unable to have more bypass operations.

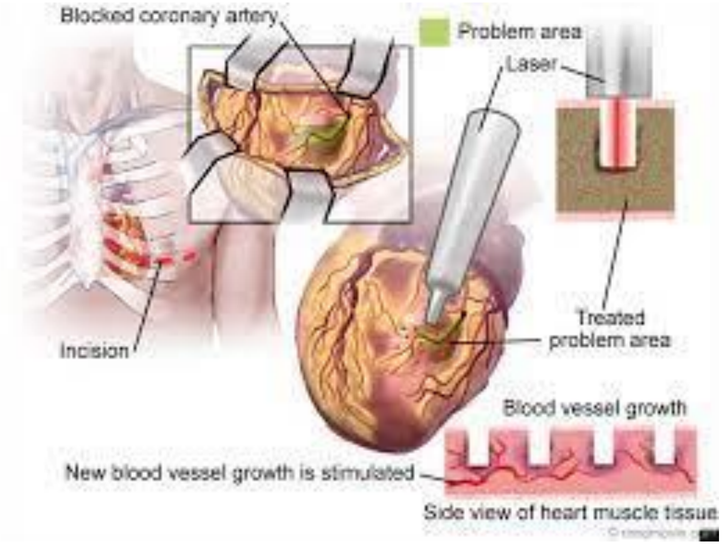
For patients who cannot have bypass surgery, there is a procedure called transmyocardial laser revascularization, also called TMLR or TMR. TMLR cannot cure CAD, but it may reduce the pain of angina.

What is Transmyocardial Laser Revascularization (TMLR)?

TMLR is a type of surgery that uses a laser to make tiny channels through the heart muscle and into the lower-left chamber of the heart (the left ventricle). The left ventricle is the heart's main pumping chamber.

After TMLR, when oxygen-rich blood enters the left ventricle, some of that blood can flow through the tiny channels and carry much-needed oxygen to the starving heart muscle.

No one really knows why TMLR helps reduce the pain of angina. Some doctors think that TMLR helps the growth of tiny new blood vessels in the heart muscle wall. This process is called angiogenesis. These new blood vessels bring more blood to the heart muscle, making it healthier. Others think that the TMLR laser destroys some of the pain-causing nerves in the heart muscle. Still others think that patients feel a placebo effect. This means that patients feel better because they got treatment, not because the treatment really worked.



Transmyocardial Laser Revascularization (TMLR)

Doctors came up with the idea for TMLR by studying the hearts of alligators and snakes, where blood to feed the heart muscle goes straight from the ventricle and into the muscle, not through coronary arteries. Doctors thought this might work in human hearts, too.

TMLR is surgery, but it can be done while the heart is still beating and full of blood. That means that a heart-lung machine is not needed. Also, surgeons do not cut open the chambers of the heart, so TMLR is not open heart surgery.

What to Expect

The operation will be scheduled at a time that is best for you and your surgeon, except in urgent cases. Be sure to tell your surgeon and cardiologist about any changes in your health including symptoms of a cold or the flu. Any infection may affect your recovery.

Also, review all medications (prescription as well as over-the-counter and supplements) with your cardiologist and surgeon. Before surgery, you may have to have an electrocardiogram (ECG or EKG), blood tests, urine tests, and a chest x-ray to give your surgeon the latest information about your health.

If you smoke, your doctor will want you to stop at least 2 weeks before your surgery. Smoking before surgery can lead to problems with blood clotting and breathing.[12]

The night before surgery, you will be asked to bathe to reduce the amount of germs on your skin.

A medicine (anesthetic) will make you sleep during the operation. This is called "anesthesia." Because anesthesia is safest on an empty stomach, you will be asked not to eat or drink after midnight the night before surgery. If you do eat or drink anything after midnight, it is important that you tell your anesthesiologist and surgeon.

You will get complete instructions from your cardiologist and surgeon about the procedure, but here are some basics you can expect as a TMLR patient.

Day of Surgery

Most patients are admitted to the hospital the day before surgery or, in some cases, on the morning of surgery.

Small metal disks called electrodes will be attached to your chest. These electrodes are connected to an electrocardiogram machine, which will monitor your heart's rhythm and electrical activity. You will receive a local anesthetic to numb the area where a plastic tube (called a line) will be inserted in an artery in your wrist. An intravenous (IV) line will be inserted in your vein. The IV line will give you the anesthesia during the operation. You will be given something to help you relax (a mild tranquilizer) before you are taken into the operating room.

After you are completely asleep, a tube will be inserted down your windpipe and connected to a machine called a respirator, which will take over your breathing. Another tube will be inserted through your nose and down your throat, into your stomach. This tube will stop liquid and air from collecting in your stomach, so you will not feel sick and bloated when you wake up. A thin tube called a catheter will be inserted into your bladder to collect any urine produced during the operation.

The cardiovascular surgeon leads the surgical team, which includes other assisting surgeons, an anesthesiologist, and surgical nurses.

First, the surgeon makes a cut in the left side of the chest to get to the heart's left ventricle. Then the surgeon uses a special carbon dioxide laser to make 20 to 40 tiny channels in the heart muscle. These channels are about 1 mm wide, or about the size of the head of a pin. The surgeon makes the channels when the heart is in systole (pumping blood), because that is when the heart's walls are the thickest and the least likely to be damaged.[13]

The channels may bleed for a few seconds, but the bleeding will stop when the surgeon presses lightly on the channels with a finger. The tops of the channels close over with a blood clot, but inside the heart, the channels stay open.

The full TMLR procedure usually takes about 2 hours.

Sometimes, one part of the heart can be treated with bypass surgery while another part of the heart can be treated with TMLR. In these cases, TMLR and bypass surgery are done at the same time.

Recovery Time

You can expect to stay in the hospital for between 4 and 7 days after TMLR.

Recovery after TMLR may take a long time. You will have to rest and limit your activities. Your doctor may want you to begin an exercise program or to join a cardiac rehabilitation program.

If you have an office job, you can usually go back to work in 4 to 6 weeks. Those who have more physically demanding jobs may need to wait longer.

Life After TMLR

Most of the time, the symptoms of coronary artery disease and angina get better after TMLR, but it may take 3 months or more to see improvement.

Patients find that after TMLR they can now do all of the activities that once caused them pain. They may also find that they do not need to take as many heart medicines, including nitroglycerin.

Studies have shown that 1 year after surgery, 80% to 90% of patients treated with TMLR still feel better than they did before they had the surgery. They also have a lower risk of heart attack.

CONCLUSION

Laser eye surgery, which some people call LASIK surgery, can correct several eyesight conditions. However, there are potential risks or side effects, and not everyone can have the procedure.

The eye has an outer layer called the cornea. Some people’s corneas can undergo changes in their shape, leading to vision issues, such as astigmatism and myopia. Laser eye surgery is a medical procedure that reshapes this layer.

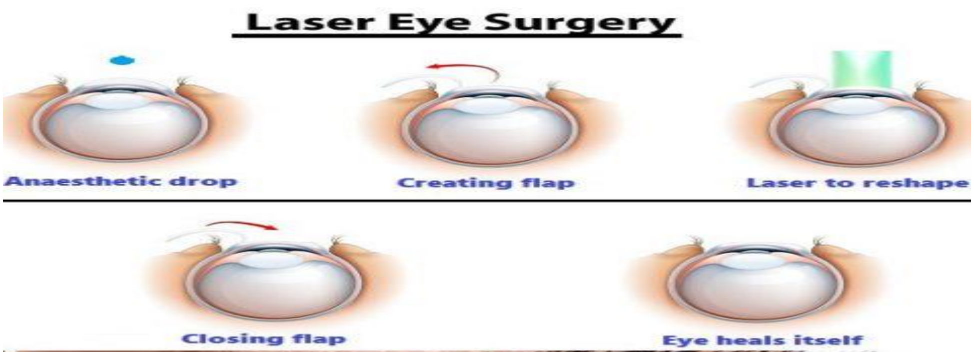
Precisely how laser eye surgery reshapes the cornea depends on the vision condition that the treatment aims to correct. Laser eye surgery can fix vision issues, such as nearsightedness and farsightedness.

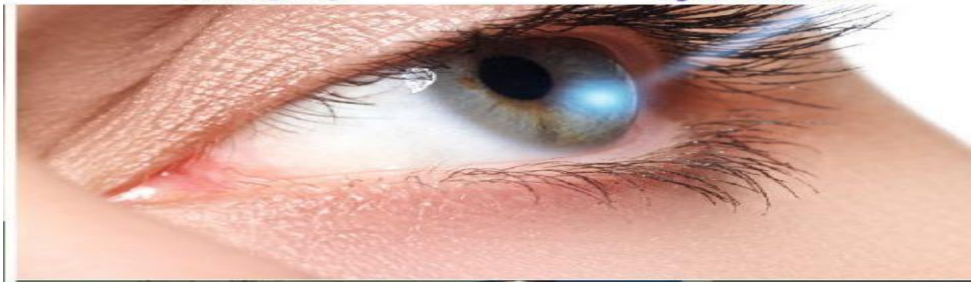
The surgery is quick, and people remain awake throughout the procedure. It is also usually painless — if a person experiences pain, it usually indicates there have been complications.

This article discusses what laser eye surgery is, who it can help, costs, duration of the surgery, recovery time, and any associated short- and long-term risks.[15]

What is laser eye surgery (LASIK or PRK)

LASIK stands for laser-assisted in situ keratomileusis and is the most common type of refractive eye surgery. LASIK was first patented in 1989 and has become the most commonTrusted Source treatment for refractive eye errors. The procedure involves lasers to reshape the cornea.





Who may it help?

According to the American Academy of Ophthalmology, over 150 million Americans use corrective eyewear, such as glasses or contact lenses, to compensate for refractive errors.
Refractive errors occur when the eye does not bend — or refract — the light to properly focus on the retina in the back of the eye. This is usually due to the shape of the cornea.
Farsightedness
The clinical name for farsightedness is hyperopia. People with this condition can see objects in the distance clearly, but other things can appear blurry at close distance. Farsightedness is due to the curvature of the cornea being too flat. Laser eye surgery can correct this by reshaping the cornea to have a steeper curve.
Nearsightedness
Nearsightedness, known as myopia or short-sightedness, is where a person can see objects close to them clearly. However, distant objects can appear blurred. This is due to the curvature of the cornea being too steep. Healthcare professionals can correct this through laser eye surgery by reshaping the cornea.
Astigmatism
People with astigmatism have a differently-shaped eye that characterizes this condition. The eye of someone without the condition is round, like a soccer ball, while with astigmatism, the eye may have more of a football-like shape. It is possible to correct this irregular curvature of the cornea with laser eye surgery in some cases.
Who is unsuitable?
People who are not suitableTrusted Source candidates for laser eye surgery include those who:
have had a change in their eye prescription in the last 12 months
take medications that may cause changes in vision
are in their 20s or younger, although some experts recommend not being under 18 years
have thin corneas, which may not be stable following laser surgery
are pregnant or nursing
Benefits
The main benefit of laser eye surgery is that mostTrusted Source people no longer have to wear corrective eyewear to see clearly. Individuals may choose to undergo the procedure for several reasons, including:
being unable to wear contact lenses but preferring not to wear glasses, perhaps for cosmetic reasons
wishing to undertake activities, such as sports, that require a person not to wear glasses or contact lenses
having the convenience of not having to wear corrective eyewear
Risks and complications
A person is more at riskTrusted Source of developing complications if they have the followingTrusted Source eye conditions:
eye infections, such as keratitis or ocular herpes
significant cataracts — people with this condition will not have corrected vision after laser surgery
glaucoma
large pupils
keratoconus, a disease that makes the cornea thinner and unstable over time
As with all surgeries, a person may experience complications, including:
Dry eyes: Up to 95%Trusted Source of people who have laser eye surgery may experience dry eyes after the procedure, where the eyes produce fewer tears. Lubricating eye drops can help with this symptom.
Glare or halo: 20% of people undergoing laser eye surgery may experience visual changes such as glare, halo, or sensitivity to light.
Double or blurry vision: As many as 1 in 50 people may report blurriness and feel there is something in their eyes. Diffuse lamellar keratitis — also called “sands of Sahara” syndrome — may be the cause.
Other complications a person may experience include:
eye infection
corneal flap complications
red or bloodshot whites of the eye
Most symptoms should resolve after the first few days, so an individual experiencing any symptoms after this time should consult with a medical professional.
What to expect during surgery
The Food & Drug Administration (FDA) suggests laser eye surgery usually takes less than 30 minutesTrusted Source. Others estimate the procedure will take around 5 minutes per eye.
People undergoing laser eye surgery should expect the following:
They will sit in a chair and recline, so they are flat on their back underneath a laser device and computer screen.

The surgical team will clean the area around the eye and place numbing drops in the eye.
Surgeons will use a lid speculum, a medical instrument, to hold the eyelids open.
A laser will cut a flap in the cornea, and the surgeon will then lift this open.
People will need to stare at a light to keep their eyes still while the laser works.
The laser will then reshape the surface of the cornea.
The surgeon will then place the flap back into position and apply a shield to protect the eye.
Recovery time
The FDATrusted Source notes that after surgery, a person may feel as though their eye is burning, itchy, or that there is a foreign object present. The surgeon may recommend a mild pain reliever, such as acetaminophen, to help with these sensations.
Surgeons will provide people with an eye shield to protect their eyes, as there will be no stitches holding the flap in place. The guard helps prevent rubbing the eye or accidentally applying pressure, such as during sleep.
Individuals will usually take a few days off from work so they can recover. They should schedule an appointment to see their eye doctor within the first 24–48 hours after surgery to undergo an eye examination. The doctor will make sure the eyes are healing as they should. After this, a person will need several additional appointments over the first 6 months.[14,15]

Way Forward

Applications
Soon after the invention of laser in 1960, scientists started exploring the possibilities of using them for medical applications. Lasers were first used for medical applications in 1961 for treatment of skin discoloration and detached retinas. Presently lasers are being widely used for numerous medical applications. These include surgery, ophthalmology, dermatology, angioplasty, cancer treatment, urology, cosmetic applications such as laser hair removal, tattoo removal and liposuction etc. Some of these important applications are discussed here in brief. When laser radiation falls on human tissues, different phenomenon may take place like reflection, transmission, scattering, re-emission and absorption. It is the absorption phenomenon, which is most important. The main laser absorbing components in tissues are:

Oxyhemoglobin (in blood): the blood's oxygen carrying protein, absorption of UV and blue and green light. Lasers for selective absorption include excimer, argon, KTP, Dye and Ruby.

Melanin: a pigment in skin, hair, moles, etc: absorption in visible and near IR light (400nm - 1000nm). Lasers for selective absorption in melanin include Diode and Nd: YAG

Water (in tissues): transparent to visible light but strong absorption of UV light below 300nm and IR over 1300nm. Lasers for selective absorption in water molecules in tissues include Ho: YAG, Er: YAG and CO_2.

Laser light interacts with the tissue and transfers the energy of photons to tissues because of absorption. Laser heating of tissues above 50°C but below 100°C induces disordering of proteins and other bio-molecules. This process is known as photocoagulation. When lasers are used for photocoagulation during surgery, the tissues shrink in mass because water is expelled at these temperatures. The heated region changes its colour and loses its mechanical integrity. Cells in the photocoagulated region die and the tissue is a dead one and can be pulled or removed. The process of laser-induced photocoagulation can be used to destroy tumors, to treat various eye conditions like retinal disorders caused by diabetes, bloodless incision or excision in laser surgery. When very high laser power densities are used, lasers quickly heats the tissues beyond 100°C resulting in boiling and evaporation of water in the tissues. Since 70% of the body tissue is water, the boiling change the tissue into a gas. This phenomenon is called photo-vaporization. Photo-vaporization results in complete removal of the tissue thus making the process suitable for skin rejuvenation, resurfacing and of course bloodless incision or excision in laser surgery. For Photo-vaporization, the tissues must be heated quickly to more than 100°C thus requiring high power density in a pulsed mode. In general power density upto $10W/cm^2$ results in heating of tissues, whereas laser power in the range of 10 - $100W/cm^2$ results in photocoagulation. Power density greater than $100W/cm^2$ is required for photo-vaporization. It is worth mentioning that a given laser can be used for photo-vaporization in the focused mode, whereas same laser can also be used for photocoagulation in the defocused mode. High power lasers like excimer lasers in the ultraviolet range, can break the chemical bonds without even heating the tissues locally thus resulting in photochemical ablation. The photochemical ablation results in clean-cut incision. The thermal component is relatively small and the zone of thermal interaction is limited in the incision wall. Different lasers and processes are useful for different type of applications. For example, for skin rejuvenation, require pulsed IR lasers for selective absorption process resulting in photo-vaporization. IR lasers are used to remove extremely thin layer of skin (<0.1 mm). Usually, in the absence of pigment in general, they take advantage of the presence of water in the skin to provide an ability to remove skin and body tissue. For hair removal, absorbing component being melanin pigment in hair and follicle, ruby laser is best suited for this application. Similarly pulsed dye laser (in yellow region) is used for removal of port-wine stain. This wavelength is absorbed in the presence of haemoglobin in blood vessels. Excess blood vessels, which are under the outer layer of the skin, absorb this laser wavelength and get destroyed. Since the laser is pulsed, other tissues are generally not damaged. Lasers used for ophthalmological applications include argon and excimer. For retina operation, visible laser can be used. Visible light is transparent to the cornea and crystalline lens, and can be focused with eye's lens on the retina. The most popular visible laser is the green argon laser.

- Treatment of glaucoma: Argon laser is focused externally on iris to make incision, creating drainage holes for excess aqueous humors to release pressure,
- Retina tear: photocoagulation burn to repair retina tears due to trauma to the head.
- Diabetic retinopathy: inadequate blood supply to the retina due to diabetes. Small photocoagulation burn by green argon laser to repair the retina due to vessels leakage.
- For cornea and lens, UV light emitted by the excimer laser is strongly absorbed by water and proteins, so their energy can be absorbed by transparent cornea and lens, permitting laser surgery on these areas.
- Cataracts: a milky structure in the lens of the eye. Photo-vaporization by using UV laser to remove the opaque regions.
- Correction of myopia: over focusing of the lens. Excimer laser removal of surface of cornea to make it flatten.

Lasers can also be used for tattoo removal, however the type of laser to be used for this application depends upon the ink used.

Applications of Lasers in Urology

There are numerous applications of lasers in urology, important of these are listed below:

- Urolithiasis: It is the condition where urinary stones are formed or located anywhere in the urinary system. The term nephrolithiasis refers to stones that are in the kidney, while ureterolithiasis refers to stones that are in the ureter. The term cystolithiasis refers to stones, which form or have passed into the urinary bladder.
- Condylomata: A condition in which warts or skin lesions appear on genital, perineal or anal areas is known as condylomata acuminata. Genital warts are an infectious disease caused by sexually transmitted viruses, the Human Papilloma virus (HPV).
- Benign Prostatic Hyperplasia (BPH): It is a common urological condition caused by the non-cancerous enlargement of the prostate gland, as men get older. As the prostate enlarges, it can squeeze down on the urethra. The symptoms associated with BPH are known as lower urinary tract symptoms. This can cause men to have trouble urinating and leads to symptoms of BPH.
- Prostate Cancer
- Open prostatectomy: This surgery involves the removal of the inner portion of the prostate via a suprapubic or retropubic incision in the lower abdominal area. This procedure is carried out generally in men with significantly enlarged prostate glands.
- Vasovasostomy: It is a surgery by which vasectomies are partially reversed. Another surgery for vasectomy reversal is known as vasoepididymostomy in which tissues are welded.
- Suture removal: Surgical suture is a used by doctors and surgeons to hold tissue together Nd:YAG and Ho:YAG are quite effective lasers.[13,14]

The interaction of laser with various tissues is accompanied by one or more of the following effects:

Thermal effect

The temp of tissue increases resulting in various biological effects. For temperature greater than 40°C, protein-denaturing process is dominant. If proteins in a living cell are denatured, this results in disruption of cell activity and possibly cell death. If the temperature rises beyond 60°C, protein coagulation takes place. At 100°C, vaporization of H_2O happens, however at temperatures beyond 250°C, carbonization takes place and even tissues start vaporizing.

The wavelengths of the laser light, the power density, and particular optical and thermal features of the tissue determine the extent of the thermal effect. For example, the wavelength of 10.6 micron, corresponding to CO_2 laser is completely absorbed, resulting in heat generation with carbonization and even vaporization. In the near infrared region i.e. for Nd: YAG laser (1.06micron), there is less absorption of energy resulting in tissue coagulation at considerable depth

For example, the holmium laser has mainly been used to heat and thus vaporize water and organic matter in the stone, thereby making it brittle.

Mechanical effect

Application of pulsed laser energy onto the surface of a stone results in fragmentation

In case a very high power density laser pulse strikes at the surface of the stone, it may result in releasing of a column of electrons and the formation of the "plasma bubble" or cavitation bubble. Further, expansion of this bubble may change the physical microstructure structure of the stone thus causing its fragmentation. For example, the holmium laser has mainly been used to heat and thus vaporize water and organic matter in the stone, thereby making it brittle.

Tissue-welding effect

Laser energy helps in filling the gaps in collagen structure, also known as the interdigitation of collagen, with minimal peripheral tissue destruction. The process can be used in vasovasostomy, urethral reconstruction, pyeloplasty (surgical reconstruction of the renal pelvis to drain and decompress the kidney), and bladder augmentation. It helps in immediate sealing, improved healing with minimal scar formation and maintenance of luminal continuity (restoration of intestinal continuity after removal of a pathological condition affecting the bowel).

Photochemical effect

It is based on the selective photo activation of a specific drug and its transformation to a toxic compound. The formation of toxic metabolites results in cellular death.

Lasers for condylomata - CO_2 laser induced vaporization of small lesions, whereas Nd: YAG coagulates and is used for larger lesions.

- Pulsed dye laser (504 nm), Argon (755 nm) for urolithiasis for controlled fragmentation
- Nd:YAG, Alexandrite and Ho:YAG for stone fragmentation, for causing stone vaporization and formation of cavitation bubble
- CO_2 and Nd:YAG for Vasovasostomy
- Nd:YAG for prostatic Ca
- Holmium: YAG, Nd:YAG, for ablation of the prostate and for removal of the prostate
- CO_2 and Nd:YAG for Penile Ca - low stage disease.
- CO_2 and Nd:YAG for Bladder haemangioma
- Suture removal Nd:YAG and Ho:YAG, Argon, Nd:YAG, Ho:YAG, Potassium Titanyl Phosphate (KTP - 532 nm)
- Semiconductor Laser (850 nm) for Interstitial prostate coagulation, tissue welding

Applications of Lasers in Ophthalmology

Use of Lasers in ophthalmology has evolved tremendously during the last few decades. An increased understanding of laser-tissue interactions in ophthalmology has led to the use of lasers in treating a wide spectrum of diseases involving both the anterior and posterior segments of the eye. These diseases include the four commonest causes of blindness: diabetic retinopathy, age-related macular degeneration, glaucoma and cataract. As soon as Ruby laser was invented in 1960, ophthalmologic applications of this laser was considered and also used as well on limited basis because of slightly poor beam quality. However, subsequent developments of new lasers like argon, krypton, excimer, CO_2, tunable dye and Nd: YAG has made it possible to treat effectively the eye related deceases.

The laser is a valuable tool for the ophthalmologist today and will continue to be in the future. Currently, through laser technology advancements, vision is being maintained for some patients who would otherwise have severely impaired eyesight because of the lack of appropriate intervention. With the recent advances in excimer laser research, many patients may not have to wear glasses at all. Laser surgery is also minimizing the need for hospitalization and is offering a cost-effective means of treatment for ophthalmologic conditions. Laser technology is indeed revolutionizing ophthalmology.

Laser-tissue interactions in ophthalmology can occur in several ways, depending on the power, pulse-duration and wavelength. These interactions can have photothermal, photochemical and photoionizing effects.

Photo-thermal effects include photocoagulation, photo-carbonization and photo-vaporization. Initially, laser light gets absorbed in the target tissues resulting in a temperature rise, thereby causing denaturation of proteins. Typically, argon and krypton lasers, with wavelengths in the visible spectrum, are used in photocoagulation and cautery (destruction of abnormal tissues). Photo-vaporization occurs when higher energy laser light gets absorbed in the target tissue, resulting in vaporization of both intracellular and extracellular water. Usually CO_2 laser is used for Photo-vaporization.

Photochemical effects include photo-radiation and photo-ablation. In the former, intravenous administration of organic compounds generally known as hematoporphyrin derivative, which are absorbed in the target tissue, resulting in its sensitization. Exposure of this sensitized tissue to red laser light induces the formation of cytotoxic free radicals. Tunable dye lasers are generally used for this purpose. On the other hand, Photo-ablation occurs when tissues are exposed to high-energy lasers of wavelengths less than 350 nm (ultraviolet). This results in breaking of long-chain tissue polymers into smaller volatile fragments. In contrast to the photo-radiation effect, where relatively long exposure times (minutes) are necessary to produce the cytotoxic free radicals, the exposure times in the photo-ablation process is much shorter of the order of nanoseconds. This ensures that heat is not conducted in the surrounding tissue. Or Photo-ablation process, usually Excimer lasers are being used for example for producing a precise cuts in corneas and to disrupt intravitreal membranes

Photo-ionization occurs when tissues are exposed to high-energy laser for a short duration of nanoseconds. This results in stripping electrons from the molecules of the exposed tissue. This cloud of electrons and ionized molecules constitutes "plasma", which then rapidly expands, causing an acoustic shock wave that disrupts the exposed tissue. The ND: YAG laser for example uses this "photo-disruptive" mechanism in knocking down secondary cataract membranes and vitreous membranes.[12]

Glaucoma

Glaucoma is an ocular disorder and is normally associated with increased fluid pressure in the eye. This can permanently damage vision in the affected eye and lead to blindness if left untreated. Glaucoma is caused due to rise in the intraocular pressure of the eye that occurs when the aqueous humor formed by the vitreous body fails to gain access at the outflow channel of the eye, the trabecular meshwork. Too much fluid presses on the nerve at the back of the eye in the case of patients suffering with glaucoma. The optic nerve is the 'electric wire' of the eye, and it takes messages about what you see on towards the brain. In the main type of glaucoma the optic nerve is pressed on by extra fluid in the eye, and this may damage the sight in the eye. A healthy eye produces a fluid like water in its middle chamber. This fluid then flows around inside the eye to the front chamber. Normally fluid is formed in the ciliary body and circulates to the front chamber, where it drains through the trabecular meshwork out of the eye (see adjoining figures). The trabecular meshwork is a type of filter system: fluid leaves the eye and enters the blood stream. Then, from the front chamber the fluid leaves the eye by entering a drainage meshwork, the trabecular meshwork. From this drainage system the fluid enters the bloodstream. In the common type of glaucoma this drainage system gets blocked. The net result is that the fluid gets trapped in the eye, and the pressure inside the eye goes up. The angle formed by the iris and the cornea, the apex of which is the trabecular meshwork, normally is about 20 to 45 degrees. In eyes with a tendency for narrow-angle glaucoma to develop, the angle may be quite narrow - about 10 to 20 degrees. In an acute case of narrow-angle glaucoma, the anterior surface of the lens occludes the pupil. This results in diminishing the aqueous flow thus increasing the posterior chamber pressure. In the common type of glaucoma this drainage system for aqueous humor can block. The fluid gets trapped in the eye, and the pressure inside the eye goes up. This pressure or fluid then presses on the nerve at the back of the eye. If the pressure is high or continues for a long time, usually years, the nerve at the back of the eye may become damaged and eventually the sight may be affected. The pressure reduces the blood flow in the tiny blood vessels in the optic nerve.[1]

In conventional glaucoma treatment, a surgical iridotomy is carried out to allow the aqueous trapped behind the iris to flow into the anterior chamber, to widen the angle and to permit aqueous to escape through the trabecular meshwork. Iridotomy process involves making puncture-like openings through the iris without the removal of iris tissue with laser surgery, however, argon, krypton or Nd: YAG lasers may be used to create an iridotomy (hole in the iris), thus relieving the pressure. The advantage of this technique is that the procedure is noninvasive and requires neither admission to hospital nor a general anesthesia. In order to remove the obstruction to aqueous outflow, at the level of the trabecular meshwork, usually, argon or krypton laser trabeculoplasty can be done. In this procedure, about 50 micron spot-sized bums are made at the level of the trabecular meshwork. The intensity of the bums is selected to create scars that contract and pull the meshwork open. The main advantage of laser trabeculoplasty is that the procedure obviates the need for hospital admission, general anesthesia and an intraocular surgical procedure. Acute cases of glaucoma, as seen in patients with diabetic retinopathy and patients having Malignant glaucoma generally known as Aphakic Malignant which may occur due to the absence of the lens of the eye, removed either surgically or otherwise, Nd: YAG hyaloidotomy can be done to create a channel for the posteriorly directed aqueous to reach the anterior chamber.

Cataract

The most common application of lasers is the use of the YAG laser to perform a procedure called POSTERIOR CAPSULOTOMY. In this procedure, a patient who has had previous cataract surgery may have subsequent cloudy vision due to clouding of the posterior capsule (so called after cataract or secondary cataract). A YAG laser can painlessly clear the vision and does not require an anesthetic injection and usually does not require postoperative medications.

During the last decade femtosecond lasers are being widely used for all the three processes involved in cataract. These processes involve creation of small incisions generally known as Clear Corneal Incisions (CCI) for surgeons to access the anterior chamber of the eye during cataract surgery, capsulotomy and fragmentation of cataract. Femtosecond lasers being used for these applications operate in the near infrared wavelength and are capable of penetrating the transparent and even opaque cornea. They are guided in their intraocular application by 3 dimensional image systems of the anatomy of the anterior segment of the eye. In this way they act in a very precise way, delivering energy to perform corneal incisions, capsulorhexis, softening or breaking the nucleus, thus enabling elimination of the cataract. The surgical procedure performed in this way, helps in optimization of the surgical time and also in minimizing the surgeon's work.

In traditional cataract surgery, the eye surgeon uses a hand-held metal or diamond blade to create an incision in the area where the sclera meets the cornea. The goal in creating this incision is to go a partial depth vertically, then go horizontally in the cornea about 2.5 mm and then enter into the eye. Then the surgeon can break up and remove the cataract, which is located right behind the pupil. Next an intraocular lens (IOL) is inserted and implanted, to replace the cloudy natural lens. Since large incisions (approximately 5 - 7mm in length) were made, sutures (Stitches) were required following surgery in order to ensure that the incisions were adequately sealed. The need for sutures prolonged the recovery process. At present, these procedures, although safe and efficient, are considered to depend greatly on the skill and experience of the surgeon. The use of femtosecond lasers for incision can today guarantee the consistency, stability, precision, length, shape and width of the corneal incisions. This step has considerably improved the process. Clear Corneal Incisions (CCIs) are generally are much smaller around 2mm in length and are considered to be self-sealing implying that no sutures are required. In comparison to scleral incisions, CCIs have reduced some potential complications and have increased the speed of recovery.[2]

A capsule that is very thin and very clear surrounds the eye's natural lens. In cataract surgery the front portion of the capsule is removed in a step called the capsulotomy, to gain access to the cataract. It is important that this capsule should not be damaged during the cataract surgery, because it must hold the artificial lens implant in place for the rest of the patient's life. In traditional cataract surgery, the surgeon creates an opening in the capsule with a small needle and then uses that same needle or a forceps to tear the capsule in a circular fashion. The opening is generally 5 to 6 mm in diameter and well centered for optimal implant fit. Use of femtosecond lasers improves the process substantially in terms of accuracy and reproducibility.

Studies have already shown that the use of lasers helps in carrying out this very important capsulotomy step works much better. Further laser capsulotomy enables better centering of the intraocular lens (IOL), which is a significant factor in determining final visual outcome. An irregularly shaped capsulotomy may influence the position of the implanted IOL leading to decentration and tilt which may cause a decrease in the patient's quality of vision. The ability to create a precise, well-centred capsulotomy should therefore optimize the surgeon's ability to achieve the patient's anticipated visual outcome.

After the capsulotomy, the surgeon now has access to the cataract to remove it. In traditional cataract surgery, the ultrasonic device that breaks up the cataract is inserted into the incision. During this process, the ultrasound energy can lead to heat buildup in the incision, which sometimes can burn the incision and negatively affect the visual outcome by actually inducing astigmatism. Further an incision burn also has a higher chance of leaking and sometimes needs multiple sutures to close.

The laser, on the other hand, softens the cataract as it breaks it up. By breaking up the cataract into smaller, softer pieces, less energy should be needed to remove the cataract, so there should be less chance of burning and distorting the incision. The femtosecond laser has the capability to assist the fragmentation (breaking up) of the cataract. The laser applies a number of pulses to the lens in a pre-designed pattern, which then allows the surgeon to use current technology to remove the lens matter.

Using the laser should also result in less chance of capsule breakage. After the calculation of the proper implant power, there is no step more important for visual outcome than preservation of the capsule where the natural lens was situated. This capsule is as thin as cellophane wrap and is important to leave undamaged so that it can hold the artificial lens implant in the proper position for the best ability to focus. Moreover, the reduced energy of the laser may also make the procedure safer to the inner eye, which reduces the chance of certain complications like detached retina.

The femtosecond laser has the capability to fasten the fragmentation of the cataract. The laser applies a number of pulses to the lens in a pre-designed pattern, which then allows the surgeon to remove the lens matter. This additional step has been shown to reduce the average time and energy required to break up and remove the lens by approximately 50%. Inherently this should make the overall procedure safer and less traumatic to the eye, which may further reduce the risk of postoperative swelling and lead also to a faster visual recovery.[3,4]

Presently Femtosecond (FS) lasers for cataract applications are near infrared lasers with a wavelength around 1030 to 1064 nm because linear absorption and scattering is relatively low in water and non-pigmented tissues including the cornea, aqueous humor, lens, and vitreous. Pulse width is of order of (200 - 500) x 10^{-15}sec and can be focused to a spot size of 2 - 3 microns within a 5 micron in the anterior segment. The use of femtosecond lasers reduces the chances of collateral damage of surrounding tissues. These lasers have energy in the range of 1 - 50 microjules and are capable of operating in the frequency range of 50 to more than 120 kHz.

Diabetic Retinopathy

Diabetic retinopathy is a situation when the retina of a person is affected over a period because of diabetes. It is a result of result of micro-vascular retinal changes and may also lead to macular problems. Small blood vessels in the eye are especially vulnerable to poor sugar control. An over accumulation of glucose damages the tiny blood vessels in the retina. During the initial stage, called non-proliferate diabetic retinopathy (NPDR), most people do not notice any change in their vision. A person may have a blurred vision. This could be because of blood-filled bulges in the artery walls, narrowing or blocked retinal blood vessels or completely lack of blood supply to tissues causing a shortage of oxygen and glucose required for keeping the tissue alive. These damages may also make the retinal blood vessels more permeable. The damaged blood vessels leak fluid and lipids onto the macula, thereby resulting in its swelling and thus leading to blurred vision.

As the disease progresses, severe non-proliferate diabetic retinopathy enters an advanced stage when blood vessels starts growing. The lack of oxygen in the retina causes fragile, new, blood vessels to grow along the retina and in the clear, gel-like vitreous humour that fills the inside of the eye. These new blood vessels can bleed, mar vision, and even destroy the retina. Fibro-vascular proliferation can also cause retinal detachment.

Fundus photography, particularly Fundus Fluorescein Angiography and Optical Coherence Tomography (OCT) are the most commonly used techniques to analyze the leaking, swelling and other problems related to retina.

There are three major treatments for diabetic retinopathy, which are very effective in reducing vision loss from this disease. These include laser surgery, injection of suitable steroids or Anti-Vascular endothelial growth factor (VEGF) into the eye, and Vitrectomy. It is worth mentioning that, although these treatments are very successful in slowing or stopping further vision loss, they, however, do not cure diabetic retinopathy.[5]

Vascular endothelial growth factor (VEGF) is a signal protein produced by cells and helps the system to restore the oxygen supply to tissues when blood circulation is inadequate. VEGF is also important in diabetic retinopathy because the microcirculatory problems in the retina of people with diabetes can cause a restriction in blood supply to tissues, causing a shortage of oxygen, a condition known as retinal ischaemia, which results in the release of VEGF., which may then cause the creation of new blood vessels in the retina and elsewhere in the eye, thereby producing changes that may damage the sight. Injection of suitable steroids or doses of Anti-Vascular endothelial growth factor (VEGF) into the eye helps in protecting the eye deteriorating further.

Vitrectomy is surgery to remove some or all of the vitreous humor particularly clouded vitreous - usually containing blood from the eye. The procedure also helps removal of layers of unhealthy tissue from the retina. In case of diabetic retinopathy, either a non-proliferative or proliferative retinopathy may damage the sight. The proliferative type is characterized by formation of new unhealthy, freely bleeding blood vessels within the eye, which is also called vitreal hemorrhage and/or causing thick fibrous scar tissue to grow on the retina thereby detaching it. When bleeding or retinal detachment occur, vitrectomy is employed to clear the blood, and scar tissues are removed.

During the last decade, lasers are widely being used for diabetic retinopathy. Laser treatment of diabetic eye disease generally targets the damaged eye tissue. Some lasers treat leaking blood vessels directly by "spot welding" and sealing the area of leakage photocoagulation. Other lasers eliminate abnormal blood vessels from the retinal area. Lasers also may be used to intentionally destroy tissue in the periphery of the retina that is not required for functional vision. This is done to improve blood supply to the more essential central portion of the retina to maintain sight. During the photocoagulation surgery, laser is used to finely burn ocular blood vessels and to remove unwanted growth so as to lower the risk of severe vision loss from this disease. A 'C' shaped area around the macula is treated with low intensity small burns. This type of laser energy is aimed directly at the affected area or applied in a contained, grid-like pattern to destroy damaged eye tissue and clear away scars that contribute to blind spots and vision loss. This method of laser treatment generally targets specific, individual blood vessels. Laser photocoagulation process can also be used over the periphery area of the retina. With this method, about 1,200 to 1,800 tiny spots of laser energy are applied to the periphery of the retina, leaving the central area untouched. This helps in clearing the swelling or thickening of the eye's macula. Laser based Photodynamic therapy (PDT) is another treatment for wet age related macular degeneration. In this technique, a light-sensitive medicine called vertiporfin is injected into the bloodstream. The medicine collects in the abnormal blood vessels under the macula. Laser light falling onto the affected area activates the medicine and causes it to create blood clots that block the abnormal blood vessels. By sealing the leaky blood vessels, photodynamic therapy slows down the buildup of fluid under the retina that distorts the shape and position of the macula.[6]

Various lasers being used for diabetic retinopathy treatment include, Argon, dye laser, Nd:YAG and Krypton. Initially argon and krypton gas lasers were used in blue-green wavelengths. Their use was limited because they had short wavelengths, caused light scatter, used high levels of energy, induced photochemical damage, and led to acceleration of cataracts. Tunable dye lasers were the next development in laser technology and were available in yellow (577 nm), orange (597 nm to 622 nm), and red wavelengths (622 nm to 680 nm). However the maintenance of the tunable lasers was expensive and difficult. Further some of the dyes used were carcinogenic. Further research resulted in the introduction of infrared (532 nm) and green (810 nm) wavelengths. The benefits of these lasers include reduced scatter, ease of delivery in dense ocular media, lower cost, and reduced maintenance. The continuous development of solid-state technology has led to the development of 577 nm wavelength lasers. The combined absorption by both melanin and oxy-hemoglobin of 577 nm causes less scatter compared with 532 nm or other yellow wavelengths (561 nm or 568 nm). This new yellow wavelength is exactly matched to the main absorption peak of oxygenated hemoglobin and thus provides a higher degree of tissue selectivity than any previous laser wavelength. Thus, 577 nm wavelength has been described as optimal for macular photocoagulation and treatment of vascular lesions and sub-retinal vascular proliferations. 577 nm lasers are generally diode pumped i.e. optically pumped solid-state lasers (OPSL). These lasers have unique wavelength flexibility and are different from other solid-state based laser. The fundamental near-IR output wavelength is determined by the structure of the InGaAs (semiconductor) gain chip, and can be set anywhere between 920 nm and 1154 nm, yielding frequency-doubled and tripled output between 355 nm and 577 nm. So in an OPSL, the laser wavelength and other operating parameters can be tailored to match the application. Lasers being used for diabetic retinopathy are these 577 nm lasers with output power in the range of 2 - 3 Watt.

Photorefractive keratectomy (PRK) and Laser-Assisted-in-situ Keratectomy (LASIK)
PRK and LASIK are laser based eye surgery procedures being used to correct a person's vision, thereby reducing dependency on glasses. Both these procedures work by changing the shape of the cornea to correct vision problems like nearsightedness, farsightedness and astigmatism. Both these procedures permanently change the shape of the anterior central cornea using a suitable laser such as excimer laser to ablate a small amount of tissue to reshape it. Though PRK and LASIK use basically the same technique, there are minor differences between them. In LASIK, an eye surgeon makes an incision (with either a laser or a blade) in the cornea to create a flap of tissue. The flap of tissue is lifted so the laser can be applied to reshape the inner layers of the cornea. The computer-controlled surgical laser carefully reshapes the layers of the cornea to repair imperfections in curvature that lead to distorted vision. The corneal flap is then put back in place and heals over the reshaped part of the cornea in a few days. In PRK, on the other hand, the eye surgeon does not create a flap of corneal tissue. Instead, the outer layer of the cornea is removed to expose an area for a laser to reshape. It may be mentioned that the outer layer of the cornea, or epithelium, is a soft, rapidly re-growing layer in contact with the tear film that can completely generate itself within a few days with no loss of clarity. The deeper layers of the cornea, on the other hand, are laid down early in life and have very limited regenerative capacity. The deeper layers, if reshaped by a laser, will remain that way permanently with very little possibility of getting changed with time.

The most significant differences between PRK and LASIK are the initial discomfort and the speed of visual recovery. Recovery from PRK takes a little longer than from LASIK because the outer layer of the cornea needs time to heal. LASIK recovery, on the other hand, is much faster. The discomfort following LASIK surgery is usually mild and short term. While most patients report seeing normally within several hours after the procedure, their vision continues to improve gradually for several months before reaching peak quality.[7]

These eye surgeries usually employ excimer laser ArF (193 nm), as this laser can control the corneal surgery very accurately. Energies greater than 200 mJ/cm^2 are used to ablate the tissues. One pulse of excimer laser removes about 0.25 microns of tissue at a time, whereas the laser overall ablates a very thin surface layer of the order of 5 - 10 micron.

The other laser being used for PRK / LASIK is an Nd: YAG / Glass based Femtosecond (FS) laser operating in the infrared wavelength range of 1053nm. This laser like Nd: YAG laser works by producing photodisruption or photoionization of the optically transparent tissue such as the cornea. Application of either FS laser or Nd:YAG laser results in the generation of a rapidly expanding cloud of free electrons and ionized molecules. The acoustic shock wave so generated results in disruption of the treated tissues. However, in the case of FS laser, the pulse duration is in the femtosecond range (10^{-15} second). Reducing the pulse duration reduces the amount of collateral tissue damage and that is what makes FS laser safe for use in corneal surgeries, which require exquisite precision. Both high energy (micro joules with pulse width of 900 - 1000 femtoseconds) with frequencies in the range of kHz and low energies (nano-joules with pulse widths of the order of 200 femtoseconds) with frequencies in the range of MHz have been used for these applications. The advantages with femtosecond lasers include faster uncorrected visual acuity recovery and less induced aberrations Dry eye is the most common side effect of LASIK, with up to 90% of patients having some sign or symptom. Femtosecond laser flaps have a relatively lower incidence of dry eyes, which is probably owing to the thinner, more uniform flap geometry.

Soon after the invention of ruby laser, it was used for treatment of skin diseases in 1963. With the invention of CO_2 and argon lasers, they were also used to treat benign vascular birthmarks. Although these birthmarks could be effectively lightened, it produced a side effect of scar formation, which was unacceptable. In the last few decades, revolutionary advances in laser technology produced a large number of lasers, lasing at different wavelengths. These have been used for the treatment of many skin conditions, like skin resurfacing, pigmented lesions, the removal of tattoos, scars, wrinkles etc and hair removal. Nowadays there is a wide spectrum of lasers available for skin resurfacing and rejuvenation. Dermatology is the science where the skin, structure, functions and the diseases connected with it are treated. The treatment is based on the absorption of laser energy by the target tissues, which get heated up to produce the desired result. The absorption characteristics of various tissues depend on the wavelength of the laser and presently there are a large number of lasers available with different wavelengths. Further, it is possible to focus the laser energy to a very small skin area without damaging the surrounding skin.[8]

Nowadays, a number of lasers are used in dermatological applications. They are argon laser (488nm & 514nm), tunable dye lasers (585 to595nm), doubled Nd:YAG (532nm), krypton laser (568nm), alexandrite laser (755nm), Nd:YAG (1064nm), Er:YAG (2940nm), CO_2 laser (10600nm) etc. The pulse width of these laser systems vary from milliseconds to nanoseconds (pulsed) or the laser may be of continuous nature (CW). Physicians have to select the most appropriate laser systems to get the best results. Cosmetic and aesthetic problems of various dermatological conditions can be successfully treated by these laser systems. Protective laser eye ware is a must during the laser treatment for the protection of the eyes from the laser. The reader may kindly see the article on laser safety to get a comprehensive idea about this aspect.

It has been already emphasized that absorption of laser energy by the tissue leads to heating of the same, which is basically burn. This is likely to produce temporary pain, redness, bruising, pigment changes, scarring and reactivation of herpes simplex. In laser-tissue interaction, thermal coagulation causes cell necrosis, homeostasis, welding, sealing of nerve endings. Heat is absorbed by melanin pigment, water, blood vessels etc, where each of chromophores has selective wavelength absorption. Thus for various dermatological treatments, different types of lasers are required.

Three factors, namely melanin, hemoglobin and scattering are the basics in laser application in dermatology and cosmetology

Melanin is the first pigment that encounters the laser. The skin is protected by melanin from excessive sunlight, especially UV. This physical property of melanin interferes with laser surgery depending on the type of lesion treated. Melanin occurs mainly in the epidermis and hair follicles and absorbs various wavelengths across the electromagnetic spectrum.

Hemoglobin contains iron and blocks to a great extent laser transmission into tissues. The optimum absorption of hemoglobin is between 514 - 590 nm and has three absorption peaks at 415nm (blue), 540nm (green) and 577nm (yellow). The blue band of oxy hemoglobin is used for targeting superficial micro vessels. The blue band penetrates deeper target tissues. Blood absorption is dominated by oxyhemoglobin and reduced hemoglobin absorption that exhibits strong bands in the UV, blue, green and yellow bands. The 577 nm (yellow) absorption band of oxyhemoglobin was chosen for targeting superficial micro vessels by selective photo-thermolysis. The blue band (420 nm) or higher band 900nm penetrates more deep and can affect deeper target tissues.

Scattering is an important factor in laser-target interaction in laser treatment. The target tissue may absorb scattered or reflected laser energy. Laser entering the tissue is basically scattered by interaction with water, lipids and cellular membrane. Further shorter wavelengths in the visible region, scatter more than the longer ones. Scattering is important in laser treatment since scattered energy gets deposited in the nearby tissues. Scattered light is ultimately absorbed with the subsequent release of heat. Scattering is one mechanism whereby; heat is lost from the lesion being treated and is deposited in non-target tissue, thereby producing collateral damage. Scattering is also the reason that the outline of bones cannot be seen when the hand is trans-illuminated.

As already stated, melanin, hemoglobin and scattering are the basics in laser application in dermatology and cosmetology. The average kinetic excitation of molecules is directly related to temperature. Basically, thermal coagulation is a burn. As the temperature is raised to 100 degree centigrade, proteins, DNA, RNA, membranes and their integral structures start to melt denature and coagulate. Thermal coagulation causes cell necrosis, homeostasis, welding, ceiling of nerve endings and gross alteration of the extra cellular matrix occurs. Carbon dioxide lasers evaporate tissue water. Other lasers target the skin pigment such as pigmented cells, blood vessels and tattoo particles. Tissue damage depends on the rate of energy deposition in the target. As already stated earlier, heat absorption is the fundamental processes in the interactions of light with the tissue target. Heat is absorbed by melanin pigment, water, blood vessels etc. But each of these has a selective wavelength absorption. The absorption coefficient depends on the concentration of the chromophores present in the lazed tissue.[9]

Laser systems can be generally divided according to their principle of action and clinical effects into ablative and non-ablative lasers. Ablative lasers like CO_2 and erbium lasers break the integrity of superficial skin layers, whereas non-ablative lasers like intense pulsed light (IPL) and Nd:YAG lasers achieve therapeutic effect not by breaking the integrity of skin, but through biological action of the light itself.

Cosmetic dermatology

Though the emphasis on the beauty of the skin has always been a primary consideration, the diseases of the skin and its treatment have taken a new turn with the invention of lasers. From the very invention onwards, lasers have played a very important role in dermatological applications. Some of the important and common applications are given below.

- Skin resurfacing
- Pigmented lesions
- Tattoos
- Hair removal

These will be discussed below.

- Skin resurfacing

Laser peel or laser vapourisation is termed as laser skin resurfacing. Laser skin resurfacing can reduce facial wrinkles, scars and blemishes. Minor flaws like scars due to acne or chickenpox, sun damaged or aged skin, warts, birth marks, stretch marks, wrinkles or fine lines around or under the eyes and fore head, non-responsive skin after face lift etc can be treated effectively by laser skin resurfacing. The surgeon exposes laser on the irregular skin and removes one layer at a time in a precise manner to achieve the best results. Skin resurfacing laser beam removes the epidermis (outer layer of skin). The under lying skin is simultaneously heated up and this action stimulates the growth of new collagen fibers. Once the area treated heals, the deep dermis is stimulated to produce natural collagen and other vital proteins for forming smoother, firmer, healthy and youthful skin. Facial laser resurfacing uses high energy, long pulsed, short pulsed and continuous wave (CW) lasers. Q-switched NdYAG laser (1064 nm) is used to treat scars and wrinkles at their root, deep in the skin. The treatment takes less than half an hour and about 6 sittings are needed in monthly intervals to get the skin toned. This procedure avoids long recovery time as in the case of other treatments. The treated area should not be exposed to sun for some time. Frequency doubled Nd:YAG at 532nm is a well-established technology for treating photoaging. Pulsed CO_2 and Er:YAG lasers have been successfully used in removing wrinkles, acne, sun damaged skin. Though side effects like post-operative tenderness, redness, swelling and scarring occur, the treatment can produce excellent results. Hypertrophic scars are difficult to eradicate with traditional treatments, Vapourising lasers like Er:YAG and CO_2 lasers have been used successfully in these cases. Recently pulsed dye lasers have been used to improve hypertrophic texture and pliability and reduce the redness of scars. It is reported that multiple treatment sessions with various lasers give very good results. Metal halide lasers like copper bromide (407 - 420nm) have been used to treat acne.

- Pigmented lesions[10]
  Q-switched Nd:YAG laser at 1064 nm wave length and its doubled output at 532nm are best suited for the treatment of dermal and epidermal pigmented lesions. Acquired lesions and other flat-pigmented birthmarks respond well at 1064 nm, but a number of sittings are required for total removal of the lesion. Hyper pigmentation of skin is caused by excess production skin pigment melanin, which appears as dark brown or black spots on skin. Earlier microdermabrasion and peeling have been tried with partially successful results for treatment of lesions, tattoos, freckles, etc. But these are found to be not much amenable to the above line of treatment. Advent of laser changed this scenario and presently a number of lasers are available for the safe and efficacious treatment of cutaneous pigmented lesions due to the wide spectrum absorption of laser energy by the melanin with minimized damage to the surrounding tissues. Most of the pigmented lesions whether epidermal and dermal can be treated with Q-switched lasers giving out put in the blue, green or infrared region. Lentigines have been successfully treated with 532nm laser, but risk of hyper pigmentation is a reality. Sun exposure for about 6 weeks should be avoided to minimise this. In the case of freckles also, the same treatment is effective and avoiding sunlight for few weeks is recommended to counter the risk of hyper pigmentation. Treatment with Q-switched Nd:YAG laser (1064nm) for dermal pigmented lesions and other flat pigmented birth marks is very successful, but a number of sessions are required for total clearing. Lasers giving output from 400nm to 1100nm are most suitable for treatment of pigmented lesions. It is found that it is not only the wavelength, but the right pulse duration also plays an important part. Long pulsed duration lasers cause lot of damage to surrounding skin, which is not the case with Q-switched lasers.
- Tattoos
  Lasers have become an efficient tool for the removal of tattoos, sun-spot and other pigmented lesions for the last many years. Basically the laser breaks the unwanted pigments into smaller particles. These are then removed through the natural processes of the body. The colour and the size of the area of the skin play a very important role in the number of the sittings required for the best results. Nd:YAG laser is used for the removal of sun spots, tattoos and pigmented lesions successfully without damaging the surrounding tissues. Though with a few sittings superficial sun-spots can be removed, large moles and lesions with deeper pigment may take several sittings to get the best results. It may be noted that colour of the tattoos especially green and blue ink are less responsive to laser treatment. It is recommended to avoid exposure to direct sun light for some time as the treated skin becomes photosensitive. Though earlier ruby (694nm) and alexandrite laser (755nm) have been used, but they have not given good results. Presently Q-switched Nd: YAG 1064nm is employed and due its longer wave-length (compared to ruby and alexandrite lasers), shorter pulse width (nano-seconds) and its higher intensity levels are found to be better for the black and blue tattoo pigment. In this case scarring and hypo pigmentation risks are found to be very low. Response to Nd:YAG laser is very much depends on the type of tattoo. For example, ink used for amateur tattoos is easy to remove whereas in the case of professional tattoos, the ink is distributed in the subcutaneous tissue and as such for complete success about 6 sittings are required. In the case of cosmetic tattoos, iron ink is used for eye-brows, eye and lip line. There is a possibility of this turning black due to oxidization and a test patch is necessary. Dark lips are very common cosmetic concern and the same may be treated with frequency doubled Nd:YAG at 532 nm to produce lip lightening.
- Hair removal
  Laser or light-assisted hair removal offers an efficient way to permanently reduce excessive hair growth. Laser hair removal is the process of removing unwanted hair by means of exposure to pulses of laser light that destroy the hair follicle and is being now widely used throughout the world. Lasers can cause localized damage by selectively heating dark target matter, melanin, in the area that causes hair growth, the follicle, while not heating the rest of the skin. Since light is absorbed by dark objects, implying that the laser energy can be absorbed by dark material in the skin with much more speed and intensity. This dark target matter, or chromophore, can be naturally-occurring or artificially introduced. Melanin is considered the primary chromophore for all hair removal lasers currently being used. Melanin occurs naturally in the skin, and gives skin and hair their color. Several wavelengths of laser energy have been used for hair removal, from visible light to near infrared radiations. These include Argon (488 nm), ruby (694.3 nm), Alexandrite (755 nm), Pulsed diode (810 - 820 nm), Nd:YAG (1064 nm).

It would not be out of place to mention that there are certain adverse effects of laser treatments, as these are basically burns. These include:

- Pain, bruises, blisters, redness may occur as temporary effects
- Possibility of infection
- Permanent pigment changes
- Rare occurrence of scarring

However, managing complications should start with the beginning of the treatment, choosing the right parameters. It may be mentioned that recurrence of some of the dermatology problems, like melasma (gray - brown patches) and freckles is a possibility. Hypo and hyper pigmentation are the most common complications observed in the treatment of pigmented lesions. If hypo pigmentation is speckled the treatment has to be stopped. Treatment may be started after 2 - 3 months, once the hypo pigmentation resolves then the laser treatment can be started, at lower fluence. Temporary erythema (redness of skin), edema (swelling) and urticaria (skin rashes) are transient and settle in a few hours.[11]

Applications of Lasers in Cardiology
Lasers are being extensively used in cardiology in various areas such as angioplasty, thrombolysis and transmyocardial laser revascularization. These are briefly discussed here:

Angioplasty is the procedure of mechanically widening narrowed or obstructed arteries. An empty and collapsed balloon on a guided wire, usually known as catheter, is passed into the narrowed locations and then inflated. The inflated balloon forces expansion of the inner plaque deposits and the surrounding muscular wall, opening up the blood vessel for improved flow, and the balloon is then deflated and withdrawn. A stent may or may not be inserted at the time of ballooning to ensure the vessel remains open. Lasers may be used to help break up the plaque or fat deposits. Laser angioplasty is similar to balloon angioplasty, but instead of a balloon-tipped catheter, one with a laser at the tip is used. The laser is guided to the blockage and then used to destroy the plaque, layer by layer, by vaporizing it into gaseous particles. The laser can be used alone, or in combination with balloon angioplasty. Most commonly used laser for this application is a pulsed XeCl Excimer laser having an output wavelength of about 308 nm, with each pulse having a duration between 100 nsec and 3000 nsec and can deliver energy density of at least 50 mJ/mm^2 to ablate plaque in a blood vessel.

Laser thrombolysis is a means for clearing blood clots present in occluded arteries as a result of myocardial infarction. Myocardial infarction occurs when blood stops flowing properly to a part of the heart, and the heart muscle is injured because it is not receiving enough oxygen. Usually this happens because one of the coronary arteries that supplies blood to the heart develops a blockage due to formation of blood clot as a result of unstable build up of white blood cells, cholesterol and fat. Many researchers have studied the mechanisms of clot ablation, and research clinicians have used the technique to treat with a number of different laser systems. Notable among these lasers are the excimer (308nm, 351nm, 100 - 200ns), tunable pulsed-dye (400 - 600nm, 1μs), and the Ho:YAG (2.1μm, 250μs) lasers. The excimer and holmium lasers are particularly popular because of the potential for a single laser system to treat both plaque and thrombus. The excimer laser targets the tissue proteins, while the holmium energy is absorbed by tissue water. Energy densities of the order of 20mJ/mm^2 are required for ablation of these clots.

Transmyocardial laser revascularization (TMLR) is a procedure, which is used on patients where the problems related to coronary artery, still exists even after most of the conventional therapies have been exhausted. Typically, these patients continue to have chest pain while on maximal medical therapy, and most are at an extraordinary risk for surgical intervention. Transmyocardial laser revascularization (TMLR) is based on the use of a high-powered carbon dioxide or other laser that interjects a strong energy pulse into the left ventricle, (one of two large chambers that collect and expel blood) vaporizing the ventricular muscle and creating a transmural channel with a 1 mm diameter. The procedure can be used to create 15 - 20 channels along the free left ventricular wall. These channels are placed 1 cm apart in the ischemic myocardium. TMLR is performed to improve myocardial oxygenation, eliminate or reduce angina, and improve the patient's cardiovascular function.

Three types of lasers are being used in these procedures: the carbon dioxide (CO_2), the holmium:yttrium-argon-garnet (Ho:YAG), and the excimer lasers. Of these, the Food and Drug Administration (FDA) has approved only the CO_2 and Ho:YAG lasers for use in TMR. CO_2 (10.6 micron) and the Ho:YAG (2.1 micron) lasers rely on thermal energy to create channels, whereas the excimer laser (308 nm) ablates tissue by dissociating molecular bonds. The CO_2 laser is transmitted through a series of mirrors and lenses. Whereas, the Ho:YAG and the excimer lasers allow the laser beam to be transmitted by an optical fiber. Usually high-energy pulses of 40 - 60 J with pulse width of few tens of milliseconds of CO_2 lasers are required for these procedures. Ho:YAG lasers used for these applications are generally with a peak power of around 10W and pulse width of 200 - 400 microseconds. Excimer lasers employed for these applications are usually 30 - 100 nanosecond pulses with energies in the range of few tens of milijoules per pulse.[12]

Lasers In Dentistry

Lasers have been in use in dentistry for the last more than two decades. These are being used to treat various problems such as tooth decay, gum disease, biopsy or lesion removal and teeth whitening etc. Lasers act as a cutting instrument or a vaporizer of tissue that it comes in contact with. When used for "curing" a filling, the laser helps to strengthen the bond between the filling and the tooth. When used in teeth-whitening procedures, the laser acts as a heat source and enhances the effect of tooth-bleaching agents such as hydrogen peroxide. Compared to the traditional dental drill, lasers have the advantages of less pain thus reducing the need of anesthesia and minimum bleeding and swelling during soft tissue treatments.

Lasers use a light beam to cut away tooth decay before filling cavities, resulting in less vibration and pain than traditional drills. Lasers in this case work by heating water molecules in the tooth, which then expand and dislodge decayed tooth structure. Lasers being used for these applications are Er:Cr:YSGG operating at 2.78 micron with pulse width of 60 - 700 microseconds and are capable of delivering energies up to 400 millijoules.

For teeth whitening applications, mainly to enhance the bleaching effect, typically laser-absorption-enhancing particles are added to the gel. The particles are capable of absorbing the light energy from the wavelength of light emitted from the laser and of re-transmitting the light energy as thermal energy. For example, an argon ion laser utilizes a blue light with a wavelength in the range of 470 nm to 520 nm. The complementary color to blue is orange, and thus an orange or red-colored or pigmented particulate material that absorbs in this range is added. Also preferred are other colours that absorb at the wavelength of the utilized laser light. A black particulate material absorbs across all wavelengths and would thus also be suitable. Other typically used lasers for heat-enhanced teeth whitening are diode lasers with a wavelength of 810 nm or Nd:YAG lasers with a wavelength of 1064 nm. Some of the disadvantages of the existing laser light enhancing methods is that the laser light is may not be fully absorbed in the relatively thin layer of the gel that is deposited on the tooth surface. As a result, the laser is transmitted into the dental tissue, which may lead to an undesired heating of the whole tooth and of the dental pulp, possibly leading to pain and irreversible damage. Recently a pulsed Er:YAG laser beam has been used for these applications. The procedure makes use of the fact that the Er:YAG laser wavelength (2.94 micron) is at the water absorption peak in the vicinity of 3 micron. The fact that the Er:YAG laser wavelength is absorbed in the major component of the aqueous bleaching gel, i.e., in water, eliminates the need for any additional absorbing particles in the gel. Further the laser parameters are adjusted for the bleaching treatments so that the laser fluence of every laser pulse is between 0.3 - 0.5 J/cm^2, which is significantly below the ablation threshold (3.5 J/cm^2) of dental tissues. This implies that there is no risk of accidentally damaging the hard dental tissues. Lasers used for teeth whitening applications include Er:YAG (2.94 micron), power 0.5 - 0.8 W, 10 Hz frequency, pulse duration 700 microsecond with total energy requirement of about 20 - 30J.

Gum disease is caused by bacteria, which feed on acids from foods and create a sticky paste around the gum-line called plaque. If the plaque is not removed with regular brushing, flossing and professional periodontal maintenance hygiene visits, it hardens into tartar. This irritates the gums and leads to infected gum tissue, causing sensitivity and bleeding. As the infection advances, the gums pull away from the roots of teeth, and deep pockets form below the gum-line. Gum disease, also known as periodontal disease, is treated by physically removing the bacteria, plaque and calculus from underneath the gums. The bad bacteria, which cause periodontal disease, can be removed in several different ways. A traditional approach of doing so is scaling and root plaining. Scaling involves the removal of the plaque and calculus deposits on the tooth surfaces, while root planing is the smoothing of the root surfaces in order to promote reattachment of the gum tissue to the tooth. The procedure is followed by a surgery, known as osseous surgery, for bacteria pocket reduction. Reducing pocket depth and eliminating existing bacteria are important to stop the decaying process and to prevent further damage caused by the progression of periodontal disease. A more modern approach is by a minimally invasive procedure called Laser Assisted New Attachment Procedure (LANAP) also known as laser periodontal therapy or laser gum therapy. LANAP which s a registered trademark of Millennium Dental Technologies, makes use of the wavelength of laser light targets diseased or infected pocket tissue away from the underlying connective tissue. Since the laser energy is quite selective for diseased tissue, the underlying connective tissue is not affected, thereby permitting healing and regeneration. This therapy involves the use of a specialized laser. Nd:YAG laser is specifically designed for these applications. This laser is a fiber compatible 6 watt free running Nd:YAG with pulse with in the range of 100 - 600 microsecond.

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Lesions are small, shallow ulcers that appear in the mouth and often make eating and talking uncomfortable. Also known as canker sores, these lesions are almost always found on the "loose" tissues of the mouth; i.e. the cheek, inner lip, tongue, soft palate, floor of mouth, and sometimes the throat. They are usually small, less than one half centimeter in diameter. A reddish halo usually surrounds them. Laser treatments are the most effective, giving immediate pain relief and causing the ulcer to heal in 24 - 72 hours. Laser vaporization offers a precise means of treating mouth lesions that reduces the potential for pain and scarring, since laser wounds heal almost without any scar formation. The lasers can be both a continuous or pulsed light and both create an intense beam of light energy that when directed at mouth tissue, converts into heat. There is a photo-thermal reaction, which vaporizes the ulcer without damaging the surrounding tissue. As the laser is passed over the ulcer for several minutes, the patient feels a warming sensation, but no pain. The laser disinfects the ulcer, reduces the inflammation, and relieves pain, and the overall result is faster healing of the lesion. The laser also seals the nerve endings, which reduces pain immediately. Lasers used for these applications are known as Low Intensities Laser Therapy (LILT). These lasers make use of 50 - 700 mw (0.05 - 0.7 W) power that can help with both a reduction in pain and provide for quicker healing compared to steroid treatment. Various laser wavelengths have been found to be effective in the treatment of Lesions including HeNe (660nm), Nd:YAG (1064 nm), Erbium:YAG (2940nm) and diode laser (780 nm).[13]

Lasers for Cancer treatment

Lasers can be used either to shrink or destroy a tumor with heat or to activate a chemical - known as a photosensitizing agent - that kills only the cancer cells. This process is generally known as photodynamic therapy or PDT. The CO_2, argon, Ho:YAG and Nd:YAG lasers are used to shrink or destroy tumors. They can be used with thin, flexible tubes called endoscopes that let doctors see inside certain parts of the body, such as the bladder or stomach. The light from some lasers can be sent through an endoscope fitted with fiber optics. This lets doctors see and work in parts of the body that could not be reached otherwise except by major surgery. Using an endoscope also allows very precise aim of the laser beam. In photodynamic therapy (PDT), a special drug called a photosensitizing agent is put into the bloodstream. Over time body tissues absorb it. The drug stays in cancer cells for a longer time than in normal tissue. Shining a certain kind of light on the cancer cells that have the drug in them "turns on" the drug, which then kills the cancer cells. Photosensitizing agents are turned on or activated by a certain wavelength of light. For example, an argon laser can be used in PDT. When cancer cells that contain the photosensitizing agent are exposed to red light from this laser, it causes the chemical reaction that kills the cancer cells. PDT has some advantages over other treatments such as Cancer cells can be singled out and destroyed but most normal cells are spared. Further the damaging effect of the photosensitizing agent happens only when the drug is exposed to light and the side effects are fairly mild. The CO_2, argon, Ho:YAG and Nd:YAG lasers can shrink or destroy tumors and can be used with endoscopes. CO_2 and argon lasers can cut the skin's surface without going into deeper layers. Thus, they can be used to remove superficial cancers, such as skin cancer. Typical powers used for CO_2 and Nd:YAG lasers lie in the range of 10 - 60 W whereas Ho:YAG lasers are pulsed and have energy is the range of 0.5 - 1.0 J for vaporization of cancerous tumors. In case of argon ion laser, the energy requirement for these applications lies in between 60 - 100J/cm^2. In contrast, the Nd:YAG laser is more commonly applied through an endoscope to treat internal organs, such as the uterus, esophagus, and colon. Laser-induced interstitial thermotherapy (LITT), or interstitial laser photocoagulation, also uses lasers to treat some cancers. LITT is similar to a cancer treatment called hyperthermia, which uses heat to shrink tumors by damaging or killing cancer cells. Nd:YAG laser light can also travel through optical fibers into specific areas of the body during LITT. Argon lasers are often used to activate the drugs used in PDT and of argon ion the energy requirement for argon ion laser for these applications lies in between 60 - 100J/cm^2.

Low-Level Laser Therapy (LLLT)

Low-level laser therapy affects cellular activity in many ways such as stimulating cell growth; increasing cell metabolism; improving cell regeneration; producing an anti-inflammatory response; producing an edema reduction; reducing fibrous tissue formation; stimulating nerve function. There are no known permanent or serious side effects from appropriately applied laser therapy.

LLLT uses low-powered laser light in the range of 1 - 1000 mW, at wavelengths from 632 - 1064 nm helps in Neurorehabilitation by stimulating a biological response. These lasers emit no heat, sound, or vibration. Instead of generating a thermal effect, LLLT acts by inducing a photochemical reaction in the cell, a process referred to as biostimulation or photobiomodulation.

There are several application techniques for utilizing low-level laser therapy on patients. The first is tissue saturation of the involved area. This may be performed by pressing the emitter or probe on the skin and holding there for a period of time and then moving it to an adjacent area, in a grid pattern until the entire area is covered. Scanning or back-and-forth movement for the duration of the treatment time also might be employed for saturating the tissues. Maintaining firm pressure on the skin surface with the emitter or probe enhances laser tissue penetration. This helps displace capillary blood flow in the superficial tissues, which decreases blood flow to the treatment area. This is desirable because photon penetration into the tissue is inversely proportionate to the amount of water content in the tissues. Blood has high water content, so it will tend to absorb more of the photon energy. This will result in less penetration into the deeper tissues. The second treatment approach is to treat trigger points. The third treatment approach is acupuncture point stimulation or laserpuncture. There have been considerable numbers of studies performed on laser stimulation of acupoints.[14]

Lasers being used are generally diode lasers based on Gallium-Arsenide (GaAs) operating in various wavelength ranges such as 630 - 700 nm, 780 - 890 nm and 900 - 1100 nm. These can be continuous or pulsed. Red-light lasers have the least amount of penetration of the three lasers with a range of 6 - 10 mm. They affect the skin and superficial tissue. Near infrared laser, on the other hand can penetrate 2 - 3 cm in depth. These wavelengths often are utilized for medium to deep tissue structures such as muscles, tendons and joints

Pulsed Diode lasers in the 10 - 100 watt range with 100 - 200 nanoseconds pulse width allows for deep penetration of 3 - 5 cm into body tissues without causing the unwelcome tissue effects of continuous high-power output, such as heat production. Pulsed lasers in general have deeper penetration as compared to the CW laser of the same wavelength having same average output power. These lasers are extremely well suited for medium and deep tissues, such as tendons, ligaments and joints.

Recently light-emitting diodes (LEDs) and infrared-emitting diodes (IREDs) have also been used for phototherapy. approximately 80 percent of the effect on tissues as lasers. The most commonly used light diodes for phototherapy are: visible red (630 nm, 640 nm, 650 nm and 660 nm) and IRED (830 nm, 880 nm and 950 nm). As compared to lasers, Light Diodes need much higher powers.

Red light at 640 nm has been shown to affect skin, so it might be effective in treating cuts, scars, trigger points and acupoints. Usual depth of penetration is less than 10 mm. The 880 nm IR phototherapy has been shown to affect deeper structures such as bone, tendons, deep muscles or other tissues up to 30 - 40 mm. Advantages of LEDs are numerous such as: no tissue damage, broad coverage because of non-coherent light. However these devices cover large areas and require several watts of power output. These figures are achieved by LED/IRED therapy because of large arrays of 40 - 60 diodes with a high power output.

Phototherapy applications are safe and usually require only a few minutes to perform. The following painful conditions have been shown to be quite responsive to phototherapy: carpal tunnel syndrome, muscle strains, tendonitis, neck and low back pain, joint sprains, tennis/golfer's elbow and soft-tissue injuries.

In addition to the above-mentioned main applications, lasers are now also being used for the following applications:

Lasers are being used in wide range of gynecological applications, from the simple removal of lesions, to bloodless high-precision cutting. Procedures such as laser removal of HPV (human papillomaviruses) lesions from the cervix, condyloma (genital infection caused by HPV) treatments, balanitis (Inflammation of males genital parts) treatments and various other laser surgeries have been reported successfully using Er:YAG and CO_2 lasers.

Nd:YAG and CO_2 lasers are also being used in Neurosurgery The procedure offers a new, minimally invasive laser therapy to remove tumors or diseased brain tissue that is too deep inside the brain to safely access with usual neurosurgical methods. Light energy from a laser is used to destroy the abnormal tissue with precision accuracy, guided by advanced MR imaging. This procedure is an excellent option for persons with deep brain tumors or seizures caused by abnormalities deep within the brain, who have not been helped by medication and for whom surgery would normally be considered unsafe.[15]

Following table briefly outlines various lasers for different medical applications.

Laser	Wavelength	Power / Energy	Applications
Nd:YAG	1.064 micron and 1.320 micron	Upto 100 W / upto 3.5 J/pulse	Urology, Tatoo removal, Ophthalmology, Neurosurgery, Gynecology, Cosmetic
Frequency doubled Nd:YAG (Potassium-titanyl-phosphate: KTP)	0.532 micron	Upto 180 W	Urology, Pulmonology
Copper Bromide / vapour	510, 578 nm		Dermatology

Laser	Wavelength	Power / Energy	Applications
Ruby (Q-switched)	694 nm		Dermatology
Fiber lasers	1040 - 1045 nm	Upto 20 W	Ophthalmology
Ho:YAG	2.1 micron	Upto 100 W	Urology, Orthopedics,
Er:YAG	1.54 micron, 2.94 micron	Upto 100 W / Upto 5 J/cm^2	Dermatology, Cosmetic,
Thulium:YAG / Thulim : silica fiber	1900 - 2000 nm	200 W	Urology, Gynecology, Neurosurgery. ENT, Pulmonology
Argon	488, 514 nm	Upto few watts / upto 100 J/cm^2	Urology, Tatoo removal, Ophthalmology, Photodynamic Therapy, Dermatology
Dye lasers	577 - 680 nm	Upto 120 mJ / upto 12 J/cm^2	Tatoo removal, Urology,
Alexandrite (Q-switched)	755nm	Upto 100 mJ	Tatoo removal, Urology
Semiconductor laser	800 - 980 nm	Upto 200 W	Urology, Dentistry, Surgery, LLLT
Ho:YAG	2.1 micron	Upto 100 W / upto 3.5 J/pulse	Urology, Gynecology, Neurosurgery. ENT, Pulmonology
Excimer	190 - 350 nm	Upto 400 mJ/cm^2	Ophthalmology
CO_2 laser	10.6 micron	Upto 50 W / 100mJ per pulse	Surgery, Urology, Dermatology, ENT

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