# LASERS
# 2. USES IN OPHTHALMOLOGY

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Ophthalmologists have been in the forefront for developing medical applications for new laser technology since the construction of the first laser in 1960.[1] Photocoagulation was the earliest therapeutic laser procedure and it remains the one most widely employed. There are a number of ocular applications, primarily in the retina but also in the anterior segment and the details of most of these clinical therapeutics will be discussed in this paper.

## Laser Instrumentation

### Main components

An ophthalmic laser consists of three main components.

Console
Control panel
Delivery system

1. Console
   The console contains the laser medium and tube, power supply and laser control systems.
2. Control panel
   The control panel is a separate module. It contains the dials or pushbuttons for controlling various parameters of the laser beam (spot size, power, and duration). All lasers have an exposure counter and some offer the facility of single or repetitive firing. Most control panels contain a standby switch as a safety measure.
3. Delivery system:
   The delivery system is usually via a fibreoptic cable attached to a binocular stereoscopic slit-lamp microscope. Fibreoptic attachments are also available for indirect ophthalmoloscopes and vitrectomy probes (endophotocoagula-tion). The $CO_2$ laser uses a hand-held operating instrument. Contact laser probes (Nd-YAG) are made of synthetic ceramic material and are used in direct contact with the tissue.

### Aiming beam

The aiming beam in all visible light lasers is an attenuated form of the actual treatment beam. In non-visible infrared lasers (Nd-YAG, diode) one or more red helium-neon beams are superimposed on the treatment beam to allow aiming and focusing.

### Laser switch

The surgeon can use a foot switch to activate the laser beam or in some models a hand switch is incorporated in the slit-lamp joystick.

### Safety filters

Safety filters are placed in the laser delivery system between the patient and the surgeon. In visible light lasers this is activated at the instant of laser energy release, preventing reflection of the treatment beam into the surgeon's eyes. This type of mechanical filter makes an intrusive clicking noise and may add to the patient's anxiety unless its purpose is explained. Infrared lasers (Nd-YAG, diode) contain a permanent filter protecting the surgeon (but not filtering the visible helium-neon beam). These lasers are therefore usually quieter to use.

### Corneal contact lenses for laser use

Various contact lenses are used in conjunction with slit-lamp laser delivery systems, depending on the tissue being treated:

a. Single mirror gonio lens

For the treatment of angle structures.

b. Abraham or Wise iridotomy lens

These lenses contain a high + dioptre magnifying 'button' which decreases the laser spot size and increase the power density. The button further provides a highly convergent beam which helps to protect tissues anterior and posterior to the target.

c. Goldmann style 3-mirror lens

Which contains a central magnifying lens (for posterior pole treatment) and 3-angled mirrors set at angle to allow visualisation of the fundus from the equator to the ora serrata. The smallest mirror can be used as a gonio lens. This lens provides a mirror image of the target tissue and its use can be daunting for the beginner.

d. Panretinal lenses (e.g. Rodenstock, Mainster, Volk-Quadrispheric)

Provide a wide angle indirect view of the fundus and are used in panretinal photocoagulation. The relative low magnification results in loss of detail and these lenses are therefore not suitable for treatment of macular lesions.

### Preparation of the patient for laser therapy

A detailed history and clinical examination will be required before undergoing any laser therapy. Special attention should be given to checking the visual acuity, intraocular pressure a base line colour fundus photograph and if required fundus fluorescein angiogram. An informed consent must be taken before any procedure.

### Anaesthesia

Most of the procedures will be able to be carried out while the patient is fully awake and only with the topical anaesthetic drop. However, some cases like treatment with krypton laser and trans-scleral YAG laser cycloablation, will require retro-bulber anaesthesia. General anaesthesia will be required while treating children and very uncooperative patients.

### Position of the patient

A correct position of the patient on slit lamp is very important. Both the patient and surgeon should be sitting comfortably. The height and the distance of the chair from the machine should be properly adjusted as the procedure may take several minutes. Pupil will be required to be dilated for treating fundus condition while for iridectomy it will need to be constricted.

Laser techniques used in glaucoma.

These include the following procedures.
Laser iridectomy
Argon Laser trabeculoplasty
Laser filtration surgery
Trans-scleral cycloablation
Argon Laser direct cycloablation.

### Argon Laser Iridectomy

Argon laser is capable of creating peripheral iridectomy in most patients by thermal coagulation, vapourization, and necrosis.[2] Adequate light absorption to achieve an opening depends on heating the underlying melenotic pigment epithelial. Indication for laser iridectomy includes pupil block in primary angle closure glaucoma, prophylactic iridectomy in the fellow eye, primary open angle glaucoma with narrow angle, and secondary angle closure with pupil block. Laser iridectomy should not be attempted in the presence of marked corneal oedema.

### Technique for argon laser iridectomy

Pupil should be miosed and a local anaesthetic drop instilled in the concerned eye. Abraham contact lens should be applied to the cornea and a suitable sight for iridectomy is selected. This sight should be off 12 o'clock position and preferably the base of a crypt. Shots of 50 mm size with 0.2 second duration and 1 watt power are used. Eight to ten applications will be required to produce a perforation. Perforation is confirmed by observing the release of pigment which is carried into the anterior chamber by the aqueous. Immediately after the procedure a drop of aproclonidne is instilled, if this is not available a tablet of diamox is given. A weak topical steroid drop 3-4 times a day will be required for a week.

### YAG Laser Iridectomy

Frankhauser and co-workers were the first to use Q-switched Nd: YAG laser photodisruption for iridectomy.[3-4] They reported 100% success in achieving a patent iridectomy in their first 85 patients. Late closure of iridectomy was not mentioned. Mohammad and Khan were able to produce perforation of the iris in 89% of eyes in the first session. 4 eyes (9%) required re-treatment while in one eye it failed.[5]

### Technique of YAG laser iridectomy

Preparation of the patient is the same as that for argon laser iridectomy. 2 - 3 shots of 7-8 mJ will be enough to produce perforation of the iris. The aiming beam of the He-Ne laser is carefully focused on the iris. It should be as peripheral as possible, and as it is more likely to produce bleeding, visible iris blood vessels should be avoided. Post-operative management is the same as for argon laser iridectomy.

Complications of laser iridectomy are closure of iridectomy, hyphaema, uveitis, cataract and secondary rise of intraocular pressure.

### Argon laser trabeculoplasty (ALT)

Argon laser trabeculoplasty has been widely used to reduce the intraocular pressure for the past many years. It was first reported by Wise and Witter[6] in 1979. It has been usually used as an additive to the medical therapy in the primary open angle glaucoma. Heat induced shrinkage of the collagen core of trabecular meshwork at the site of argon laser application, causes opening of the adjacent spaces of trabecular meshwork, thus leading to increase outflow facility of aqueous.[7]

More recently, it is now believed that some biochemical changes in and around the trabecular meshwork explains its mechanism of action.[8].

### Indications for ALT

1. Non compliance of the patients to medical treatment.
2. Where there is need to stop a specific medication.
3. After trabeculectomy for additional lowering of intraocular pressure.
4. Prior to cataract extraction in a glaucoma patient.

ALT is not effective in secondary glaucoma except in glaucoma capsular. ALT should not be carried out in patients with a narrow angle glaucoma and where adequate trabecular meshwork is not visible.

It should also be not used in the presence of corneal oedema, iritis and hyphaema.

### Technique of ALT

After anaesthetising the eye with a topical anaesthetic, gonio lens is applied to the cornea. Fifty shots of 50 mm size 0.1 second duration, and 1 watt power are applied over 180° of the anterior chamber angle at the junction of the pigmented and non pigmented trabecular meshwork. The visible reaction to laser burn should be definite blanching of the pigmented trabecular meshwork with occasional small gas bubbles. Post-operatively all glaucoma medications should be continued with an addition of topical steroid drops.

Complications of ALT include rise of intraocular pressure and anterior uveitis. After 6 weeks about 80% of the patient will show a fall of 7 - 8 mm Hg in the intraocular pressure. However, after one year, 25% of the patient who are initially successfully treated will required additional treatment, and 10% of the patient treated successfully will fail to be controlled each year.

### Trans-scleral Nd: YAG laser cycloablation

Using the free running or thermal mode specially designed Nd: YAG laser is capable of producing 20 msec pulses of 1064 nm light. In this mode the sclera can be penetrated to the ciliary processes and the technique has been shown to produce effectively necrosis of the secretory ciliary epithelium. The technique consists of applying maximally defocused pulses, at 2mm from the corneal- scleral limbus with a minimum of 20 applications over 180° The intraocular pressure falls dramatically within 48 hours. Success rate of 75% is expected.

### Argon laser direct cycloablation

Trans pupillary argon laser photocoagulation of the visible ciliary processes and laser endo-photocoagulation via pars plana has been shown to have a pressure lowering effect but these approaches are only possible in limited number of patients.

Nd: YAG laser can also be used for trabeculo-puncture, cyclodylasis, goniotomy and suture lysis.

### Posterior capsulotomy

Since the conversion of cataract surgery from intra-capsular extraction to the extra-capsular extraction, the short pulsed Nd: YAG laser has rapidly become the tool of choice for cutting the opaque posterior capsule.[9] All patients require a complete ophthalmic history and examination before treatment including visual acuity, intraocular pressure, slit-lamp examination and fundoscopy. Pupillary dilatation is desirable but not necessary. Before pupillary dilatation the center of the pupil should be marked by a single shot. Local anaesthetic drop should be instilled and Abraham contact lens with a central button of 60 dioptres should be applied to the cornea. The He-Ne aiming beam should be accurately focused, and 1 or 2 shots of 1 to 2 mJ is usually required. If there are stress lines in the capsule, shot should be applied across these lines. This will result is largest opening per pulse (Fig. 1). Capsulotomy should be as large as the size of pupil in ambient light. In the presence of psuedophakia, damage to the intraocular lens should be minimized. If the machine has defocusing facility, shots are applied to the area just behind the capsule. In aphakia the reverse of deep-focus approach namely, the deliberate focus anterior to the capsule has been advocated by the some as mechanism for opening the capsule while leaving the anterior hyaloid membrane intact.

After laser capsulotomy, use of topical steroids, pressure reducing agents, and cycloplegics vary widely according to the individual surgeon's clinical experience. Ideally a drop of aproclanidine before and

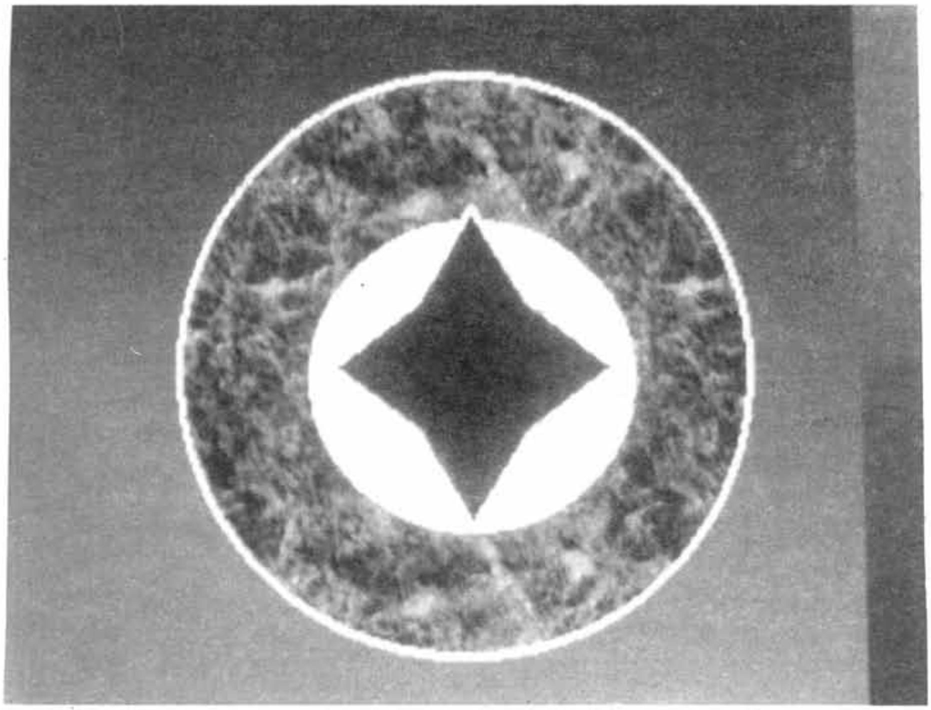

Fig. 1: YAG laser posterior capsulotomy

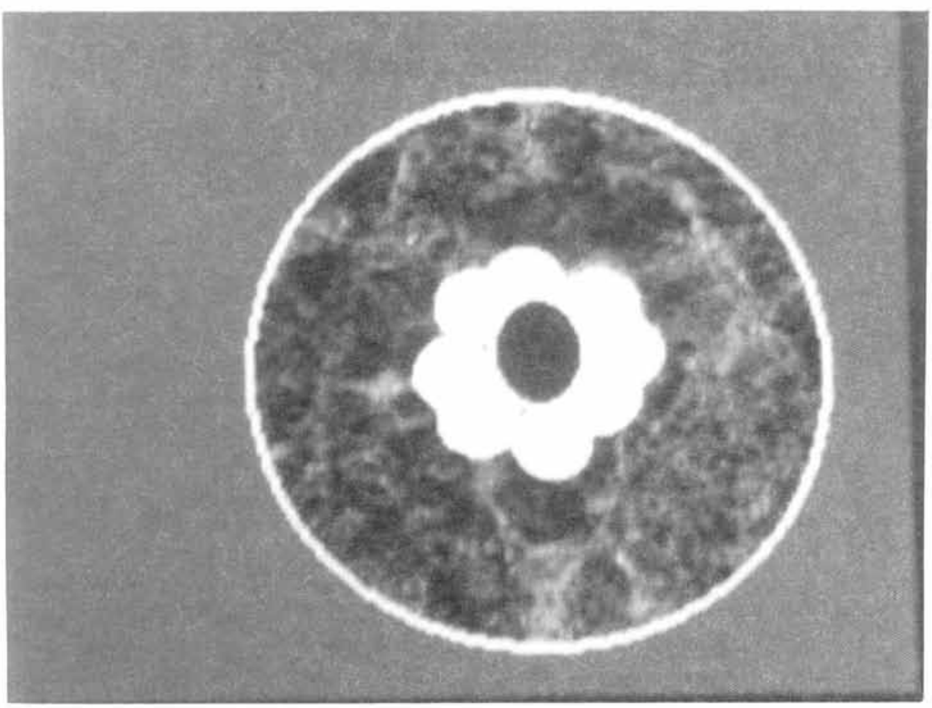

Fig. 2: Placement of laser burns for photomydriasis

after the procedure will reduce the chances of rise in intraocular pressure. Those patients who are on anti-glaucoma medication, should be closely observed over the next 4 - 6 hours after treatment. Contra-indications to laser capsulotomy are corneal scars, inadequate stability of the eye, glass intraocular lenses, known or suspected cystoid macular oedema, active intraocular inflammation and those with the high risk for retinal detachment. Complications of YAG laser capsulotomy are heamorrhage from the iris, rise of intraocular pressure, iritis, and retinal tear leading to retinal detachment.

**Pupilloplasty and photomydriasis**

Pupilloplasty is a photocoagulation technique which is used to alter the shape and size of an up-drawn pupil. Photomydriasis is used to enlarge a small pupil. For both the procedures the argon laser spot size of 250 mm, 0.1 - 0.2 second duration and power of 500mw is used. In case of up-drawn pupil two rows of contiguous laser burns are placed on the pupillary border. The first row is placed just inside the outer limit of the iris collarette. The second row is placed just peripheral to the first row (Fig. 2). In case of photomydriasis the shot are placed in two concentric rows just adjacent to the pupillary border.

If Nd: YAG laser is used for sphincterotomy, usually a setting of 6 - 10mJ is required. Sphincter is the toughest region to cut, with minor arterial circle, the most prone to haemorrhage. Treatment should begin in the peripheral iris stroma and progress towards pupil (Fig. 3).

**Anterior vitreolysis**

Because of the high success rate of Nd: YAG laser anterior vitreolysis in the treatment of aphakic and pseudophakic cystoid macular oedema, particular important to examine carefully for presence of vitreous stands to the wound in any patient with a CME. Pupil should be constricted with strong miotics to induce stretch of the vitreous strands which facilitates its identification and cutting with the laser. The energy setting of the Q-switched Nd: YAG laser is usually 6 - 12mJ, in order to obtain and adequate cutting power.

**Lid conditions**

a. Trichiasis

Argon laser has been successfully used for the treatment of trichiasis. Laser setting of 100mm spot size, 0.1 second duration and 1 watt power is used. Shots are applied to the root of the eyelash.

b. Pterygium

There is a high chance of recurrence in surgically removing a fleshy, highly vascularized pterygyium. Argon laser may be used before surgery to reduce this risk. Argon laser shots of 200mm size, 0.1 second duration and 1 watt power are applied to the body of the pterygyium in area just outside the limbus. Shots should not be applied over the cornea. Three or four laser sessions may be needed to achieve adequate avascularization.

**Laser treatments of fundus disorders**

There are a number of fundus disorders which are now routinely treated with laser. These include diabetic retinopathy[10,11] central retinal vein occlusion[12,13] retinopathy of prematurity, sickle cell retinopathy[14] subretinal neovascular membrane, retinal vasculitis, intraocular tumours, inflammatory lesions, retinal tears and degenerations and central serous retinopathy.[15] Before treatment a detailed history and clinical examination should be carried out. A colour fundus photograph should be taken and if required fundus fluorescein angiography is carried out. Pupil should be maximally dilated for the treatment.

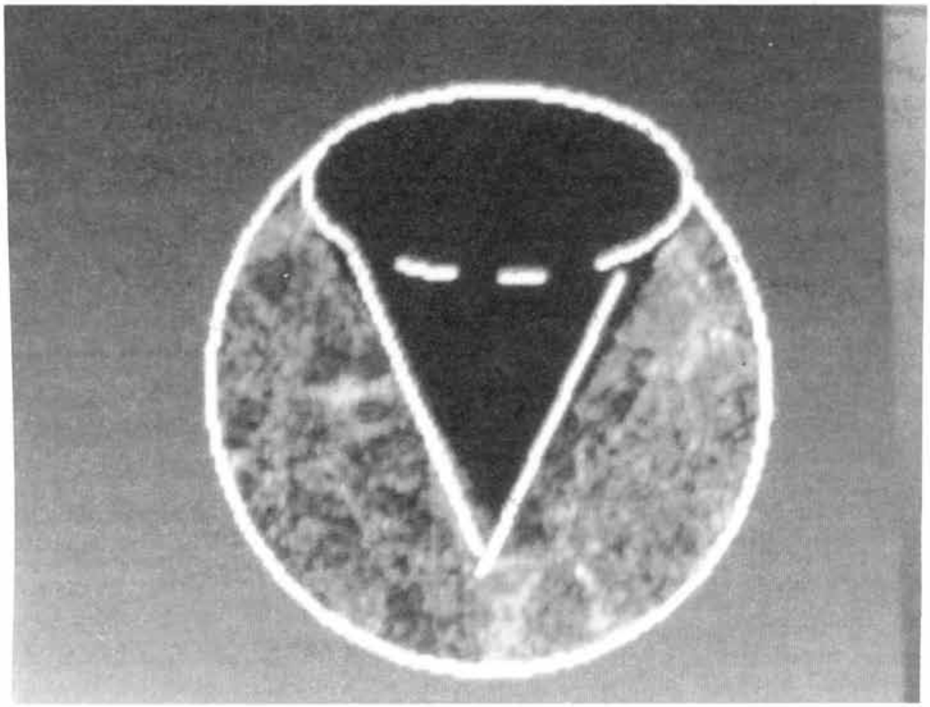

Fig. 3: YAG laser pupilloplasty

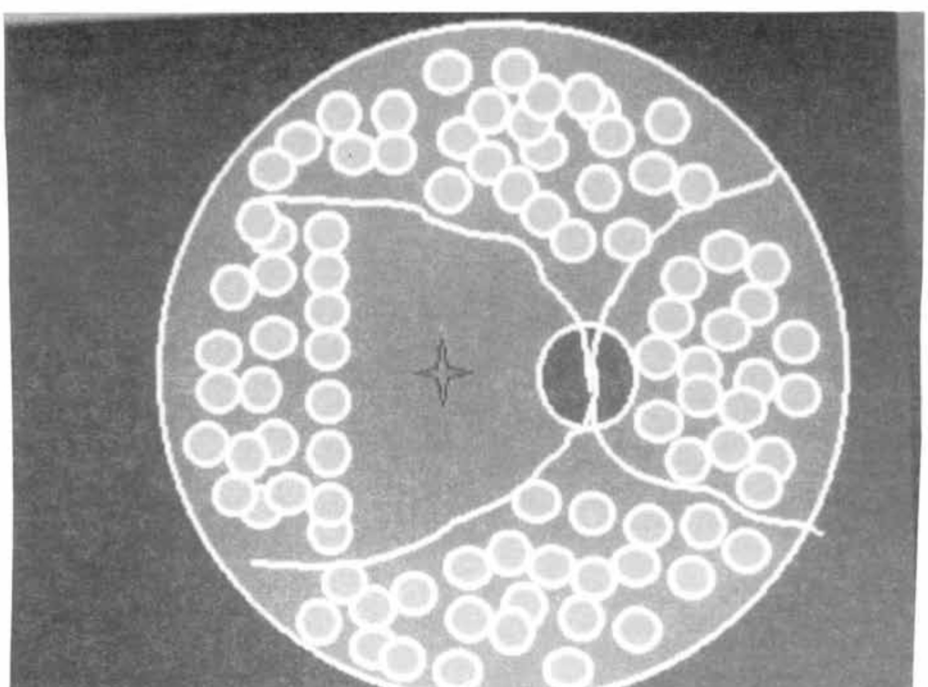

Fig. 4: Placement of laser burns for PRP

## Lasers used in the treatment of fundus disorders

Thermal lasers that are used in the treatment fundus disorders are blue argon, green argon, krypton red, dye lasers, infrared diode and double YAG laser.

### Argon Laser and krypton laser

Blue argon laser was originally extensively used for photocoagulation, but because of its potential macular phototoxicity, is now mainly replaced by green argon. Blue argon laser is absorbed by the macular xanthophyll pigment, thus making the treatment of macular disorders very hazardous. Argon blue and argon green lasers are well absorbed by haemoglobin thus making it more suitable for the treatment of vascular disorders and vascular tumours. Krypton red laser with its longer wavelength is virtually not absorbed by macular xanthophyll pigment thus making it more useful for parafoveal and subfoveal lesions. It penetrates deeper into the retina than argon and absorption by RPE is the determining factor in the thermal occlusion of subretinal neovascular membrane. The red light of krypton laser is not absorbed by haemoglobin, thus making it unsuitable for direct treatment of vascular disorders. However this property makes it more suitable for treatment in the presence of haemorrhage.

### Dye Lasers: (560-680 nm)

These lasers have the theoretical facility to select a suitable wavelength for a particular retinal structure to be treated. Most photocoagulation needs would be met by a tunable dye laser emitting between 560 and 640 nm, as well as at standard wavelength of its argon laser pump.

### Infrared Diode lasers

These have been successfully used in a number of common retinal vascular disorders as well as in the treatment of sub-retinal neovascular membrane.

### Double YAG laser

Double YAG laser with a wavelength of 532 nm has now recently be introduced for the treatment of a number of fundus disorders, and because of its green light and solid state has become very popular.

## Specific laser treatment

### Panretinal photocoagulation (PRP)

PRP is carried out for proliferative diabetic retinopathy and ischaemic type of retinal vein occlusion. Ischaemic retina is believed to produce a vaso-active substance which leads to the formation of new vessels on the disc and on the retina. The rational behind PRP is the destruction of this ischaemic retina which leads to reduction in the production of vaso-proliferative substances. The technique consists of applying 1500 to 2000 laser burns in the periphery of the retina. The spot size varies from 250 to 500 mm with the duration of 0.1 second. Intensity of the burn should be just enough to blench the retina, heavy burns should be avoided. The treatment should be completed in 2 to 3 sessions. Initially the superior and inferior quadrants should be photocoagulated. The burns should start 1 disc diameter from the disc margin. In the next session, the nasal and temporal quadrants are photocoagulated. While photocoagulating the temporal side, a vertical row of burns should be applied about 2 disc diameter temporal to the macula as a land mark so that further laser burns are placed just outside this line. The burns should be placed adjacent to one another and should not overlap. Depending on the underlying aetiology several courses may have to be applied over a period of many weeks (Fig. 4).

### Focal Laser retinal treatment

This treatment is required for background diabetic maculopathy where microvascular abnormality is in the center of circinate ring of hard exudates. Lesions near the macula are best treated with the argon green or krypton red laser. Smaller burn size of shorter duration should be used for working near macula (Fig. 5).

### Macular grid photocoagulation

In this technique argon green or krypton red laser of small spot size of about 100 mm is applied over the macular area in shape of grid fashion for the treatment of the ischaemic maculopathy and cystoid macular oedema. The rational for treatment is the experimental finding that the laser treatment of RPE stimulates the endothelial cell of proliferation of retinal capillaries. Further support for the RPE theory is the fact that krypton laser is effective in macular grid technique despite not being absorbed by haemoglobin in the vascular abnormalities (Fig. 6).

The Early Treatment Diabetic Retinopathy Study (EDTRS) demonstrated that eyes with clinically significant macular oedema benefit from argon laser photocoagulation. In this study discrete areas of leakage were treated with focal laser and areas of non-perfusion or diffuse leakage were treated with grid photocoagulated.[16]

### Prophylactic treatment of flat retinal tear

A double row of laser burns is applied in the normal retina around the tear. The laser burns should be adjacent to each other and no untreated area should be left in between the laser burns (Fig. 7).

### Laser treatment of small intra-ocular tumours

Small intra-ocular tumours like melanoma and retinoblastoma situated in the posterior pole may be treated with laser. Laser burns are applied in the normal retina around the tumour mass and not over the tumour itself. This will stop blood supply to the tumour mass leading to its regression.

### Treatment of sub-retinal neovascular membrane

SRVN may occur in any condition affecting the integrity of choriocapillis-Bruch's membrane-RPE-outer retinal layer complex. They are ARM degeneration, myopic degeneration, angioid streaks, vitilliform macular dystrophy, fundus flavimaculatis, optic nerve head drusens, ocular histoplasmosis, toxoplasmosis, toxocariaris, rubella, post-traumatic and idiopathic.

A good quality fluorescein angiogram should be obtained and the extent of neovascular membrane is outlined. Treatment should be carried out with either argon green or krypton red laser. The initial burns are placed along the boundary of the neovascular membrane using a 200m spot size, 0.2 - 0.5 second duration. After the boundaries of the lesions have been treated, the area within the boundaries is treated subsequently with burns of the same spot size or larger using a duration of 0.5 to 1 second. The desired endpoint intensity of the laser lesion is to create a uniformly white lesion.[17,18]

Complications of laser treatments of fundus disorders:

Inadvert treatment of iris leading to iritis, lenticular opacities, traction of vitreous bands leading to retinal detachment, choroidal haemorrhage, puncture of Bruch's membrane with sub-retinal neovascular membrane formation, traction retinal detachment, foveal burn, burn to the optic disc, visual field defect, choroidal effusion, angle closure glaucoma, and vitreous haemorrhage.

### Photoablation Refractive Keratectomy (PRK)

In 1983, Trokel and co-workers[19] reported the first use of the excimer lasers to achieve precise controlled etching of the

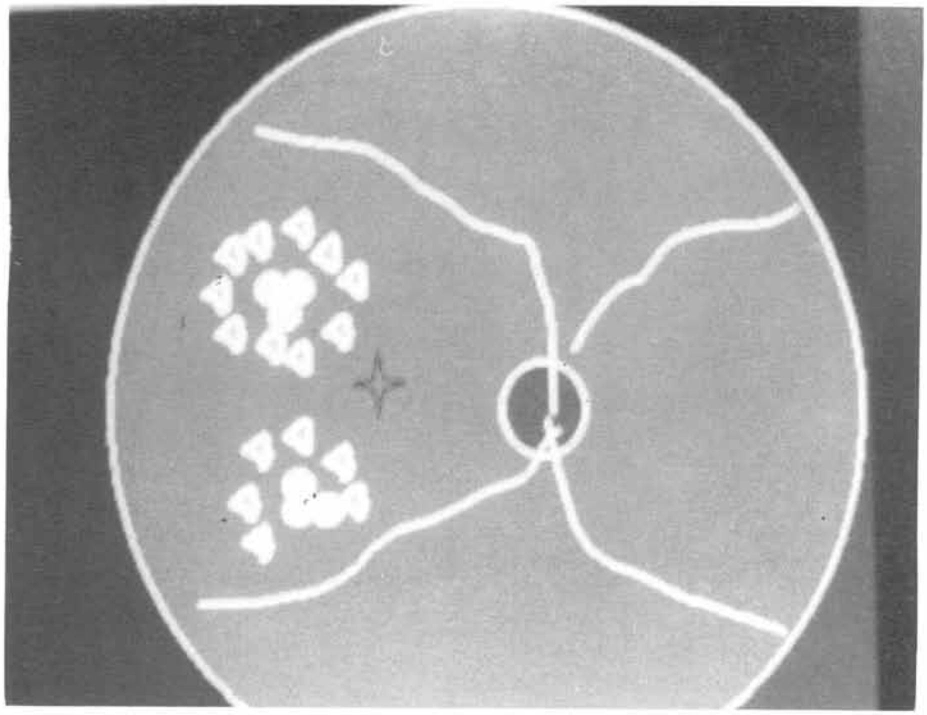

Fig. 5: Focal laser treatment for circinate maculopathy

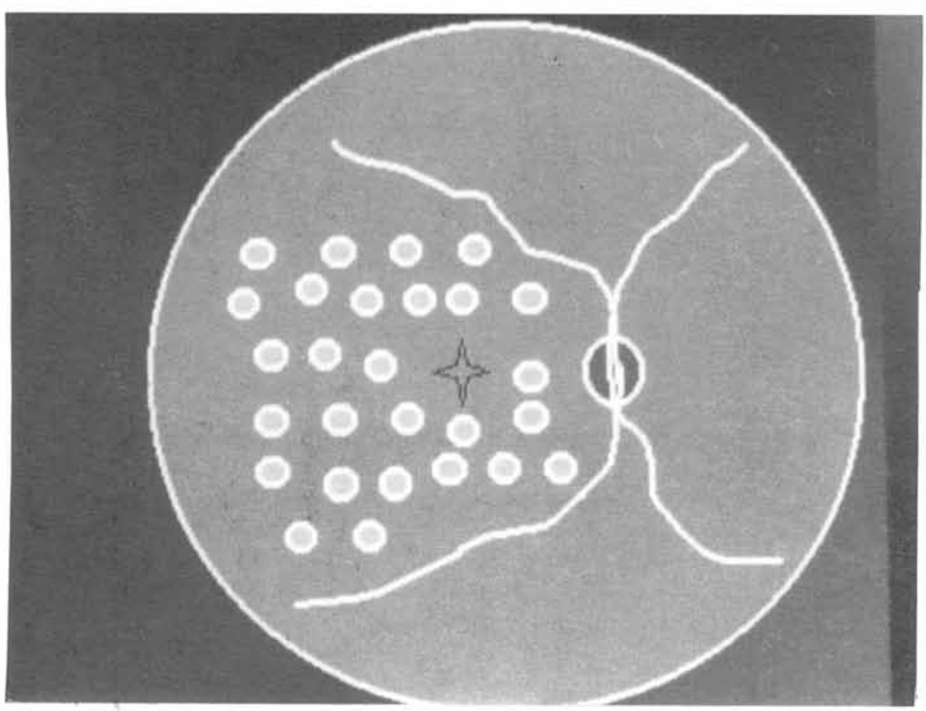

Fig. 6: Grid photocoagulation

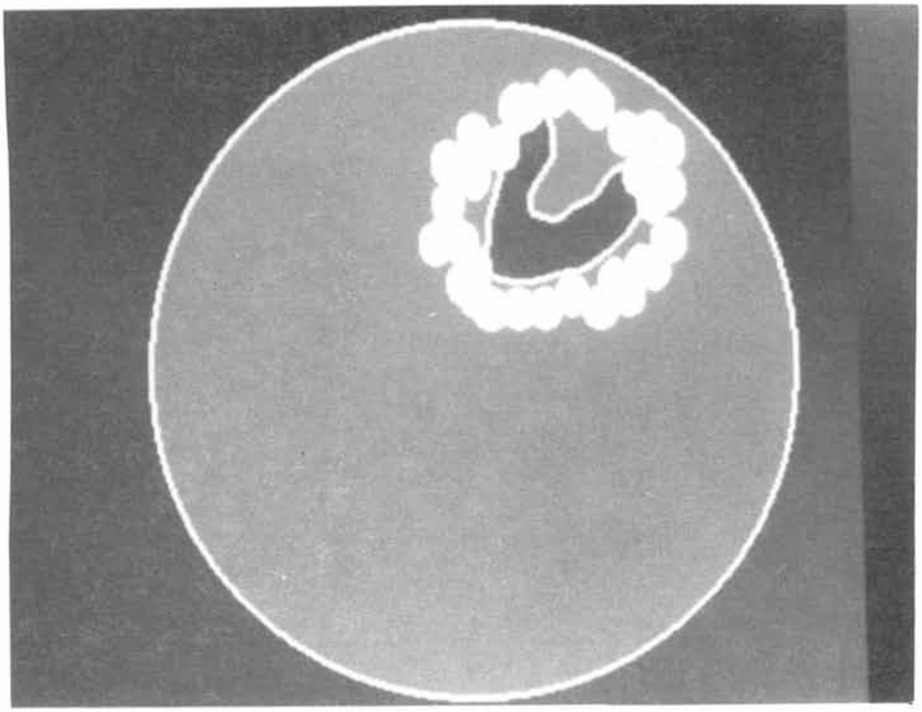

Fig. 7: Laser treatment of flat retinal tear

cornea. Using 193 nm radiation they selectively ablated narrowly defined areas of bovine corneas by employing mask of various designs to restrict the laser energy. Laser damaged was localised to the zone of ablation, with no evidence of thermal effects. Puliafto and co-workers[20] showed that the ablation of the cornea with 193 nm laser was far superior as compared to that achieved with 248 nm laser. Kert-Muir[21] and associates found that excimer laser ablation yields tissue at-least ten times as smooth as conventional diamond knife surgery and further described the pseudomembrane that seals laser treated surfaces and appears to minimize post-operative scarring. A team lead by L'Esperane and Taylor performed the PRK trial on humans in the United States.[22] Initial US Food and Drug Administration in the investigational device exemptions limited early work to blind eyes and those scheduled for enucleation and results were entirely consistent with the preceding animal work. Using a delivery system with enlarging apertures for myopic correction, this group treated eyes with parameters of 10 MZ and 80-120 mJ/cm$^2$/ pulse, creating ablation ranging from 3 - 5 mm in diameter and 30 - 150 mm in depth. Since then excimer laser has now been extensively used for correcting myopia and now even stigmatism.

Post-operative complication includes photophobia, corneal haze, microbial keratitis, glare, decreased glare contrast sensitivity, under correction and over correction.

Long term complication include regression and over-correction. Most of the immediate complications can be reduced by ablation under a thin corneal flap (160 m thick and 7-7.5 mm in diameter) fashioned by microkeratome.

**Photo therapeutic keratectomy (PTK):**

Excimer laser has been used successfully in malignant melonoma of the conjunctiva, ptyerigia, recurrent corneal erosions, persistent epithelial defect following kertoplasty and herpetic keratitis.[23] It has also been successfully used in conditions as anterior stromal and superficial scarring following infection or trauma, herpetic karatitis, anterior corneal dystropies, and band keratopathy.[24]

### Trephination

Excimer laser can also be used for precise lenticule trephination such as an obtaining tissues for routine penetrating keratoplasty.[25]

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