Endolaser

30

Laser, as photocoagulation in general, uses light to cause tissue coagulation as the energy from the light source is absorbed by the tissue and converted into thermal energy.[1] Laser's significant therapeutic benefit is thus delivered via a force that is destructive in nature.

Laser to the retina is typically applied at the slit lamp or via the IBO. Unlike endolaser, with these techniques the laser is delivered from outside the eye. Both involve at least some inconvenience to the patient,[2] and even if retrobulbar anesthesia is used, treatment close to the fovea poses some risk of misdelivery.

All other parameters (see **Table 30.1**) being equal, three factors determine the effectiveness of the laser therapy: the depth of penetration of the laser beam[3] and the type and amount of tissue pigment[4] that absorbs the laser energy. **Table 30.2** provides a list of selected conditions in which (endo)laser[5] therapy is applied.

Endolasers of different types[6] are available; the use of Argon green (514 nm) is described here.

[1] Coagulation necrosis occurs with denaturation of the cellular proteins when the temperature exceeds 65° C.

[2] With IBO, scleral indentation is usually needed, which can be rather painful, even under anesthesia.

[3] YAG laser (1,064 nm) can penetrate the choroid and cause bleeding and vascular occlusion.

[4] Melanin in the retina.

[5] Most, although not all, of the conditions listed can also be treated by laser therapy delivered at the slit lamp or via the IBO. In principle, endolaser as a technique is preferable because it allows more precise and convenient delivery to the target – but, naturally, it also requires surgery.

[6] Argon, diode, double-frequency YAG, dye, krypton etc.

F. Kuhn, *Vitreoretinal Surgery: Strategies and Tactics*,
DOI 10.1007/978-3-319-19479-0_30

Table 30.1 The parameters influencing the efficacy of the endolaser

Variable	Variable	Increasing effect	Decreasing effect
Laser parameter	Duration	Longer	Shorter
	Power	Higher	Lower
	Size	Smaller	Larger
Distance of probe from retina		Closer	Further away
Angle of probe relative to the retina[a]	Perpendicular	Maximum	N/A
	Parallel	N/A	N/A
	In-between perpendicular/parallel	Closer to 90°	Closer to 0°
Pigment content of the retina		More	Less
Fluid content of the retina (edema)		Less fluid	More fluid

[a]The spot is a perfect circle if the angle is at 90° and becomes increasingly oval as it approaches 0°.

Table 30.2 Selected indications for endolaser therapy

Indication[a]	Comment
Central serous chorioretinopathy	To close the vascular leakage as seen on fluorescein angiography
CNV	To destroy a (parafoveal) membrane[b]
Diabetic retinopathy[c]	Panretinal or focal treatment, depending on the severity of the disease; the goal is to destroy ischemic areas that produce vasoproliferative agents and to prevent bleeding and exudation
High IOP[d]	Endocyclophotocoagulation to destroy (some of) the ciliary processes
IRMA[e]	To close the vascular leakage
Macular edema in diabetes, vein occlusion etc.	To dry the macula – the mechanism how laser may work is not known
Prophylactic[f]	To prevent RD (endolaser cerclage)
PVR	To prevent redetachment (endolaser cerclage)
RD	To seal the break and to prevent redetachment (endolaser cerclage)
Retinal tear	To seal the break to prevent RD development
Retinal telangiectasias[g]	To reduce exudation and prevent progression
Retinal vascular tumors[h]	Destruction of the feeder vessel or the tumor itself
Retinoschisis	To prevent progression or mark the central border of the pathology
Retinotomy/retinectomy	To seal its edge to prevent redetachment
ROP	Retinal ablation to halt disease progress
Vessel, abnormal	A feeding vessel of a tumor or other pathology containing one or vessels in a proliferative membrane may be closed with high-intensity laser application. Argon green (512–534 nm) is the best option for this purpose because it is absorbed by blood. Nonetheless, diathermy or preoperative bevacizumab is typically preferred to laser in these cases

[a]In alphabetical order.
[b]This option should not be neglected even in the anti-VEGF era.
[c]And other vasoproliferative diseases such as Eales'.
[d]Unresponsive to other treatment modalities.
[e]Microaneurysms, perivascular leakage, telangiectasias.
[f]E.g., in an eye with high myopia.
[g]Coats' disease, idiopathic juxtafoveal telangiectasias, Leber's miliary aneurysms.
[h]Capillary hemangioma, cavernous hemangioma, racemose hemangiomatosis, vasoproliferative tumor.

30.1 The Consequences of Laser Treatment

- The retina becomes edematous after laser treatment. The surgeon notices that within a few seconds, the spot, which was white with sharp borders upon delivery, turns fuzzy-bordered, and its color turns a bit grayish.
- With time,[7] the spot turns into a scar. The RPE, the photoreceptors, and the retinal layers external to the inner nuclear layer are involved in the scar; there is some hyperplasia and hypertrophy of the remaining RPE. Glial cells also contribute to the development of the scar.
  - The visual consequence of the scar is a miniature, focal scotoma: the overlying nerve fibers are spared (see **Fig. 51.4**).
  - If too high laser power is used, all retinal layers, including the nerve fibers, are scarred over.[8]
  - The size of the scar increases by ~50% with time.

Q&A

Q *What may be the undesirable consequences of an "overpowering" (endo)laser spot?*

A Pain, even if the rest of the operation was painless; corresponding defect in the visual field; significant retinal bleeding; retinal break formation; break in Bruch's membrane with development of a neovascular scar; if a spot is close to the fovea, RPE migration into it with loss of the central vision; and the vitreous "burned" into the scar, making PVD creation impossible.

- After treatment, the oxygen consumption of the retina is reduced.
  - Oxygen is able to diffuse through the laser scars without being consumed by the photoreceptors, relieving the inner retinal hypoxia and raising its oxygen tension.
  - The retinal arteries constrict and the blood flow decreases. The hypoxia relief reduces VEGF production, and the neovascularization process stops or regresses.

30.2 The Setup

The initial step is to ensure that the laser filter is properly situated on the microscope. It should be mounted so that it provides protection for the surgeon, his assistant, the nurse, and the video camera. The first three are a matter of safety[9], the fourth of convenience. It is advisable for all in the OR to wear safety goggles when the endolaser is in use.

[7] Roughly a month is needed for the chorioretinal adhesion to reach its maximum strength.

[8] I have seen many patients with almost black fundi, with the hyperpigmentation approaching or even reaching into the fovea.

[9] For the surgeon, to view endolaser delivery without the proper filter is unpleasant at best and blinding at worst.

The laser pedal should be in the middle (see **Fig. 16.3a**) and operated by the nondominant foot.

30.3 The Technique of Endolaser Treatment

Unlike cryopexy, laser is ineffective if applied over detached retina.[10] This is the reason why, for instance, in RD surgery laser is delivered after drainage of the subretinal fluid and under air.

Pearl
As a general principle, the parameters should be adjusted so that the effect is a discreet but visible whitening of the retina with no apparent major tissue disruption (strong whitening, bubble formation, significant bleeding, audible "pop").

30.3.1 General Considerations

To deliver a spot that causes mild retinal whitening, all three main parameters must be properly set.[11]

- My default parameters are the following:
  - Duration, 100 ms; spot size, 100 μ; energy, 150 mW.
  - Since the effect also depends on the pigmentation of the fundus,[12] major changes in the settings may become necessary. It is best to test the parameters at a peripheral location (see below).
- An additional parameter to set is the "repeat" mode (see below).
- Ideally the laser probe is curved so that the surgeon can always keep it perpendicular to the surface and be able to reach any retinal area without difficulty or risk in the phakic eye.
  - The straight probe has significant limitations regarding reach and safety.[13]

[10] This is true only to a certain extent. Even when the retina is detached, if an RPE reaction to the laser is visible and the retina is attached within hours, the chorioretinal scar still may form. Such treatment, however, is difficult and somewhat unreliable; it is far better to reattach the retina first.

[11] Remember: the power required to produce a visually visible spot decreases with increasing pulse duration and decreasing spot size (see **Table 30.1**).

[12] Lightly pigmented eyes (e.g., high myopes) require higher power or longer duration. The reason why laser treatment is not used in a staphyloma-spanning posterior RD (see **Chap. 56**) is the lack of melanin (hence the white fundus) and therefore uptake of the laser energy.

[13] It is more difficult to perform peripheral laser in the 6–12 o'clock meridian and impossible on the opposite periphery in the phakic eye.

  - The curved probe (may be retractable if made of memory material) can be held truly perpendicular to the retina at all locations – but the surgeon must remember to pull the laser probe into the shaft before exiting the cannula with it (see **Sect. 21.7**).
  - In a phakic eye it is possible with the curved probe to avoid damaging the lens, but extra caution is still needed: the surgeon tends to focus on delivering the laser spots, not on the actual position of the laser probe's shaft.
- The spots should not be confluent; as a general rule, the distance between spots should be roughly the same as the spot diameter.
  - When panretinal treatment is employed, this rule is difficult to keep (see below).
- The working distance[14] is typically ~1–2 mm – with some caveats.
  - When lasering under air (see **Sect. 31.2**), it may be difficult to clearly see the tip's distance from the retina, especially in the periphery. The laser probe must be advanced close to the retina,[15] and the surgeon should carefully observe the distance between the shaft's tip and the shadow it casts.
  - Different areas in the fundus have different degrees of pigmentation. If the laser power proves too strong (weak) at the "test site," it is more efficient to increase (decrease) the working distance than continually adjusting the power on the console.

Pearl
When working in "repeat" mode (see below), too short a working distance is dangerous: it is easy to bump into the retina as the probe is moved along.

- The initial "test" spot should always be delivered well outside the macula. If no effect on the retina is seen, examine the aiming beam (this may tell you whether the cable is broken) before you increase the power/duration or shorten the working distance.
- PFCL has a cooling effect and this makes recognition of the spots more difficult – overtreatment is a risk.
- Avoid lasering a hemorrhage[16] since the blood may absorb it and cause damage to the more superficial retinal layers.

[14] The distance between the tip of the laser probe and the retina.

[15] Such close proximity may require a reduction in the laser power.

[16] The microaneurysm, which may be indistinguishable from a small bleeding in diabetes, is an obvious exception.

Pearl
It is somewhat controversial whether a posterior retinal break or retinotomy (i.e., in an area where the vitreous has been verifiably removed) requires laser treatment. *In principle*, the answer is no, since no traction is left behind; the laser spots also increase the size of the scotoma. *In practice*, laser may make sense because of any possible future traction. An individual decision is needed (I very rarely do laser for posterior retinal breaks; see also **Sect. 8.1**).

- Edema, whether caused by RD[17] or other conditions, reduces the efficacy of the treatment.

30.3.2 Panretinal Treatment

The technique presented here about the order of spot placement reflects my personal approach. Every surgeon must develop his own philosophy – what matters is that some kind of order be kept.

- I initially apply 2–3 rows in a circle around the macula so as to reduce the risk of inadvertently venturing too close to the fovea during the delivery of many hundreds of laser spots.[18]
- I follow with the full treatment on the opposite side of the retina, then switch hands to complete the laser application on the other half of the fundus.
- Usually I do the treatment centrally first and in the periphery second, due to the ease of maintaining visibility, especially in the pseudophakic eye (see below). It is advisable to use the dominant hand to complete the laser application at the posterior pole.

[17] The treatment is over a retina that has just been reattached.

[18] The risk is that the concentration drops once the exhausting part of the surgery has been completed (see **Sect. 3.7**).

- Switching hands at some point is unavoidable in order to complete the treatment.
  - When to switch hands has no strict rule: it need not be exactly at the 6 and 12 o'clock meridian. When the spots are becoming oval, a switch is in order.

Q&A

Q *May the surgeon complete the panretinal laser coagulation during the same operation, or should it be finished during a 2nd session at the slit lamp or via the IBO?*

A Even 1,500–2,000 spots, delivered during a single session (see **Fig. 30.1**), have not been associated with any detrimental effect – in fact the outcome may be better than with multiple sessions. The reason why multiple sessions are used at the slit lamp has more to do with patient comfort and convenience, which are not an issue with endolaser (Using micropulse laser at the slit lamp, it is now possible to complete the treatment in a single session.)

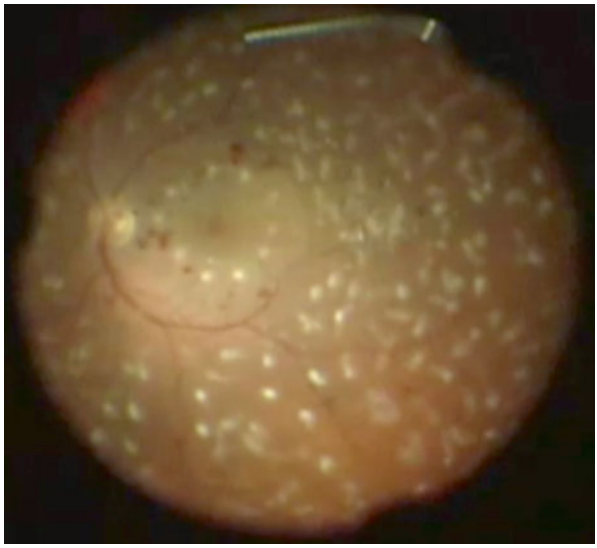

Fig. 30.1 Panretinal endolaser. The treatment of the posterior pole has just been completed; the spots are white and only slightly edematous. The curved (non-retractable) endoprobe is still visible inferiorly

- I always use the "repeat" mode of the laser equipment; no surgeon should be forced to step on the laser pedal 1,000 times. This is not only inconvenient but also risky: eventually you will have to readjust your posture and may accidentally deliver laser to an unintended location.

Pearl
The more experienced the surgeon, the shorter the repeat time can be.

- The edge of the IOL causes parallaxis (see **Sect. 25.2.4.3**). The surgeon, if the pupil is wide enough, will have to alternatively view the retinal periphery outside or through the optic.
  - If this is the case, it is best to finish a large area's laser treatment viewed either outside or through the optic and then move on to the other area. Switching the view back and forth in quick successions is tiresome.
- When lasering close to the macula, extra steps are necessary to avoid "hitting the bull's eye."[19]
  - Use the single, not the repeat, mode (one spot per one pedal pressing).
  - Make sure the spot is not too strong (see above).
  - Avoid lasering in the foveal avascular zone (see **Sect. 26.1.3**).
- If the laser is employed for macular edema, inject bevacizumab or TA a few days earlier so that the macula is rather dry at the time of surgery, and then try "laser maculopexy" (see **Fig. 30.2**).

Pearl
All ophthalmologists must keep in mind that with time the optic disc will turn pale after panretinal laser treatment. This is a normal phenomenon and must not be appreciated as a disease-related atrophy.

30.3.3 Endolaser Cerclage and Its Complications

A variant to panretinal treatment, this laser is aimed at preventing RD or redetachment.[20]

- Deliver a more compact treatment[21] than for panretinal lasering (see **Fig. 30.3**).
  - In an emmetropic eye, 900–1,200 spots are needed.

[19] The risk of delivering a laser spot in the foveola is smaller during endolaser than at the slit lamp or via the IBO since the eye's position is firmly controlled by the two intraocular instruments in the surgeon's hands. This is true, however, only if the surgeon does not lose concentration during the process (see above).

[20] Only the technique is presented here; the indications are listed in **Chap. 54**.

[21] I.e., the spots are closer to each other.

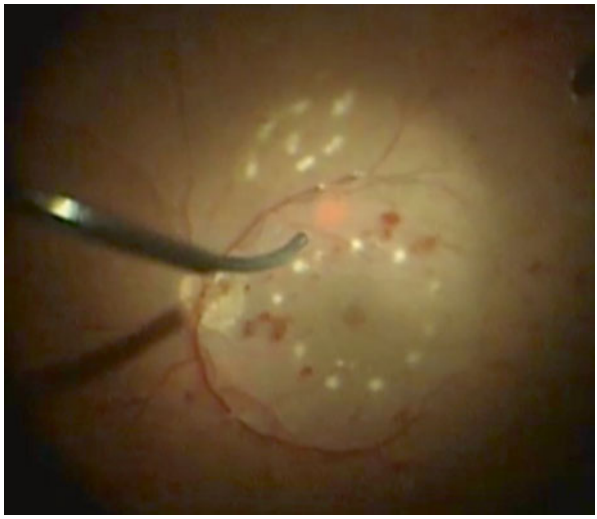

Fig. 30.2 Laser maculopexy. The macula has been dried with a prior intravitreal bevacizumab injection (see the text for details). A circular laser treatment is delivered close to the avascular zone to act as "nails" to reduce the risk of re-swelling of the retina

- The area to treat is from the ora serrata to slightly central to the equator (see **Fig. 30.3**).[22]

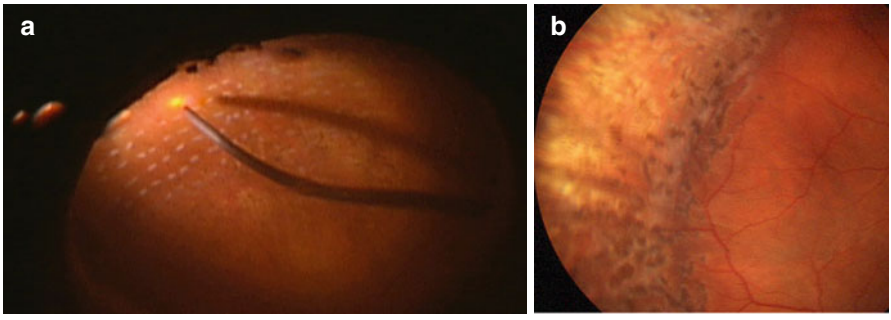

Fig. 30.3 Endolaser cerclage. (**a**) Endolaser cerclage is being performed. The posterior border of the area to be treated is posterior to the equator. (**b**) The healed spots form a confluent area of scars to counteract the effects of any remaining or new traction (or retinal break) in the anterior retina

- At the 3 and 9 o'clock positions, reduce the power/number of laser spots to avoid damaging the long ciliary nerves. A *dilated pupil* is one of the potential complications of endolaser cerclage.[23]
  - The other complication, just as with panretinal treatment, is *EMP*, occurring in 1–2% of the eyes. Prophylactic ILM peeling should be considered.

[22] The result is the creation of an "ora secunda" (a term coined by Robert Morris, MD).

[23] Fortunately this is extremely rare. If it does occur, pilocarpine 1–2% twice a day should be prescribed. After a few weeks, the pupil almost always regains its normal size; if not, the patient should continue using pilocarpine as needed. Pupilloplasty is another possibility (see **Sect. 48.2.3**).

Endolaser cerclage is best done using the wide-field front lens of the BIOM under air[24]; this allows visualizing the retina up to the ora serrata if the pupil is wide enough. An alternative option is scleral indentation.

Pearl
If the RD risk is similar in the fellow eye, prophylactic endolaser cerclage must be discussed with the patient (see **Sect. 42.1**). If done properly, such an intervention is *almost* a guaranty against future RD (see **Sect. 54.2.4.1**).

30.3.4 Endolaser as a Walling-Off (Barricading) Tool

- In eyes with *peripheral retinoschisis*, the purpose of the laser treatment is twofold:
  - By creating a barrier of adhesion, it prevents progression of the condition toward the macula.
  - By marking the border of the pathology, it allows the ophthalmologist to accurately monitor whether progression has occurred.[25]
- In eyes with *PVR* or *PDR* and partial RD whose progression is prevented by silicone oil, the laser barricade acts as an additional weapon in maintaining retinal attachment.

The laser spots should be tightly placed (see **Fig. 30.4**) or be "painted" by continuous application and extended all the way to the ora serrata on both ends to prevent the intraretinal fluid to "come around the laser wall." The treatment must be especially firm inferiorly, where, due to gravity, the risk is higher than in the superior part. 2–3 rows are needed to ensure maximum effect.

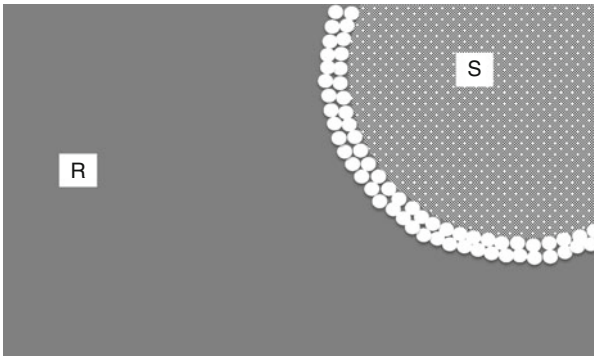

Fig. 30.4 **Walling-off laser**. The retinoschisis (*S*) is surrounded by two contiguous rows of laser applications (represented by *white circles*) to prevent progression of the condition into the attached retina (*R*). See the text for more details

[24] Acting as a lens, the air increases the visual field. This effect is especially useful in the aphakic eye if the AC is also filled with air.

[25] As detailed in **Sect. 57.1.2**, the ophthalmologist's goal is to *avoid* surgery in this condition. The laser application is therefore ideally done at the slit lamp, not intraoperatively.

30.3.5 Endolaser as a Welding Tool

- The *retinal break* is the most common indication and has the same goal as in the case of cryopexy (see **Fig. 29.1b**). The laser spots must surround the break in a contiguous fashion, by 2–3 rows.
- A *retinotomy* that is posterior so that all vitreous can safely be assumed to have been removed does not require laser treatment – but the surgeon may feel he will sleep better if he does it. If the retinotomy is in an area where it is not certain that the vitreous removal was complete (see **Fig. 63.9**), it is advisable to surround the lesion with laser.
- Following *retinectomy*,[26] a laser treatment similar to that shown on **Fig. 30.4** is recommended to prevent elevation of the remaining retinal edge.

30.4 Peripheral Laser and the Beginner VR Surgeon

Performing panretinal laser in the periphery, and especially laser cerclage, is perhaps the most frustrating part of VR surgery for the beginner. The procedure appears rather easy when *viewed* through the assistant's microscope or on a videotape but can be cruelly difficult when *performed*, for numerous reasons.

- Visibility is poor, especially if the laser is performed under air and in the pseudophakic eye, due to parallaxis, and if either of the capsules is hazy (see above). It is difficult to view the retina, the tip of the laser probe (i.e., the proper working distance; see above), and the delivered laser spot unless the power is too strong.
  - Condensation of the back surface of the IOL in the air-filled eye adds to the difficulty (see **Fig. 25.2**).
- Occasionally, even if visibility is acceptable, no visible laser spot appears after the application. One of the many possible causes[27] is that during the previous spot, the tip touched the retina and the surface is covered with tissue.
  - If the laser is performed under fluid, any small air bubble that is inside the vitreous cavity will adhere to the tip of the probe and prevent laser delivery.
- The most distal portion of the shaft should be held perpendicular to the retina (the plane of the tip itself is parallel to it). If a straight probe is used, the surgeon has no control over this, and the shape of the laser spots will become oval. If a *curved probe* is used, the procedure's technical complexity grows because the surgeon must adjust the position of the probe according to how the geometry of the treated area (in effect the angle between retina and the probe itself) changes.
  - If a retractable probe is used (see **Fig. 30.2**), one possibility is to increase or decrease the length of the shaft. This allows the surgeon to maintain the

[26] In diseases such as PDR or PVR.

[27] Others include damage to the fiber-optic cable, malfunctioning of the equipment, or intraocular causes such as lack of fundus pigmentation or increased tip distance from the retina.

correct angle between the shaft and the retina, but the adjustment is rather cumbersome and somewhat dangerous.[28]
  - A better option with the retractable probe (and with a probe whose curvature is fixed, see **Fig. 30.1**) is to twist the shaft around its main axis. In most areas, it is easy to have visual feedback of the position (angle) of the bend, but in the horizontal meridian, the surgeon sees the shaft as a straight line; it is impossible to determine whether concavity of the bend on the probe points upward or downward.
  - The further the probe is away from the horizontal meridian, the more sideways it will be held,[29] increasing the visibility of its curvature.
- The light pipe's position must also be monitored to avoid bumping it into the retina or the lens.
  - Even if the retina is not injured mechanically, phototoxicity remains a risk if the light pipe is held too close to the retina (see **Sect. 22.1**).
- In addition to the constant adjustment of actions of the two hands described above, the surgeon's two feet must also have closely coordinated movements (with each other and with the hands): the nondominant foot operates the laser pedal, the dominant foot the X/Y joystick (see **Fig. 30.5**).

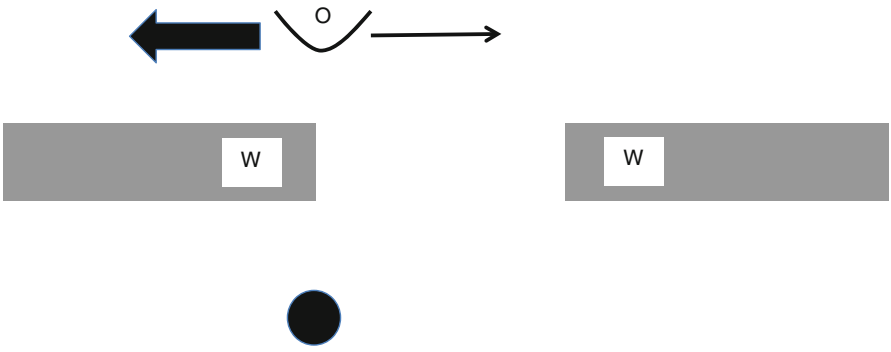

Fig. 30.5 **Schematic representation of the adjustment of the image during endolaser cerclage**. If an object (*black dot*), which is in another room and partially hidden behind the wall (*W*), is to be viewed through a doorway, the observer (*O*) simply moves so that the view is unobstructed (*thin arrow*). If the retinal periphery is to be viewed through the BIOM, sometimes the opposite is needed: moving as if further behind the wall (*thick arrow*)

[28] The retractable shaft may be pushed too far out, hitting the retina, or the entire probe is accidentally moved as the surgeon's index finger tries to locate the slider. In addition, the slider may initially resist the movement (similar to what is described under **Sect. 20.3**).

[29] The plane of the bend thus changes from the sagittal to the frontal.

- The process is lengthy; the surgeon's eyes become dry and his lower back starts to hurt (see **Chap. 16**).
- The patient's nose may be in the way.

Pearl
To avoid the frustration, do not start performing laser cerclage early in your VR career, and even then do it only gradually (smaller, more central areas but away from the macula first). Do not be discouraged by the early difficulties; all surgeons had to go through the same process.

30.5 Endocyclophotocoagulation

If the IOP is high and cannot be controlled medically, one of the many options is cyclodestruction. Proper scleral indentation by the surgeon (see **Sect. 28.4**) allows visualization of the ciliary processes, which can be individually shrunk by applying high-power laser treatment (see **Fig. 30.6**). The effect is both visible and occasionally audible (see **Chap. 25**).

Even though the success rate of the intervention is usually rather limited, do not treat more than 180° in the initial session: the effect on the individual process is irreversible.

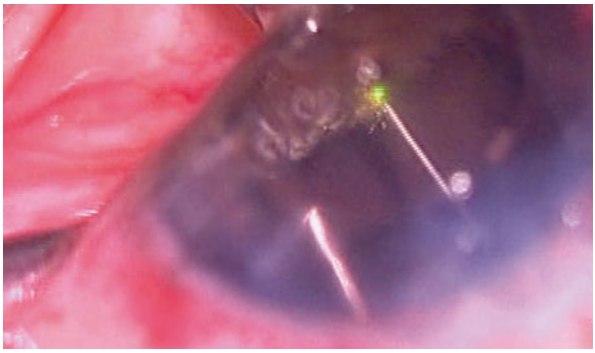

Fig. 30.6 Endocyclophotocoagulation. Scleral indentation brings the ciliary processes into view; laser is applied to destroy the selected processes. The infusion cannula is also visible inferiorly

30.6 Laser Cerclage at the Slit Lamp

It is possible, even if more difficult, to perform proper treatment at the slit lamp. Instead of the three-mirror contact lens, use a contact lens with a very large field[30] and try to achieve a similarly wide zone of treatment as described above (**Sect. 30.3.3**).

[30] Such as the Super Quad 160 lens (Volk, Mentor, OH, USA).