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IQ 577 Laser System: Bridging Past, Present, and Future Laser Technologies

Leading physicians share their perspectives and clinical experiences using a true-yellow, 577 nm laser.

Continuous-wave and Micropulse 577 nm Yellow Laser Photocoagulation: A Laser for All Reasons

Martin A. Mainster, PhD, MD, FRCOphth



Retinal photocoagulation is effective, but it is also destructive. In the past, the prevailing view was that to be useful, laser therapy had to destroy oxygen-consuming rods and cones or retinal pigment epithelium (RPE) cells that produce angiogenic mediators.

That perspective has been disproven now by numerous clinical trials and better understanding of the cellular and molecular changes induced by laser exposures.

PHOTOCOAGULATION'S BIOLOGICAL EFFECTS

Photocoagulation upregulates inhibitors and downregulates inducers of VEGF-related angiogenesis, as shown by microarray and quantitative polymerase chain reaction techniques.¹⁻³ It downregulates matrix metalloproteinases, which degrade extracellular matrix, and it upregulates their tissue inhibitors, thereby inhibiting initiation and maintenance of angiogenesis.⁴ It induces bone marrow-derived stem cells to migrate to exposure sites, where they

can differentiate into and replace dysfunctional or injured cells.⁵⁻⁷ It also induces RPE apoptosis and choroidal heat shock proteins.^{8,9} Additionally, it upregulates pigment epithelium-derived factor (PEDF), a powerful inhibitor of angiogenesis.¹⁰

MICROPULSE PHOTOCOAGULATION

Randomized prospective clinical trials demonstrate that subthreshold micropulse photocoagulation is as effective a treatment for diabetic macular edema as conventional, more damaging laser therapy.^{11,12} Moreover, a recent study documents that it can improve visual sensitivity, whereas standard suprathreshold ETDRS-type photocoagulation decreases sensitivity.¹³

The bottom line is that subthreshold micropulse photocoagulation can be constructive without being destructive, whereas conventional suprathreshold photocoagulation causes permanent rod, cone, and retinal ganglion photoreceptor damage, with corresponding losses in scotopic, mesopic, and circadian photoreception.^{17,20}

Micropulse photocoagulation can decrease retinal damage by: 1) using subvisible or barely visible treatment endpoints; 2) localizing laser effects with exposures 100 times shorter than those available with manual or automated-pattern conventional photocoagulators; and 3) optimizing laser wavelength.¹⁴

SUBTHRESHOLD ENDPOINTS

Photocoagulation occurs when laser radiation is absorbed primarily by melanin in the RPE and the choroid.¹⁴⁻¹⁷ Light absorption in pigmented tissues converts laser energy into heat, increasing the temperature of the pigmented tissue targets. Heat conduction then spreads this temperature rise from laser-irradiated pigmented tissue to overlying neural or collateral retina. Overlying retina damaged by heat conduction loses its transparency and scatters white slit lamp light back at the observer. Retinal whitening is the optical signature of a chorioretinal burn. More damage means less transparency and a whiter lesion.^{14,17}

There are many “thresholds” for retinal laser exposures. Hemorrhages occur at roughly three times the exposure needed to produce ophthalmoscopically apparent lesions. Invisible lesions that are angiographically apparent occur at approximately half the laser exposure needed for a visible lesion. Maximum permissible exposure (MPE) levels established by international laser safety standards represent roughly one-tenth the laser exposure needed to produce a retinal effect.^{14,17,18}

In clinical terms, “subthreshold” means “invisible.” Smaller retinal irradiances (power density in W/cm^2) produce therapeutic effects with lower retinal temperature rises that cause less or no retinal damage.^{14,17}

LOCALIZING RETINAL EFFECTS

Figure 1 shows retinal temperature increase in the neural retina, the RPE, and the choroid for a 200-micron diameter retina spot, and laser exposures ranging in duration from 1 microsecond to 0.1 second.^{15,16} For very short microsecond exposures, retinal temperature increases only in the RPE and choroid, where light is directly absorbed. For lengthier exposures, heat conduction spreads temperature elevations to the neural retina that are comparable to those in the RPE and choroid. Thus, neural retinal damage is caused primarily by heat conduction, and shortening a laser pulse can localize its chorioretinal effects.¹⁴⁻¹⁷

To confine laser effects to RPE cells, which are only 10 to 14 microns tall, laser exposures must be less than approximately 0.7 msec in duration, which is roughly 50 times shorter than the shortest exposures available with manual or automated-pattern conventional photocoagulators. Additionally, delivery of the full laser energy dose in a single

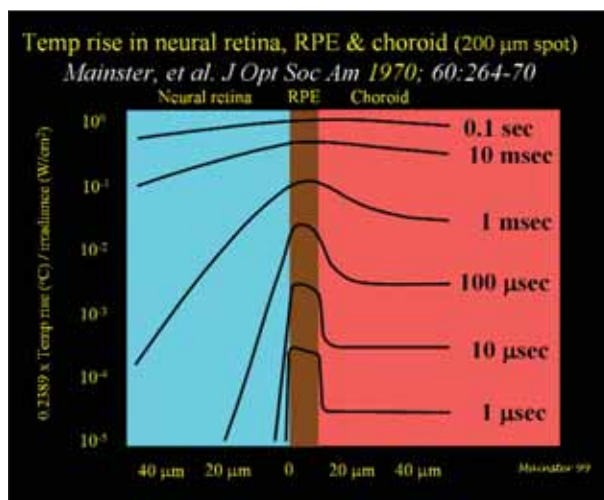


Figure 1. Temperature increase for a 200-micron diameter retina spot in the neural retina, the RPE, and the choroid with laser exposures ranging from 1 microsecond to 0.1 second.

0.7 msec pulse can cause hemorrhage and postoperative choroidal neovascularization, which is one of the reasons ruby lasers were abandoned early in the evolution of clinical photocoagulators.¹⁴

Micropulse photocoagulation provides an effective workaround for this problem. Laser energy is delivered in a burst (“envelope”) of micropulses, rather than a single pulse. There is insufficient time for heat conduction to spread temperature rise to adjacent sites, each micropulse denatures only a small fraction of target tissue molecules, and repetitive micropulses combine to produce therapeutic effects.¹⁴

OPTIMIZING LASER WAVELENGTH

Another way to localize damage with micropulse photocoagulation is by optimizing laser wavelength.¹⁷ Over the years, numerous laser wavelengths have been used for retinal photocoagulation and laser trabeculoplasty. Melanin is the most effective chorioretinal absorber. Its absorption decreases with increasing wavelength, as does that of deoxyhemoglobin and oxyhemoglobin, as shown in Figure 2. Figure 2 also shows that oxyhemoglobin has an absorption peak at 577 nm in the yellow part of the visible spectrum.^{14,17}

Red and infrared laser light cause deeper, less visible, and often more painful lesions.¹⁷ Conversely, deeper lesions may reduce damage to retinal ganglion photoreceptors.^{19,20} A common misperception is that red light is particularly useful for laser photocoagulation when there is hazy media or vitreous hemorrhage. The fact is the retina is visualized with white slit lamp light, not with red laser light. Treatment in hazy media is limited by visualizing retinal

targets with white slit lamp light, not by difficulty getting a laser beam to a visible target.^{14,17}

No controlled trial has proven the clinical advantage of one laser wavelength over another in standard grossly suprathreshold retinal photocoagulation, but dye lasers exploited the 577 nm yellow peak of oxyhemoglobin to improve the comfort and convenience of standard clinical retinal photocoagulation.^{14,17} The 577 nm yellow laser light provided excellent lesion visibility, low intraocular light scattering and pain, negligible xanthophyll absorption, and high choriocapillaris absorption for more uniform effects in patients with light or irregular fundus pigmentation.¹⁷ In fact, there is about a 15% reduction in the variability in laser light absorption with 577 nm yellow light as compared with 532 nm green light.

Two things happened when dye laser photocoagulators were introduced in the mid-1980s. First, they quickly became popular with retina specialists. Second, although clinicians could select green, yellow, and red light, many decided rapidly to leave the photocoagulator set at 577 nm yellow light. Dye lasers went away in the 1990s because they were costly, complex, difficult to maintain, and simply not economically justifiable. Since then, 561 nm green light has been marketed as an alternative “yellow” light, but 561 nm light is not yellow.²¹ Furthermore, it is not an optimal clinical wavelength because it has higher absorption in deoxyhemoglobin than oxyhemoglobin and lower absorption in oxyhemoglobin than either standard 532 nm green or 577 nm yellow light.^{14,17}

LASER MULTIFUNCTIONALITY

It has taken two decades for laser technology to catch up with clinical demands, but new semiconductor laser devices now provide cost-effective, reliable, solid-state

577 nm yellow laser light for clinical use, exploiting the same 577 nm yellow peak in the absorption spectrum of oxyhemoglobin that dye laser users found so effective. The IQ 577 photocoagulator (Iridex Corporation, Mountain View, CA) uses this new technology to provide two watts of 577 nm yellow laser light for optimized wavelength for: 1) standard retinal photocoagulation; 2) MicroPulse retinal photocoagulation; 3) standard laser trabeculoplasty, and; 4) MicroPulse laser trabeculoplasty.

Despite pharmacological advances, laser photocoagulation remains a critical part of modern retina and glaucoma practice. Clinical instrumentation and methods are available for minimizing collateral retinal laser damage and increasing postoperative visual sensitivity. Optically-pumped semiconductor technology now provides 577 nm yellow laser light optimized for conventional and micropulse photocoagulation. ■

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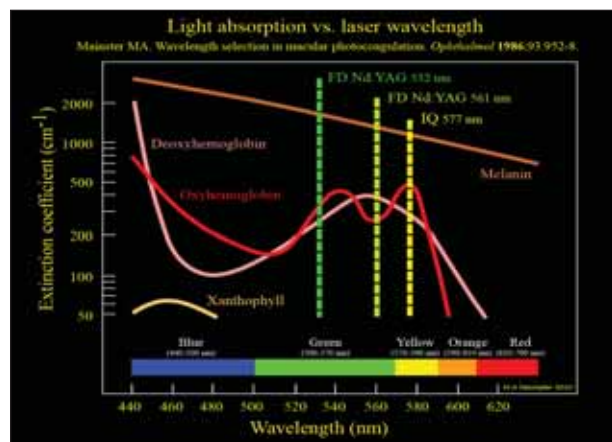


Figure 2. Unlike green 532 nm and 561 nm laser light, 577 nm laser light is optimized for peak oxyhemoglobin absorption.

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First Impressions of the Iridex IQ 577 Yellow Laser: Seeing Is Believing

Richard B. Rosen, MD, FACS, FASRS, CRA



As we all are aware, diabetic macular edema (DME) is the cause of mild to moderate vision loss in about 40% of patients who have diabetes, so it is a formidable problem for us to manage. In the 1980s, we based our treatment for DME on contact lens examination.

In those days, thickness was thickness, and there was no real distinction in terms of different types. Today, we have the benefit of better imaging technology that shows more detail within the retina, so we can decide which eyes may be more appropriate for a particular treatment.

The ETDRS study¹ showed a reduction in vision loss with standard grid laser therapy, and patients were grateful, but most patients today hold us to a higher standard. My patients ask, "When am I going to see better, doctor?" Answering that can be a challenge, because often they have systemic issues that are difficult to manage.

In general, the benefits of laser photocoagulation include reduced retinal thickening and some slight visual improvement, but we are still grappling with the problem of thermal injury. The impact of inducing scotoma is sizable, particularly as it affects a patient's ability to read. Most patients do not experience appreciable visual acuity improvement.

In recent years, researchers have investigated pharmacologic remedies, but the data have shown laser photocoagulation is still better for our patients with macular edema.^{2,3} Laser is our gold standard, and in terms of overall management, I think it will continue as such for some time. The question remains: How do we optimize laser therapy to enhance visual and anatomic results and minimize patient discomfort?

POLISHING THE GOLD STANDARD

When Iridex introduced the IQ 577 yellow laser, I saw that it had some interesting clinical advantages. Visibility at the slit lamp is better with the yellow laser. Because 577 nm is at the peak absorption of oxyhemoglobin, the IQ 577 produces consistently sharp burns. Blanching occurs with lower

power settings and is confined to a smaller area due to the reduced scatter of the laser. In terms of panretinal photocoagulation, the 577 nm yellow causes less pain because it uses less energy than either 532 nm or 561 nm systems.

A notable feature of the IQ 577 is its ability to turn off the red aiming beam while the footswitch is depressed. This is important because the surgeon's eyes tend to fatigue, looking at the bright laser, even when the aiming beam is turned down as much as possible. With the aiming beam turned off, you can easily distinguish early burn development.

APPLYING THE "RESIDENTS TEST"

What I particularly like about the IQ 577 and find useful for residents is that the eye safety filter system allows the simultaneous use of a red-free filter on the slit lamp while treating. As we know, the red-free accentuates the visibility of xanthophyll pigment so the surgeon can clearly see the fovea and the parafoveal region. We can see what we should be treating from the fluorescein, but we cannot necessarily distinguish it clinically, especially when viewing a fundus image. Trying to decide where or how close to the macula to treat can be difficult.

The red-free filter distinguishes the macular pigment and highlights any microaneurysms. The surgeon commonly will not treat with red-free light when using a green laser because it is somewhat disorienting, and visualization is compromised. With a green (532 nm) system, the protective filter blocks the green light coming from the slit lamp. It can be difficult to have the light bright enough to see with-

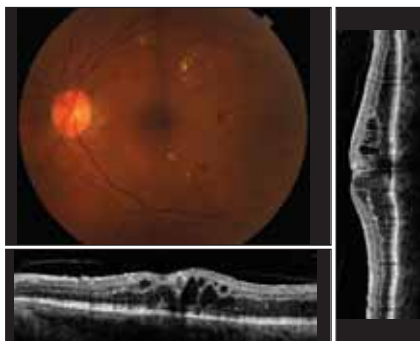


Figure 1. Disturbance of the macular contour and loss of landmarks may impair the surgeon's ability to recognize the edge of the fovea.

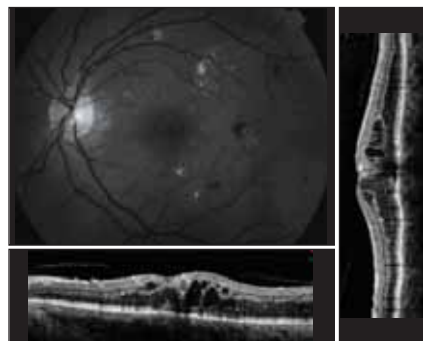


Figure 2. Red-free illumination can facilitate identification of the xanthophyll pigment, which can encircle the foveal avascular zone, and helps guide the surgeon's targeting.

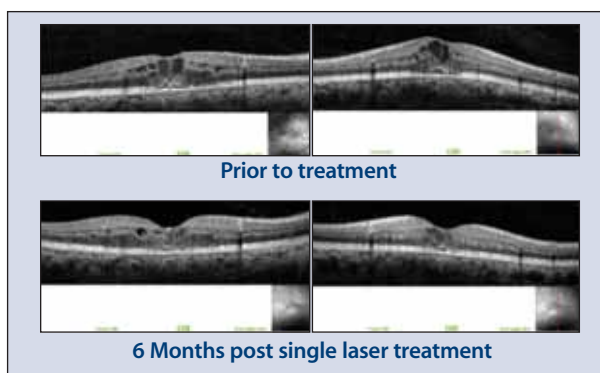


Figure 3. After a single treatment with the IQ 577, this patient's macular edema resolved.

out creating additional discomfort for the patient. With the IQ 577, however, we can comfortably see the target area because the filter blocks the yellow (577 nm) light—not the green light.

I like to test certain theories with my residents because they do not have intellectual baggage from years in practice. I tell them, “I’m going to let you treat these areas, but you have to use the 577 nm yellow laser and see what it does.” Two residents so far have told me, “Using the red-free filter makes me a lot more confident. I know when I’m close to the fovea. With normal lighting, especially with macular edema, I don’t have many landmarks.” That, in itself, is a big plus for the IQ 577 in terms of the surgeon’s confidence compared to using the 532 nm laser (Figures 1 and 2).

True Yellow 577 for the Treatment of Retinal Disorders: Searching for the Holy Grail

Robert P. Murphy, MD



Our goal over the past several decades has been to find the “holy grail of laser-ology”: the ability to achieve the best vision possible while minimizing tissue damage. There has been a quietus in development and experimentation with lasers, but I think that period is over, and we are coming into an interesting new era of lasers. I will briefly discuss the evolution of the yellow laser, some key features of the IQ 577 Laser System and a topic close to my heart, the micropulsing of lasers.

TRUE YELLOW LASER RE-EMERGES

In the late 1980s, 577 nm laser technology was introduced in the form of a large, tunable dye system, requiring special

To give a quick example of the ability to treat close to the fovea, Figure 3 shows the case of a 58-year-old man who was actively working but had reached a point where he was unable to drive. His BCVA was 20/80. Triamcinalone treatments did not produce improvement. After a single treatment with the IQ 577, his BCVA is 20/40⁻¹, the central area resolved, and his fovea is visible again.

SUMMARY

The IQ 577 gives us more options than we have had in the past. The laser provides improved visualization aided by the ability to treat while using the red-free filter in the slit lamp, and the 577 nm wavelength requires less power and shorter pulse durations to treat, improving the patient’s comfort. ■

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electrical and water conduits for power and cooling. One of the key advantages of the 577 nm wavelength is that it avoids absorption in xanthophyll, allowing treatment closer to the macula. Another notable difference is 577 nm lasers can produce a visible burn with less power and less collateral damage than produced by the blue-green or green laser wavelengths. This translates into less discomfort for patients, less axial and lateral thermal spread, less anatomical and functional damage, and less progressive scar enlargement. Our goal is to get the job done with the least amount of tissue damage and scarring, so in this case, less truly is better.

Ophthalmologists’ interest in a yellow laser always has been high; however, the technology succeeding dye lasers gravitated toward solid-state systems and away from the

Extinction Coefficients: Oxyhemoglobin (HbO) and Reduced Hemoglobin (Hb)				
Laser	λ (nm)	HbO	Hb	Ratio HbO/Hb
Argon Green	514	150	160	0.94
Solid State Green	532	320	250	1.28
Krypton Yellow	568	330	330	1.00
Solid State "Yellow"	561	250	380	0.66
Dye Laser	577	460	270	1.70
IRIDEX Yellow	577	460	270	1.70

Figure 1. 577 nm laser light has 1.4 times higher absorption than 532 nm and 1.8 times higher absorption than 561 nm in oxyhemoglobin.

key 577 nm wavelength. Although other "yellow" lasers eventually emerged, their wavelengths differed from 577 nm and did not offer the same advantages. As shown in Figure 1, not only does the preferred 577 nm laser have peak absorption in oxyhemoglobin, but it is more efficient than 532 nm and 561 nm systems. Furthermore, the "yellow" 561 nm lasers are even less efficient than the conventional green (532 nm) systems.

In 2008, Iridex brought back the true-yellow 577 nm wavelength, this time in a solid-state platform, the IQ 577. This is the first ophthalmic photocoagulator to incorporate a solid-state laser capable of delivering up to 2 watts of power at the critical 577 nm wavelength. The stability and reliability of a solid-state device coupled with the ability to deliver faster treatments and create smaller lesions with more controllable, reproducible, lighter burns make it a truly desirable system.

IQ 577 ADVANTAGES

The advantages of using a 577 nm laser are clear. Retinal photocoagulation with the IQ 577 is characterized by the highest oxyhemoglobin absorption, the highest oxyhemoglobin-to-melanin absorption ratio, negligible uptake by macular pigments including xanthophyll, lower phototoxicity, lower scatter, lower treatment power requirements, and excellent visualization of even the mildest tissue reactions.

I started using the IQ 577 about a year ago. Compared with the green laser, I can see that the IQ 577 creates a precise, well-defined burn with minimal bloom. That is an advantage when your goal is to make smaller, lighter lesions in the retina. Immediately, I noticed the ability to treat with significantly less power, in some cases 50% to 70% less. Likewise, I could reduce the pulse duration to further minimize the discomfort to the patient.

Patients are more comfortable with treatment by the IQ 577, and they will tell you so. Pain level depends on the wavelength (absorption), the duration of application

(pulse length), and the power setting. Because the IQ 577 is a more efficient laser and its wavelength is well absorbed in the retina, you can reduce the power, reduce the duration of beam application, and consistently see a sharp, concise spot.

Higher efficiency means lower power settings, and reducing the duration and power help reduce pain and discomfort, especially with panretinal photocoagulation (PRP) and other laser-intensive treatments. For example, when performing a PRP with a 500 μ m spot size, you can set the time at 0.07 seconds and reduce the power to less than 200 mW. You still produce a nice lesion that will not spread, and it is much more comfortable for patients. The need for retrobulbar anesthesia is eliminated.

Also interesting for me is the repeatability of the laser burn. Unlike other systems, when using the IQ 577, I have to readjust the power only a couple of times at most during a treatment. The laser is efficient, in that it can achieve a consistent lesion throughout the retina, regardless of the local pigmentation of the target area. In short, it performs with nearly "set it and forget it" treatment parameters.

Finally, the IQ 577 provides uncompromised visualization. When performing photocoagulation, achieving the desired endpoint depends on our ability to accurately visualize the coagulation effect on the retina. Older systems with dark safety filters made seeing the endpoint difficult. The IQ 577 laser with new, clearer safety filters does not compromise our view of the retina.

INTUITIVE SYSTEM

I am the kind of person who does not usually read the instruction booklets. My evaluation of a new product has a lot to do with how easily I can learn to use it without reading the manual. The IQ 577 is totally intuitive. Everything is where it should be. It is easy to use and user-friendly. The laser console and the remote have the same controls, and a

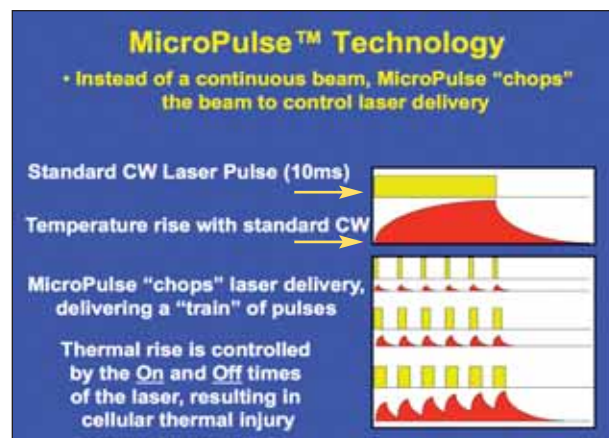


Figure 2. MicroPulse introduces a novel way to manage laser-tissue interaction.

wireless power-adjust foot pedal allows you to adjust the power to titrate the intensity of the burn. It is beautifully designed with ergonomic user-interface, color touch-screen graphics, voice prompts, and dual-port device connectivity.

Someone asked me recently what criteria I would use if I were buying a new laser today. Clearly, having the 577 nm wavelength is a tremendous advantage, but micropulsing also will be necessary in all the lasers of the future. If you buy a system without the ability to pulse the laser, you're basically buying 20- or 30-year-old technology.

MICROPULSE ADVANTAGE

Iridex has been a leader in the concept of micropulsing since its introduction in 1992. The laser delivery mode allows much finer control of the output and, thus, the laser-tissue interaction. It gives you more control over the thermal effects of the laser on the tissue and facilitates tissue-sparing procedures. It has been used successfully to treat patients with diabetic macular edema, proliferative diabetic retinopathy, central serous retinopathy, and glaucoma.

With the old continuous-wavelength laser, you dial in one- or two-tenths of a second and press the pedal, triggering an event that is out of your control. The retinal temperature rises until the end of the pulse, triggering thermal decay, which further heats and coagulates nearby tissues even after the pulse terminates. You have no control over this thermal decay process, making it easy to overtreat or perforate the choroid during macular treatment, especially when using a small spot size.

MicroPulse introduces a novel way to manage laser-tissue interaction (Figure 2). Instead of a single large laser pulse, you introduce a series of multiple, short (microsecond)

pulses. Each short pulse creates a small thermal effect in the tissue. The temperature of the tissue decays back to baseline after each micropulse and prior to arrival of the next pulse. The heat deposited during each micropulse is small, so the subsequent thermal decay is largely confined to the immediate target region.

The pulse is set, the duty cycle is set, and now you can control the final laser-tissue interaction by gradually increasing the power. The thermal effect is not additive. This makes it virtually impossible to perforate the choroid or get a surprise white burn, which can happen with other lasers, including the green laser. This level of control and target specificity afforded by micropulse was not possible using older, continuous-wave lasers. You have exquisite control over the final laser-tissue interaction. A laser without this feature is already an obsolete laser.

SUMMARY

The IQ 577 has an elegant design and an excellent user interface. The console is immediately responsive. Performance is very good, and compared to the green laser, less power is required to create most burns. You can consistently achieve the desired goal of mild, light but effective burns. You can see the burns earlier, and they are more reproducible. Treatments take less time, and patients are more comfortable and happier. ■

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Micropulse Treatment for Central Serous Retinopathy

André Maia, MD, PhD



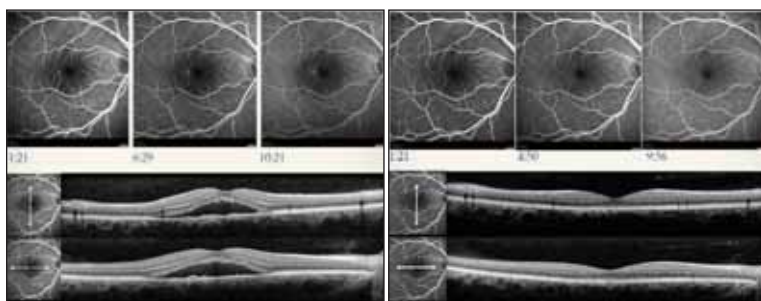
Central serous retinopathy (CSR) is an idiopathic disease that typically affects people from 20 to 50 years old. The disease predominantly affects men and is more common in whites. It is a well-established disorder, leading to serous retinal detachment and elevation of the central macula. The acute form of the disease is associated with focal leakage at the level of the retinal pigment epithelium.

The disease is generally self-limited. Most patients have spontaneous resolution within 2 months, and visual acuity usually resolves to 20/30 or better without treatment. A few patients may develop chronic or progressive disease,

resulting in vision loss. For these patients, focal laser photocoagulation, photodynamic therapy, and micropulse laser are treatment options. In my experience, micropulse laser with the IQ 577 is a safe and effective procedure to treat CSR, as the following cases illustrate.

CASE 1

A 36-year-old man had a history of reduced visual acuity in the right eye (20/80) for about 8 months. The fundus examination showed a foveal detachment on the right eye. In the early and late phases, the angiogram (Figure 1, top) shows a small leakage close to the center of the fovea. Spectral domain optical coherence tomography (OCT)



Figures 1 and 2. Case 1 angiograms pre- and post-treatment with the IQ 577 laser.

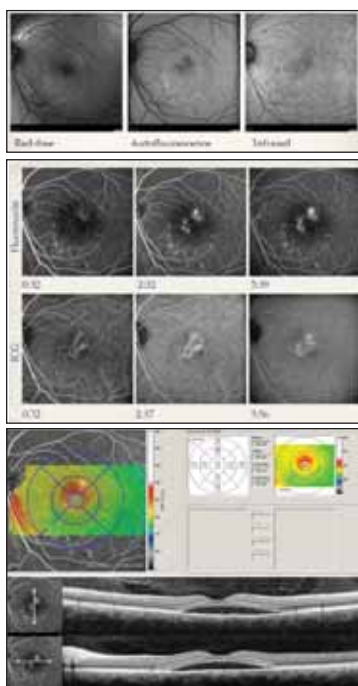
shows the retinal detachment involving the fovea (Figure 1, bottom).

We treated this patient with the following MicroPulse settings on the Iridex IQ 577 laser: 200 μ m spot, 120 mW, 15% duty cycle for micropulse (0.3 milliseconds on and 1.7 milliseconds off), 215 shots at 300 milliseconds per shot (delivering 150 micropulses with each shot).

After 14 days, the patient's visual acuity had improved to 20/20 partial. The post-treatment angiogram (Figure 2) shows no laser burns and no leakage.

CASE 2

A 47-year-old man had a history of reduced visual acuity (20/80) in the left eye for 18 months. On autofluorescence and infrared (Figure 3), we see alterations of the retina and



Figures 3-5. Case 2 pretreatment status.

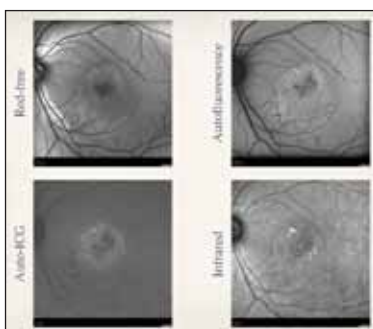


Figure 6. Case 2 after first treatment with the IQ 577 laser.

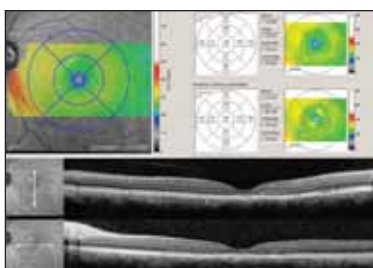


Figure 7. Case 2 after second treatment with the IQ 577 laser.

hypo- and hyperautofluorescent spots in the center of the macula where the detachment was located. On the angiogram and the ICG (Figure 4), we see leakage close to the center of the fovea. The OCT (Figure 5) shows a detachment of the retina in the center of the macula.

This patient was treated with bevacizumab (Avastin, Genentech, Inc.). When he returned 30 days later, his visual acuity had not changed, and OCT showed no change. We treated him with the IQ 577 laser in its MicroPulse treatment mode. We delivered

471 shots in the center of the macula using a 300 msec pulse duration, 200 mW, 200 μ m spot size, and 15% duty cycle. Nine days later, the patient's vision had improved to 20/60. There were small changes in the infrared but no changes in the autofluorescence after treatment (Figure 6) and almost complete resolution of the retinal detachment.

The patient returned 7 days later, and his visual acuity was 20/70. I saw a recurrence, a bigger detachment than before. I re-treated with 566 shots on the detached area of the retina, using a 300 msec pulse duration, 160 mW, 200 μ m spot size, and 15% duty cycle.

Fifteen days later, the patient's visual acuity had improved to 20/25 and, as shown on the OCT, the retina was almost flat (Figure 7). The angiogram shows no changes in the RPE, autofluorescence, or infrared due to

laser treatment. This patient was treated twice with this technique with no changes in fluorescence, autofluorescence, or infrared, and his visual acuity improved after an 18-month history. In my opinion, this is an incredible case.

SUMMARY

I believe 577 nm micropulse is a very effective laser treatment for chronic CSR. It may cause less or no damage to the retina. We need new studies, so that long-term results can be analyzed. Our goal should be to have absolutely no scars on the retina with this treatment. Most patients respond very well within 30 days of treatment. ■

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