Multispot and Multiwavelength Lasers for Diabetic Retinopathy

Advanced laser technology allows less damaging, more efficient treatment delivery.

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Since the ETDRS, panretinal photocoagulation (PRP) or macular laser in the form of focal or grid treatments have been the standard of care for treating patients with diabetic retinopathy. The first lasers were argon and krypton gas in blue-green wavelengths.[1,2] 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.[3] 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). Maintaining the tunable lasers, however, was expensive and difficult, and some of the dyes were carcinogenic.[4] 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.[5]

Further development of solid-state technology brought about the production of 577-nm wavelength lasers.[4] The combined absorption by both melanin and oxyhemoglobin of 577 nm causes less scatter compared with 532 nm or other yellow wavelengths (561 nm or 568 nm), allows better selective treatment of vasculature, and compensates for the reduction in absorption by retinal pigment epithelium (RPE) melanin compared with 532 nm. The energy concentration to a smaller volume allows use of lower powers and shorter pulse durations. This wavelength provides greater transmittance through some corneal or lenticular opacities,[6] and it falls occurs outside the absorption spectrum of retinal xanthophylls, potentially allowing treatment close to the fovea.[6] High choriocapillaris absorption should also help

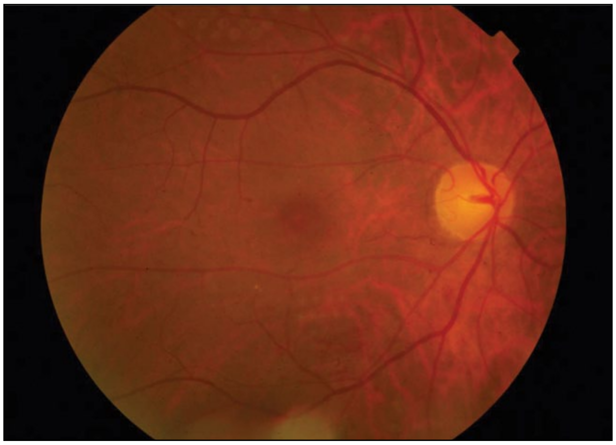

Figure 1. Right eye fundus photograph of a patient treated with green, yellow, and red laser. Three rows of laser burns are seen inferior to the macula in a region of diabetic edema.

to provide more uniform effects in patients with light or irregular fundus pigmentation.[7] Studies have shown a higher likelihood that green laser might lead to submacular fibrosis or choroidal neovascularization. Thus, 577-nm wavelength has been described as optimal for macular photocoagulation and treatment of vascular lesions and subretinal vascular proliferations.[7,8]

Laser light absorbed by melanin of the RPE leads to destruction of mitochondria-rich, and therefore oxygen-demanding, photoreceptors. The resulting mitochondria-deficient glial scars facilitate oxygen diffusion directly from the choroid to the inner retina by reduced oxygen consumption in the outer retina. Relief of inner retinal hypoxia reduces production of VEGF receptors, which limits neovascularization.[9,10]

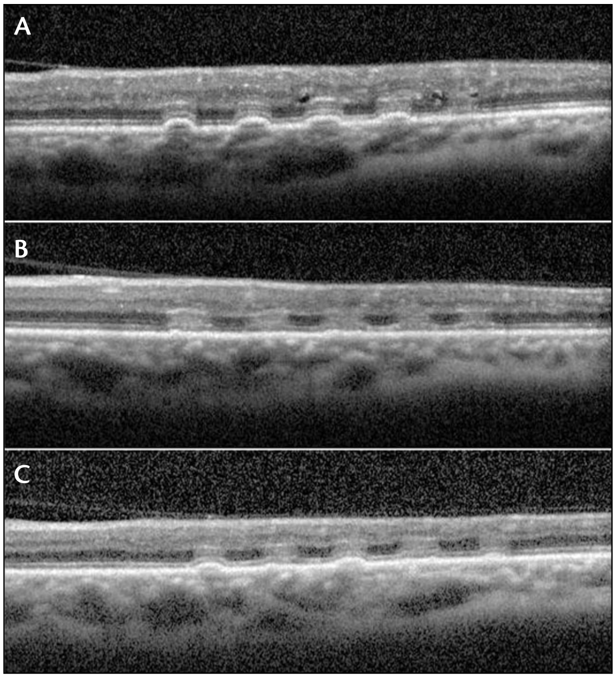

Figure 2. Optical coherence tomography (OCT) image of green laser burns shows increased reflectivity, subretinal fluid, and intraretinal vacuoles (A). OCT image of yellow laser burns shows a uniform effect with minimal disruption of the surrounding tissue (B). OCT image of red laser burns shows increased disruption of the outer retinal layers (C).

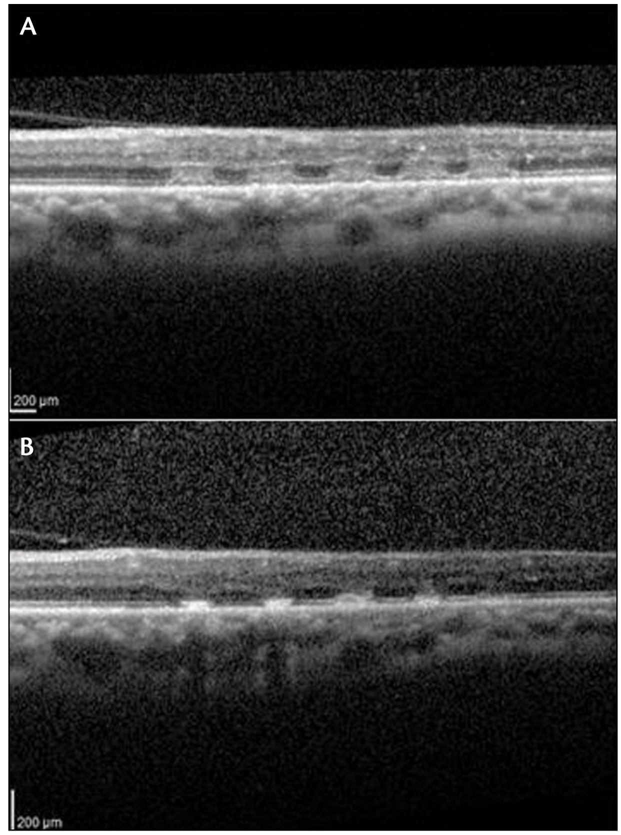

Figure 3. Optical coherence tomography images showing the involution of the yellow laser burn marks at days 1 (A) and 30 (B).

MULTISPOT LASERS

Standard laser photocoagulation is performed using single spots with pulse durations of 100 to 200 ms in a continuous mode. The sessions are lengthy and taxing for both patient and surgeon.[11] Also, treatments such as PRP carry risk of complications such as macular edema.[12]

Limitations include the inability to apply laser spots in patterns in the periphery and the tedious burn placement with appropriate spacing.

The multispot laser bypasses some of these limitations.[12] Multiple uniform laser burns delivered simultaneously by a single footpedal depression in a variety of patterns using proprietary software create adjustable predetermined square arrays, arcs, and grids with variable spot sizes and variable distance between spots, all controlled through an intuitive interface.[11] This defines new strategies in terms of power, software, and hardware technology to formulate safer macular laser applications.[10] These devices save time, streamline patient flow for the retina practice, and reduce discomfort from long laser sessions.[13,14] These conclusions were drawn from a prospective randomized clinical trial performed to compare the efficacy, collateral damage, and convenience of PRP for proliferative diabetic retinopathy or severe nonproliferative diabetic retinopathy with a 532-nm solid-state green laser (GLx) compared with a 532-nm pattern-scan laser.[15] The latter laser showed less collateral damage and similar regression of retinopathy compared with GLx, was less time consuming, and was less painful for patients.[16-18]

The PASCAL laser (Topcon) uses a proprietary, semiautomated pattern generation technique that allows rapid delivery of laser pulses in a predetermined sequence, with durations of 10 ms to 20 ms at each spot, as opposed to 150 ms to 200 ms with conventional laser. The fluence is only a quarter of that delivered by conventional laser (30 J/cm^2 vs conventional, 127 J/cm^2). It might be thought that treatment effect would be diminished because of the reduction in fluence, but investigators have not found this to be the case.[19]

Precision control, safety, and efficiency of the photocoagulation procedure is combined with optimized patient comfort and convenience.[20-22]

Patient satisfaction questionnaires state a preference for multispot laser over conventional laser with the experience with conventional laser being described as tiring and painful.[11,18]

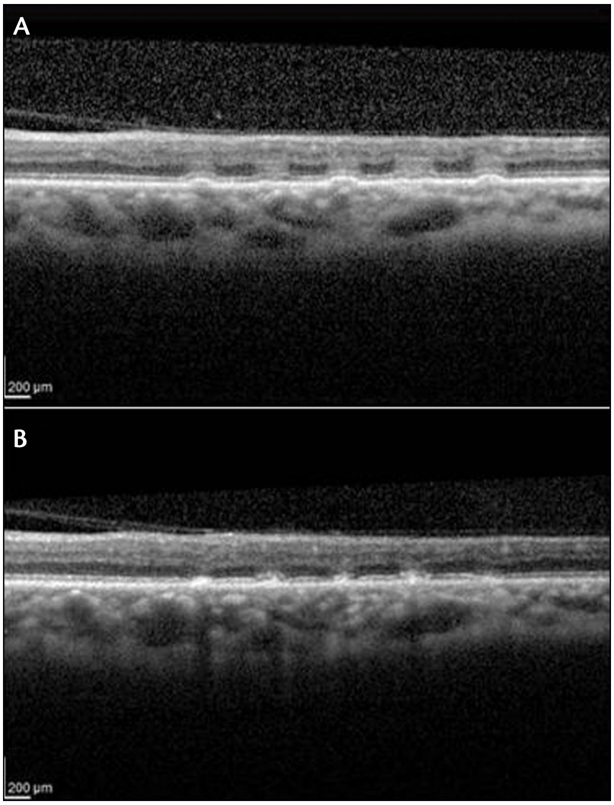

Figure 4. Optical coherence tomography images showing the involution of red laser burn marks at days 1 (A) and 30 (B).

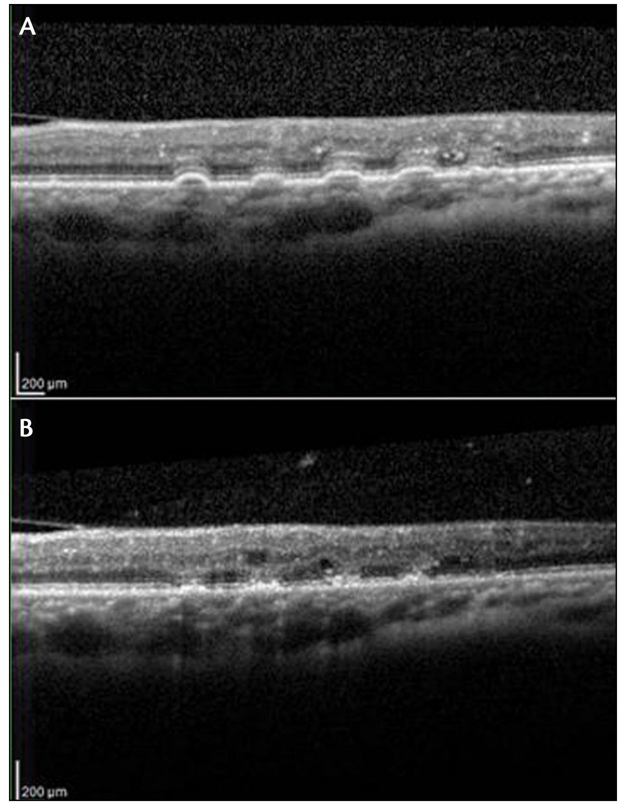

Figure 5. Optical coherence tomography images showing the involution of green laser marks at days 1 (A) and 30 (B).

The efficacy of the PASCAL laser in the macular area has been supported by the PETER PAN study.

In our experience comparing multispot laser in 1 eye and conventional laser in the contralateral eye, we observed less field loss in all eyes treated with multispot laser. Improved ease in treating the extreme periphery was also observed.[11]

Frequency-domain optical coherence tomography has confirmed that burns from the multispot lasers are confined and localized to the outer retina, and fundus autofluorescence has confirmed the presence of burns that are not always visible on fundus biomicroscopy.[23,24]

In our experience, comparison of burns in lapine eyes with half the fundus lasered with PASCAL and the other half with argon using the same power revealed small blisters in the PASCAL-treated tissue, with minimal disruption to the rest of the layers. In the argon lase-treated area, the elevation and destruction of the receptors around the treatment area were greater.[11,22,25-27]

The efficacy of the PASCAL laser in the macular area has been supported by the PETER PAN study, in which barely visible subthreshold laser has been shown to be effective in the macular area or as PRP.[22,28]

COMBINATION OF MULTISPOT AND MULTI-WAVELENGTH

The 577-nm wavelength and the multispot delivery mode combination facilitates lower required energy levels than that of conventional 532-nm laser, resulting in less pain and a milder inflammatory response for the patient.[18] Treatment grids are homogeneous and evenly spaced, and similarly intense spot patterns are adjustable for individualized treatment needs. The rapidity of the delivery significantly reduces effects of patient movement.[14] The longest bursts last 0.5 seconds, but those consisting of 9 spots are practically instantaneous and avoid the effect of most eye movements.[12]

A combination of benefits of multispot and multi-wavelength lasers is seen with the MC-500 Vixi Multicolor Scan Laser Photocoagulator (Nidek), which allows the user to select from 3 wavelengths either alone or in combination: 532-nm green, 577-nm yellow, and 647-nm red. This enables the user to select the necessary color combination to increase efficiency of treatment for a specific indication.[6]

The Vixi laser includes 8 preprogrammed scan patterns with a memory function for up to 14 patterns. Available patterns include a single spot, squares, circles, arcs of various dimensions, triple arcs, macular grids, triangles, lines, and curves. The most frequently used scan patterns can be recalled from memory for future use. The scan spot size is continuously variable from 50 µm to 500 µm in single mode and from 100 µm to 500 µm in scan and automanipulation mode. Automanipulation mode delivers repeated laser emissions with variable interval times and conventional coagulation settings in a selectable scan pattern. It allows the surgeon to continue laser emission while confirming spot placement. The scan mode is used for repeated laser emissions with a fixed interval time, high power, and instantaneous speed. It saves time by requiring fewer sessions,[14] consumes less energy, and provides more versatility than conventional models.[6]

Compared with green wavelength, yellow wavelength enables more efficient photocoagulation through opaque media such as cataract. In eyes with retinal hemorrhage, better penetration is achieved with the red wavelength. Hence, with this multi-wavelength, multispot laser, treatment may be started with a particular color and continued with a different color. The laser can be used with existing slit lamps, transforming them into a stage for scanning laser treatments. All units incorporate the safety optics with low impact on cornea (SOLIC) optical design, which ensures low-energy density on the cornea and lens even with large spot sizes.[7]

In our experience, this laser saves time by requiring fewer sessions, consumes less energy, and provides greater versatility. Laser output can be limited to a single wavelength or modulated to a combination of colors for specific treatments.

STUDY ON EFFECTS OF DIFFERENT WAVELENGTHS

We compared the 3 wavelengths in patients with diabetic macular edema who were scheduled for a grid laser treatment. In the area of thickened retina we placed 3 sequential line patterns of laser marks, 1 each with red, green, and yellow wavelength using similar power settings (Figure 1). Following the laser treatment, a spectral-domain optical coherence tomography (SD-OCT) scan using the Spectralis (Heidelberg) was taken through the area containing these 3 rows of laser. The comparative scans of each are shown in Figure 2, which shows that the green wavelength burn tends to cause more collateral damage as compared with yellow, and that red tends to produce a deeper burn. We further carried out repeat scans in the same area after 1 month to examine the involution of these laser burns. The least amount of collateral damage was seen with the yellow wavelength (Figures 3-5).

We compared the 3 wavelengths in patients with diabetic macular edema who were scheduled for a grid laser treatment.

Based on these findings, we conducted a study comparing the morphologic effects of the yellow and green wavelengths using the Vixi laser for patients undergoing laser for diabetic retinopathy.[29] Fifty-six eyes of 28 patients received PRP in this prospective study. The green laser was applied to the right eye and yellow to the left. The study areas were imaged on the same day and after 1 month with color fundus photography and SD-OCT.

We found more morphologic changes in the retinal layers in the form of hyperreflectivity, subretinal fluid, and intraretinal vacuoles on OCT scans of the right eyes. At 1 month, SD-OCT scans of the right eyes showed greater alteration in the form of hyperreflectivity involving the RPE and neurosensory retina compared with the left eyes. Hence, yellow was seen to cause less collateral damage to the neuroretina and permit a level of reorganization in the outer retina.[15]

SUMMARY

The pattern scan yellow laser uses less power and decreases patient discomfort.[18,22,30] The treatment is delivered in minimal time with a gentle effect on the targeted area; there is minimal effect on the surrounding retinal tissue and an absence of late scarring. Treatment can be delivered through opaque media, and we believe there is potential synergy when combined with intravitreal anti-VEGF therapies.[31] ■

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