Comparison of Diode and Argon Laser Trabeculoplasty in Cadaver Eyes


Purpose. To evaluate differences in the effects of diode and argon trabeculoplasty on cadaver eye trabecular meshwork.

Methods. The argon laser was used at a 50 μ spot size, 500 to 1000 mW of power, and a 0.1 second time interval, and the diode laser was used at a 0.1 to 0.2 second time interval, 100 μ spot size, and 400 to 1200 mW of power. Analysis was performed using videography, microscopy, and scanning electron microscopy.

Results. This study found grossly that burns with the argon laser caused tissue blanching and pigment dispersion, whereas no reaction was observed with the diode laser. The diode laser made no observable histologic alterations, but the argon caused fragmentation and coagulation of trabecular beams. Scanning electron microscopy showed that the diode laser caused an area of trabecular beam coalescence measuring 50 to 100 μ in diameter with energies ≥ 0.12 J. A surrounding zone of more superficial trabecular beam fragmentation measuring 200 to 400 μ in diameter also was observed. Similar energy levels from the argon laser caused hole formation 200 to 400 μ in diameter. Lower argon energy levels (0.05 J) caused inconsistent coalescence 50 to 100 μ in diameter similar to the diode laser.

Conclusions. This study suggests that in the trabecular meshwork the diode laser causes a reaction at, but not at less than, energy levels shown previously to produce a clinical ocular hypotensive effect. Also, at similar energy per area, the tissue effects of the diode and argon laser are comparable. Invest Ophthalmol Vis Sci. 1994;35:706-710.

Trabeculoplasty typically is used to lower the intraocular pressure in patients with glaucoma who have failed maximally tolerated medical therapy. Although laser trabeculoplasty has been used almost exclusively with the argon laser, reports diode laser was used to successfully accompany the effects of applications of argon laser light in the trabecular meshwork of eyes with gross inspection, light microscopy, and scanning electron microscopy to determine the differences in the characteristics of thermal burns with the argon and diode lasers across various parameters used clinically.

METHODS

We obtained six freshly enucleated human cadaver eyes through the South Carolina Lions' Satellite Eye-bank in Charleston, South Carolina. Methods used for securing these cadaver eyes were humane, included proper consent and approval, and complied with ARVO guidelines. We transected each sagittally into two equal halves with the crystalline lens removed. Both halves of four eyes were treated, one-half (180°) with the diode laser and one-half (180°) with the argon laser. In one eye, one-half was treated with argon, and the other half was used as a control. In the last eye, one-half was treated with the diode laser and the other half was used as a control. Each eye had a mild-to-moderate pigmented trabecular meshwork without marked pigment variability. One percent hyaluronic acid.
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Acid was used to separate the iris from the cornea so that the trabecular meshwork could be visualized.

Argon blue-green (488 and 514 nm) laser burns were administered to the trabecular meshwork from a dye laser (Coherent Medical Group, Palo Alto, CA) using parameters designed to simulate those used in clinical practice,1 which included a 50 μm spot size, 0.1 second duration, and 500, 700, and 1000 mW of power. Each argon laser application was focused on the superficial trabecular meshwork using the aiming beam. Sequential applications were spaced 3 to 4 aiming beam diameters apart in the midportion of the trabecular meshwork.

Diode laser applications to the trabecular meshwork were performed with the Microlase (Keeler Instruments, Broomall, PA), a portable photocoagulator incorporating two infrared diodes with wavelengths of 780 and 830 nm. The parameters chosen reflect those used previously to treat patients with glaucoma,2 as well as parameters that might have potential clinical usefulness and included a 0.1 and 0.2 second duration, a 100 μm spot size, and 400, 700, and 1200 mW of power. Each diode application was focused by adjusting the biomicroscope so that the clearest optical image of the trabecular meshwork was observed. The aiming beam was used for correct positioning of each application, not for focusing, according to the manufacturer's recommendations. Sequential applications were placed approximately two aiming beam diameters apart in the midportion of the trabecular meshwork. Table 1 summarizes the different parameters used in this study.

Laser applications were evaluated grossly by using 35 mm still photography. Gross effects observed for were obliteration, shrinkage, and blanching of trabecular tissue, as well as pigment dispersion and gas formation.

Light microscopic preparation was performed by first placing the tissue in an automatic processor (Shandon Corp., Cheshire, England) and then treating it with graded ethanol and chloroform concentrations for 10 hours. Next, the tissue was embodied in paraffin and sectioned at 3 μm intervals. A water bath using chromium gelatin was used to prepare glass slides, and the tissue was stained with hematoxylin and eosin. Tissue alterations observed for were trabecular obliteration, fragmentation, and coagulation necrosis, as well as the presence of cellular debris.

Scanning electron microscopy was performed by first fixing the tissue in phosphate buffered 5% glutaraldehyde (pH 7.2) for 24 hours. The eye was sectioned anterior to posterior into four equal quadrants. The tissue was subsequently washed with cacodylate buffer and postfixed in 1% osmium tetroxide for 24 hours. The tissue was bathed through ascending concentrations of ethanol and PELODY and then dehydrated, critical-point-dried, and coated with gold and palladium. Trabecular meshwork was studied with a JEOL JSM35C scanning electron microscope (Japan Electron Optical Labs, Japan). Reactions observed for were alteration of trabecular tissue and tissue debris. The width of the tissue damage was measured in microns.

RESULTS

On gross inspection, the diode laser failed to cause tissue alteration at any energy level evaluated. In contrast, the argon laser caused tissue blanching and pigment dispersion at each energy level studied.

By light microscopy, alteration in the trabecular tissue by the diode laser was not visible at any parameter tested (Fig. 1). In contrast, the argon laser caused coagulation necrosis and tissue fragmentation of trabecular beams at each energy level studied (Fig. 2).

By scanning electron microscopy, the diode laser created two zones of observable damage at energy levels of 0.12 J or above. The first was an inner zone of

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<th>TABLE 1. Differing Powers and Durations of Treatment Used Upon the Trabecular Meshwork</th>
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trabecular beam coalescence approximately 50 to 100 μ in diameter (Fig. 3). A second outer zone of more superficial uveal meshwork loss and fragmentation, measuring 200 to 400 μ in diameter, was observed surrounding the inner zone of coalescence (Fig. 4). These findings were noted inconsistently intermixed with areas with no observable damage after photocoagulation. At lower energy levels (0.04 to 0.07 J), no definite damage to the trabecular meshwork was observed.

The argon laser at 0.07 and 0.10 J caused hole formation 200 to 400 μ in diameter to the outer portions of the trabecular meshwork (Fig. 5). A small zone of coalescence of superficial uveal meshwork surrounding the hole was noted inconsistently. At 0.05 J, areas of trabecular coalescence or mild depression measuring approximately 50 to 100 μ were inconsistently observed.

FIGURE 2. Light microscopic photograph of trabecular meshwork after argon laser trabeculoplasty (700 mW, 0.1 seconds, 50 μ). Trabecular beam fragmentation and coagulation with depression of the trabecular meshwork are visible (hematoxylin and eosin, original magnification X 125).

FIGURE 3. Scanning electron micrograph showing trabecular beam coalescence (white arrow) following diode laser trabeculoplasty (1200 mW, 0.1 seconds, 100 μ) (original magnification X 1300).

FIGURE 4. Scanning electron micrograph showing tissue coalescence (white arrow) surrounded by more superficial trabecular beam loss (black arrows) after diode laser applications (1200 mW, 0.2 seconds, 100 μ) in the midportion of the trabecular meshwork (original magnification X 90).

DISCUSSION
For the past decade, laser trabeculoplasty has been performed in selected patients with glaucoma to reduce intraocular pressure. Although argon blue-green laser light has been the most common laser energy used for this procedure, argon-green, krypton-yellow and red, and Nd:YAG laser energy also have been studied. Recently, several studies have shown that the diode laser could be used to perform laser trabeculoplasty. These investigators used between 800 and 1200 mW of power, a 100 μ spot size, and a 0.1 to 0.2 second duration. They found the diode laser causes a sustained reduction in intraocular pressure for up to a year, which is similar to the results provided by the argon laser.
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FIGURE 5. Scanning electron micrograph of two argon laser applications (700 mW, 0.1 seconds, 50 μ) in the midportion of the trabecular meshwork showing loss of trabecular beams with a peripheral rim of tissue coalescence (original magnification ×100).

However, the type of burn produced by the diode laser potentially may differ from that of the argon for several reasons. First, the diode laser has less melanin absorption and less scleral reflectance than the argon laser.9,10 Also, 100 μ is the smallest available spot size on the diode laser as opposed to 50 μ on the argon laser. Consequently, a higher power and longer exposure time must be used on the diode laser to deliver an amount of energy per area similar to that used on the argon laser.

In a previous report, McHugh and associates used scanning electron microscopy to study burns created by both diode and argon lasers in human eye enucleated for malignant melanoma.11 The pattern of trabecular damage was similar between the two lasers, except that the diode laser created a deeper burn toward Schlemm's canal.

In the present paper, we evaluated differences in the characteristics of burns created in the trabecular meshwork by argon and diode lasers in cadaver eyes with gross inspection, light microscopy, and scanning electron microscopy. We varied parameters that might be used clinically (i.e., power and duration of application) on the diode and argon lasers to determine their differing tissue effects.

This study found with scanning electron microscopy that the diode laser potentially caused two zones of relatively superficial damage to the trabecular meshwork at energies of 0.12 J or greater. These consisted of a small inner zone of tissue coalescence measuring 50 to 100 μ in diameter and a surrounding larger outer zone of more superficial trabecular beam loss and fragmentation measuring 200 to 400 μ in diameter. Despite the larger spot size used on the diode laser, the area of tissue damage was not greater than that produced by the argon laser. No observable damage occurred with the diode laser at lower energy levels. These findings are consistent with clinical experience of a reduction in intraocular pressure using 0.12 or 0.24 J of energy. The diode lesions were not noted grossly, which caused difficulty in judging the quality of the laser application.

The argon laser produced a depression to the outer layers of the trabecular meshwork possibly near Schlemm's canal measuring 200 to 400 μ in diameter at energy levels of 0.07 and 0.1 J. At 0.05 J, only more superficial disruption and coalescence of trabecular beams were noted inconsistently. Trabecular meshwork changes resulting from 0.05 J of argon energy over 50 μ were comparable to most of the applications from the diode laser at similar energy applications per area (0.12 or 0.24 J over 100 μ).

However, the type of lesions produced between the argon and diode lasers differed when typical clinical energy levels were compared. The diode laser caused a limited superficial area of coalescence, whereas the argon laser caused a deeper disruption of trabecular tissue. The diversity in the lesions produced by the argon and diode lasers in this study may have resulted from the greater amount of energy per area from the argon laser. However, the exact reason for the differences between the two lasers is not readily explained by our results and differs from the findings of McHugh and associates, who showed a deeper burn with the diode laser.11 Because the diode laser caused less tissue alteration at clinically effective energy levels, it might, in patients with glaucoma, produce less postoperative inflammation and increased intraocular pressure than the argon laser.

Reports evaluating the effect of the argon laser on trabecular meshwork tissue have involved in vivo human or monkey studies. Tissue changes found were disruption of trabecular beams, fibrinous exudate, cellular debris, irregular flattened areas,8,9,19 and trabecular meshwork depression.14 Also, activated endothelial cells and mononuclear sheets covering the treated area of the meshwork have been noted.12
In tissue characteristics that can be compared between in vivo and cadaver eye models, low-energy (0.05 J) argon laser burns were similar to those found in previous studies. However, at higher energy levels (0.07 to 0.1 J), the extent of argon damage to the trabecular meshwork appeared greater in our study than did equivalent energy levels in previous studies. The reason for this is unknown, but it may have resulted from the 23% to 40% greater energy transmission in photocoagulating cadaver eyes. No energy loss resulted from a contact lens or from corneal tissue, as would have occurred had trabeculoplasty been performed in live animal or human eyes.15,16

This study suggests that a tissue reaction occurs in the trabecular meshwork using a diode laser at, but not at less than, energy levels used previously in a clinical setting. Also, the effect of the diode and argon laser upon the trabecular meshwork is comparable at a similar energy per area despite the larger spot size and longer wavelength on the diode laser.

This study did not examine the effect of various parameters in performing diode laser trabeculoplasty in patients with glaucoma. Further study is needed to determine which parameters provide the best long-term intraocular pressure effect with minimal complication.

Key Words
argon laser trabeculoplasty, diode laser, glaucoma, diode laser trabeculoplasty

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References