# RETINAL INJURY AFTER INADVERTENT HANDHELD LASER EXPOSURE

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**Purpose:** To evaluate acute and long-term clinical and spectral domain optical coherence tomography features after handheld laser exposure to the retina.

**Methods:** Retrospective case series of three children with retinal injury secondary to inadvertent handheld laser exposure. All individuals underwent ophthalmologic examination and spectral domain optical coherence tomography at presentation and follow-up 11 months to 18 months after exposure.

**Results:** Three male children aged 6 years to 10 years sustained bilateral macular injury after exposure to a handheld green or red laser. Two of the three handheld lasers were ordered from foreign internet retailers and were labeled as Class 3B devices. Acutely, flat yellow deep retinal lesions with pigment irregularity were apparent. Spectral domain optical coherence tomography demonstrated disruption of the external limiting membrane and outer photoreceptors, a hyperreflective mound extending from the external limiting membrane to the retinal pigment epithelium, and linear opacification in Henle's layer. Over time, there was partial restoration of the external limiting membrane and persistent irregularity of the outer photoreceptor layers. Two individuals with severe vision loss acutely had some improvement of Snellen acuity at a 1-year follow-up.

**Conclusion:** Handheld lasers can produce permanent retinal damage with visual sequelae if improperly used. Spectral domain optical coherence tomography demonstrates chronic disruption, primarily in the retinal pigment epithelium/photoreceptor region.

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Handheld lasers are commonly used as pointers in academic, laboratory, and industrial settings. These devices are more frequently used by the general public because of ease of availability from the internet and their low cost. The American National Standards Institute (ANSI) regulates that lasers sold in the United States to be used specifically as "pointers" must be categorized as Class 3A (defined as up to 5 mW emission and visible wavelength between 400 and 700 nm) or less. However, "handheld lasers" can be obtained from foreign distributors over the internet, which may not conform to the ANSI regulations regarding hazard labeling and power output.[1] In 2010, the Food and Drug Administration (FDA) released a report highlighting the potential eye and skin hazards of available handheld lasers (Class 3B or higher), particularly when used recreationally by children.[2]

We report three young boys who sustained bilateral retinal damage after handheld laser exposure during unsupervised recreational use. In two cases, the causative handheld laser was obtained from foreign manufacturers through the internet. The acute and long-term clinical and spectral domain optical coherence tomography (SD-OCT) findings are presented including the newly described OCT feature of acute opacification of Henle's fibers in the outer nuclear layer.

## Methods

A retrospective case review of three individuals with retinal injury secondary to handheld laser exposure was conducted. All individuals underwent ophthalmologic examination and SD-OCT at presentation and at follow-up, which ranged from 11 months to 18 months

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after exposure. The diagnosis was based on history of recent exposure to handheld lasers as well as findings on examination and SD-OCT. The lasers were inspected for labeling of classification, power, and wavelength. The power output and wavelength of one device was measured at an external laser laboratory. The clinical and imaging features were analyzed.

## Case Summary

### *Case 1*

A 10-year-old white boy was referred for evaluation of acute scotoma in the right eye. His medical, family, and ocular history was unremarkable. Four days before retina referral, he was playing with a handheld laser and directed the beam at a mirror in an attempt to produce a laser light show. He looked at the beam obliquely as it reflected from a mirrored door from a distance of 1.5 feet for 2 seconds. He noted a bright flash and immediate brief pain in his right eye. The device was in a box specifically labeled "green laser pointer" with the following specifications marked on the laser: maximum output $<$200 mW, wavelength 532 nm, Class 3B (Figure 1G). The device was obtained from a foreign retailer through the internet and received as a gift.

Visual acuity was 20/30 in his right eye and 20/20 in his left eye. Anterior segment examination was unremarkable in both eyes. Fundoscopic examination of the right eye revealed a flat, deep diagonal foveal lesion comprised of central pigment clumping surrounded by hypopigmentation (Figure 1A). In the left eye, a small hypopigmented spot was noted above the fovea (Figure 1C). Fluorescein angiography revealed blocked fluorescence corresponding to hyperpigmentation and window defect in the areas of pigment loss (Figure 1, E and F). Spectral domain optical coherence tomography of the right eye demonstrated a juxtafoveal hyperreflective mound extending from the region of the external limiting membrane (ELM) to Bruch membrane, as well as disruption of ELM and outer photoreceptor ellipsoid and interdigitation bands (Figure 1B). Opacification of the nerve fibers in Henle's layer was present in the lesion. The left eye acutely demonstrated a focal linear column of hyperreflectivity extending from the retinal pigment epithelium (RPE) to the ELM corresponding to the area of pigment disruption (Figure 1D).

He was treated with a 6-day oral methylprednisolone dose pack (Medrol dose pack, initial dose 24 mg and tapered 4 mg a day). The small lesion in the left eye completely resolved clinically and on OCT imaging by 2 weeks after the exposure. At follow-up 18 months after exposure, vision had recovered to 20/20 in each eye. He complained of a permanent pericentral scotoma in the right eye. Fundoscopic examination of the right eye showed irregular RPE pigment clumping with surrounding hypopigmentation (Figure 1H). Spectral domain optical coherence tomography of the right eye revealed improved appearance of the ELM, but discontinuity of the ellipsoid and interdigitation bands persisted (Figure 1I). The underlying RPE appeared irregular with thinning at the borders of the lesion. Opacification of Henle's layer continued to be apparent.

### *Case 2*

A 9-year-old white boy was referred for acute bilateral decreased vision of 4 days duration. The referring physician was concerned that the retinal lesions represented Best disease. His medical, family, and ocular history was unremarkable. He denied ocular pain or trauma. Best-corrected visual acuity was counting fingers at 3 feet in each eye. Anterior segment examination was normal. Fundoscopic examination revealed bilateral, flat yellow foveal lesions with linear extensions and RPE disruption radiating from the fovea (Figure 2, A and C). There was no retinal hemorrhage or intraretinal fluid. The electrooculogram Arden ratio was $>$2.0. On further inquiry, he reported directing a handheld laser into a mirror to create a laser light show and staring directly at the reflected beam for multiple episodes, each lasting for minutes. The handheld laser power output was measured by an external laser laboratory at 121 mW with a red wavelength of 654 nm.

Spectral domain optical coherence tomography scan of both eyes showed opacification and disruption of the ELM with a hyperreflective column extending from the RPE through the outer photoreceptors ellipsoid and interdigitation zones (Figure 2, B and D). The RPE was irregular in the lesion. Focal opacification of Henle's layer was apparent arising from the outer nuclear layer. In the left eye, there was a hyporeflective cavity adjacent to the ELM (Figure 2D). In this patient, the central fovea was involved in both eyes.

He was acutely treated with a 6-day methylprednisolone dose pack. Six months after exposure, best-corrected vision measured 20/200 in each eye, and he reported persistent central scotomas bilaterally. Fundoscopic examination showed replacement of the yellow foveal lesion with central RPE clumping surrounded by pigment loss and mottling (Figure 2, E and G). Spectral domain optical coherence

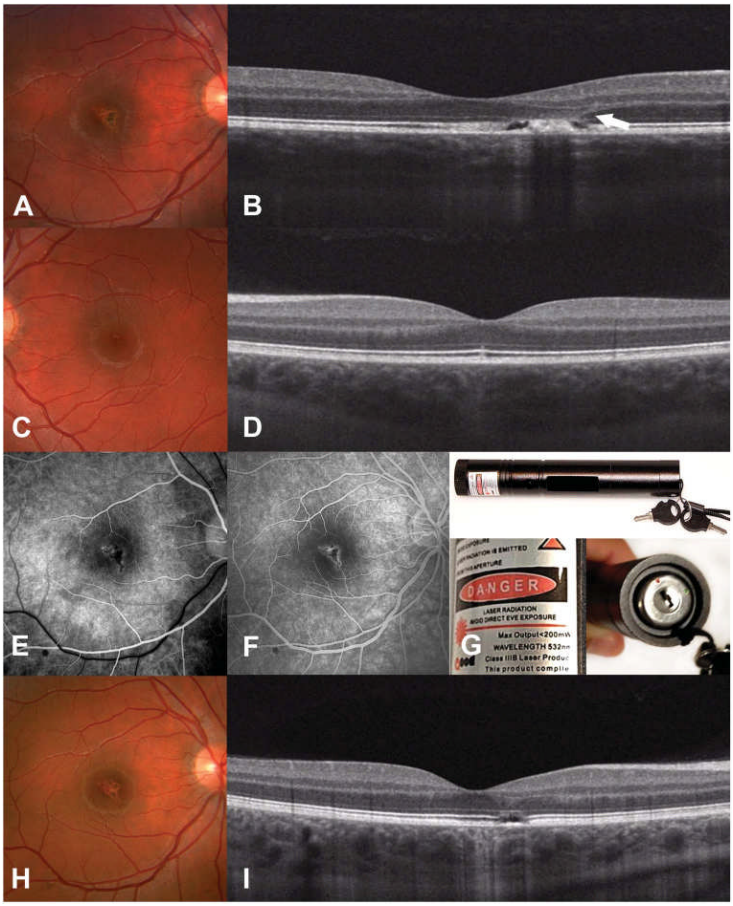


**Fig. 1.** Color photograph of the right eye (**A**) at presentation revealed a flat yellow lesion. Corresponding SD-OCT (**B**) demonstrated disruption of ELM and outer photoreceptor bands with a column of hyperreflectivity involving Henle's layer (arrow). The left eye (**C**) had a small hypopigmented spot above the fovea with a corresponding focal hyperreflective column on SD-OCT (**D**). Fluorescein angiogram of the right eye (**E** and **F**) showed the areas of window defect and blockage. The handheld laser with key switch labeled Class 3B, maximum power <200 mW, wavelength 532 nm (**G**). At 18 months after exposure, the right eye (**H**) showed RPE clumping and hypopigmentation, and SD-OCT (**I**) revealed restoration of ELM, but discontinuity of the outer photoreceptor bands.

tomography of both eyes (Figure 2, F and H) demonstrated some restoration of the outer nuclear layer and ELM layer. There was persistent loss of ellipsoid and interdigitation zones, suggesting permanent damage to photoreceptors. The RPE appeared thickened at the center of the lesion with attenuation at the borders consistent with clinical appearance. There was artifact shadowing and hypertransmission of OCT signals beneath the irregular RPE. The subfoveal hyporeflective space was now less apparent in the left eye.

Twelve months postexposure, vision improved to 20/100 and 20/70 in the right and left eyes, respectively. Spectral domain optical coherence tomography revealed focal loss of the subfoveal ellipsoid band, a hyporeflective cavity under the ELM (Figure 1, J and L). The opacification of Henle's fibers was no longer apparent.

*Case 3*

A 6-year-old Asian boy was referred from his pediatric ophthalmologist for evaluation of bilateral, new onset macular lesions and reduced vision. Four months before presentation, acuity was 20/20 in each eye without apparent retina lesions at a pediatric eye examination. His medical, ocular, and family history was unremarkable. His parents reported several

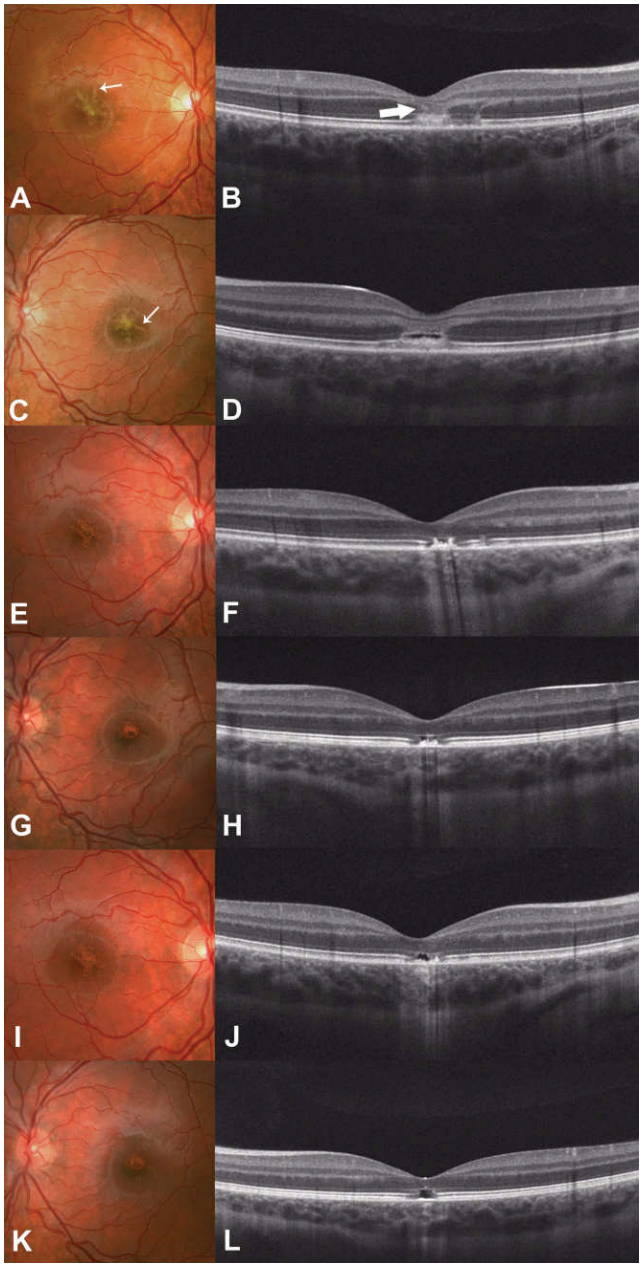


**Fig. 2.** At presentation, bilateral foveal lesions (**A** and **C**) were flat and yellow with linear radiations (thin arrows). Spectral domain optical coherence tomography in both eyes (**B** and **D**) showed an anvil-shaped hyperreflective column (arrow) and outer photoreceptor disruption. The left eye (**D**) had a hyporeflective zone between the ELM and ellipsoid layer. Six months after exposure, both eyes (**E** and **G**) showed RPE clumping and hypopigmentation. Spectral domain optical coherence tomography of both eyes (**F** and **H**) demonstrated restoration of the outer nuclear layer and ELM, but discontinuity in the outer photoreceptor layers with RPE migration in the outer retina. Twelve months after exposure, both eyes (**I** and **K**) had decreased pigmentation in the areas of previous clumping. Spectral domain optical coherence tomography (**J** and **L**) showed loss of the ellipsoid and interdigitation bands with decreased RPE irregularity within the lesion.

months of disruptive behavior and decreased vision in the right eye over several weeks. His parents had purchased a laser pointer over the internet and had noticed the patient playing with it alone. The laser was marked with the following parameters: maximum output power <5 mW, wavelength 532 ± 10 nm, Class 3 laser product (Figure 3G).

His vision was counting fingers in the right eye and 20/20 in the left eye. Anterior segment was normal. Fundoscopic examination revealed a flat, yellow foveal lesion with radiating streaks of RPE disruption in the right eye and flat, yellow juxtafoveal spots with RPE clumping in the left eye (Figure 3, A and C). Fluorescein angiography demonstrated central blocked fluorescence with window defects radiating from the lesion (Figure 3, E and F). Spectral domain optical coherence tomography of the right eye revealed a mound of hyperreflectivity extending from the RPE to the outer nuclear layer causing focal, central foveal thickening with adjacent disruption in the outer photoreceptor ellipsoid and interdigitation layers and some opacification of Henle's fibers (Figure 3B). Spectral domain optical coherence tomography of the left eye demonstrated focal disruption of the ELM, outer photoreceptor ellipsoid, and interdigitation layers with RPE thinning (Figure 3D). Electrooculogram was normal.

Eleven months after presentation, visual acuity improved to 20/100 in the right eye and remained

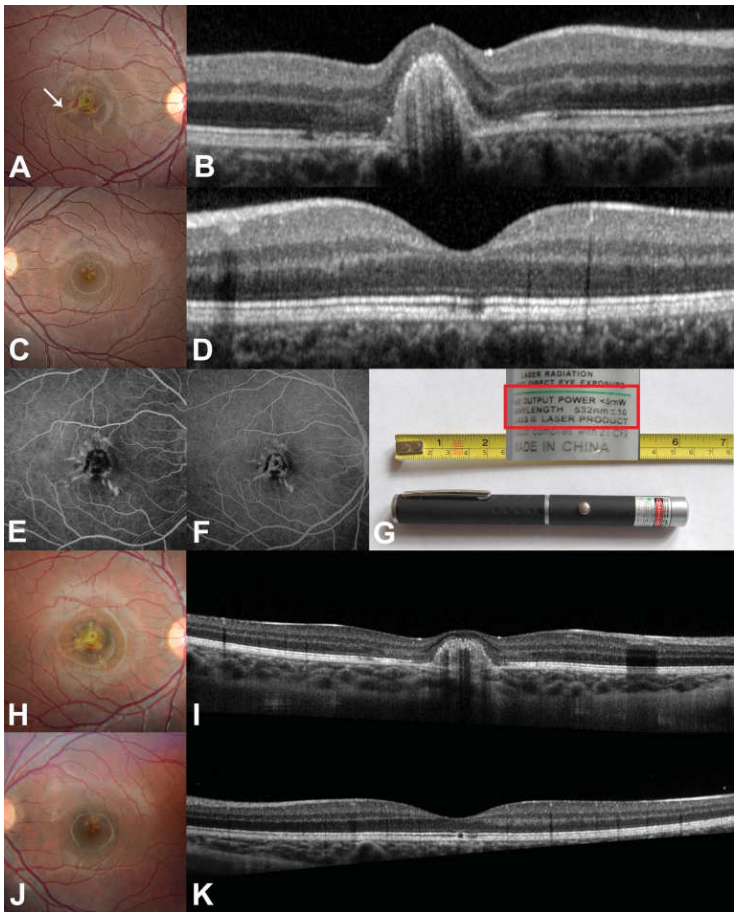


**Fig. 3.** Fundus photography at presentation of the right eye (**A**) showed a flat, yellow foveal lesion with asymmetric streaks of RPE disruption (arrow). Spectral domain optical coherence tomography of the right eye (**B**) showed a mound of hyperreflectivity causing central foveal thickening with surrounding foci of disruption in the outer photoreceptor bands. The left eye (**C**) had distinct, flat yellow spots adjacent to the fovea, and the corresponding SD-OCT (**D**) demonstrated focal disruption of ELM and outer photoreceptor layers. Fluoroscein angiography of the right eye (**E** and **F**) showed blockage in the areas of pigmentation with window defects radiating from the lesion. The laser pointer was labeled as Class 3, maximum output <5 mW, wavelength 532 ± 10 nm (**G**). Color photographs (**H** and **J**) and SD-OCT (**I** and **K**) at 11 months showing a persistent although reduced mound of central hyperreflective material in the right eye, with the development of a hyporeflective linear space along the outer nuclear layer. There was bilateral discontinuity in the outer photoreceptor layers.

20/20 in the left eye. Fundoscopic examination revealed a central yellow deposit with linear extensions in the right fovea and irregular pigment loss and mottling in both eyes (Figure 3, H and J). Spectral domain optical coherence tomography of the right eye revealed a persistent although reduced mound of subretinal hyperreflective material, as well as disruption of the outer photoreceptor ellipsoid and interdigitation layers (Figure 3I). Spectral domain optical coherence tomography of the left eye showed a persistent small defect in the ellipsoid and interdigitation layers (Figure 3K).

## Results

This series is comprised of 3 boys aged 6 years to 10 years with clinical signs of bilateral exposure to green or red handheld lasers. Two lasers were classified as Class 3B and one as Class 3A. In the three eyes that sustained some degree of permanent vision loss, the acute lesions were located in the center of the fovea. The retinal findings in these three cases consisted of yellow lesions with varying degrees of RPE clumping and mottling. In all cases, the inner retinal layers did not seem to be affected. The initial SD-OCTs demonstrated disruption of the ELM with a hyperreflective thickening extending from the ELM to Bruch membrane and adjacent disruption of the ellipsoid and interdigitation zones. Follow-up SD-OCT performed 11 months to 18 months after acute injury showed some restoration of the integrity of the ELM and reduction of the hyperreflectivity between ELM and Bruch membrane. Opacification of Henle's fiber layer was present in the acute lesions, and this became less apparent over time. The persistent irregularity in the outer photoreceptor ellipsoid and interdigitation zones is consistent with segmental loss of photoreceptors.

## Discussion

The three cases in this series are distinct, yet some common features exist. The affected individuals were all young male children. The parents were either unaware that the child had the laser or unfamiliar with the potential for physical damage from playing with a handheld laser. Case 1 was the oldest child at age 10 years, and he recognized the signs of physical damage and turned off the laser after a brief exposure of seconds. The remaining two boys were younger and reported staring directly at the laser or at the reflected beam in the mirror for longer periods of time. Movement of the laser beam may account for the linear streaks of RPE disruption radiating from the lesions. Children may be more likely to look directly at a laser beam out of curiosity and are particularly vulnerable to laser injury because of their clear ocular media. One hypothesis for the bilateral foveal injury in Case 2 may result from alternating fixation from the dominant to nondominant eye after flash blindness occurs to the dominant eye.

Table 1 summarizes case reports of handheld laser or laser pointer injury between 1999 and 2014 (Pubmed: retina, laser injury, laser pointer).[3–23] For all cases of inadvertent exposure, there is a slight preponderance of males as well as for teenager and young adults. Case 3 in our series who is 6 years old is the youngest individual reported. There seems to be increased reports of injuries in the literature since 2007 from commercially available handheld lasers of various wavelengths. This may relate to the increased availability to the public by the internet, promotion of handheld laser for recreational use such as popping balloons, and increased awareness of this entity. Originally, it was postulated that lasers in ANSI Class 3A or less could not produce serious ocular damage with exposure times $<10$ seconds.[24] Experimental studies intentionally exposing patients with uveal melanoma undergoing planned enucleation to laser pointers for up to 15 minutes showed changes only on electron microscopy for Class 3A red laser pointers but demonstrated both clinical and histopathologic changes for Class 3A green laser pointers when viewed for the same durations.[18,19] Case 3 in our series confirms that the blatant misuse of a Class 3A–labeled laser pointer can produce permanent retinal injury.

There are 4 case reports between 1999 and 2010 of inadvertent retinal injury from red or green Class 3A or less laser pointers with all subjects recovering preexposure visual acuities.[17,20–22] Between 2010 and 2013, there were 8 case reports of retinal injury secondary to inadvertent green laser exposure, 5 of which were handheld lasers (Class 3B, power, 5–500 mW) and remaining 3 cases did not report output specifications.[5–11,14,15] All 8 reports were young male subjects aged 11 years to 15 years except for one 25-year-old male subject. All of these cases presented initially with decreased visual acuities and retinal lesions that had a similar clinical appearance to our series. Six of the 8 patients recovered with reduced central visual acuities ranging from 20/32 to 20/60. In contrast, 3 eyes (Cases 2 and 3) in our series with lesions in the center of the fovea had mild visual recovery at 1 year but maintained permanently reduced vision at 20/70 to 20/100. Two reports previously described SD-OCT findings of acute hyperreflective lesions which resolved and chronic outer photoreceptor disruption.[7,10] Acute opacification of Henle's fibers in the outer nuclear layer noted on SD-OCT in our cases has not previously been reported after laser exposure.

Table 1. Reports of Retinal Injury from Laser Exposure

| Author | Year | Age (years), Gender | Presentation | Laser Specifications | Duration of Exposure | Follow-up | Treatment |
|---|---|---|---|---|---|---|---|
| Yiu et al[3] | 2014 | 9, M | Accidental exposure from adult | Blue 1,250 mW | Seconds | 2 months | Observation |
| Alsulaiman et al[4] | 2014 | 16–30, M | Accidental or deliberate self-exposure | Blue 400–1,000 mW | Seconds | 3 weeks to 3 months | YAG hyaloidotomy, vitrectomy, observation |
| Dirani et al[5] | 2013 | 13, M | Deliberate self-exposure | Green 5 mW | 1 minute | 3 months | Oral prednisone |
| Dhoot[6] | 2013 | 16, M | Accidental exposure from friend | Blue 1,000 mW | — | 6 months | Macular hole surgery |
| Rusu et al[7] | 2013 | 15, M | Accidental self-exposure, reflected from mirror | Green internet | — | 6 months | — |
| Turaka et al[8] | 2012 | 13, M | Accidental exposure from friend | Green 5 mW | 1 minute | 1 day | Oral prednisone |
| Pollithy et al[9] | 2012 | 11, M | Deliberate self-exposure | Green 55 mW | Seconds | 13 weeks | — |
| Hossein et al[10] | 2011 | 25, M | Accidental exposure | Green 3.5–4.5 mW | 1 second | 7 days | Oral prednisone |
| Ueda et al[11] | 2011 | 13, M | Accidental exposure from classmate | Green 20 mW | 2 seconds | 6 months | NSAID |
| Boosten et al[12] | 2011 | 21, F; 25, M | Accidental exposure from professional laser show | Class 4 (laser show) | 1 second | NA | Observation |
| | | 44, M | Clinical study: intentional exposure before planned enucleation | Green 500 mW | 0.5–64 seconds | NA | Observation |
| Kandari et al[13] | 2010 | 27, 33, M | Accidental military war exposure, accidental self-exposure | Military laser, red laser (unspecified) | Seconds | 6 months | — |
| Fujinami et al[14] | 2010 | 11, M | Developmental delayed child with multiple deliberate self-exposures | Green laser pointer | 10 seconds | 24 months | Observation |
| Ziahosseini et al[15] | 2010 | Teenager, M | Deliberate self-exposure | Green internet | — | 2 months | Observation |
| Wyrsch et al[16] | 2010 | 15, M | Accidental self-exposure, reflected from mirror | Green 150 mW | Seconds | 4 months | Ranibizumab |
| Wong et al[17] | 2007 | 38, M | Accidental exposure from son | Infrared 800–825 nm <5 mW | 1 second | 2 months | Observation |
| Robertson et al[18] | 2005 | 55, F | Clinical study: intentional exposure before planned enucleation | Green <5 mW | 1, 5, 15 minutes | 20 days | Observation |
| Robertson et al[19] | 2000 | 36, 59, 62; 1M:2F | Clinical study: intentional exposure before planned enucleation | Red 1 mW, 2 mW, 6 mW | 15 seconds | 2 weeks | Observation |
| Zamir et al[20] | 1999 | 19, F | Deliberate self-exposure | Red <1 mW | 10 seconds | 3 months | Observation |
| Luttrull and Hallisey[21] | 1999 | 34, M | Deliberate self-exposure | Red <5 mW | 30–60 seconds | NA | Observation |
| Sell and Bryan[22] | 1999 | 11, F | Deliberate self-exposure | Red <5 mW | 3 seconds | 11 months | Observation |
| Sethi et al[23] | 1999 | 9–68, 7M:7F | Work, driving, prank, lecture, accidental exposure | NA | Variable | 10.5 months | Observation |

F, female; M, male; NA, not available; NSAID, non-steroidal anti-inflammatory drug.

The induced ocular damage depends on multiple variables including the laser specifications and type of exposure. Green wavelengths concentrate damage in the RPE and outer retina related to 532 nm wavelength uptake by melanin pigment in the RPE. Shorter-wavelength green or blue laser devices may be more damaging than the red ones because shorter-wavelength light has more energy and can induce photochemical damage in addition to thermal damage. A green handheld laser is produced using a diode-pumped solid-state laser. An infrared diode pumps a Nd:YAG 1,064-nm crystal to produce the 532-nm beam by frequency doubling. A safety concern for handheld green (and blue) lasers is that the infrared invisible diode wavelength may be emitted from the laser in addition to the green laser light unless specific filters are placed within the handheld device. A study by the National Institute of Standards and Technology confirmed that emission of potentially deleterious levels of infrared light from inexpensive green lasers does occur.[25] This feature of green lasers is particularly hazardous because the infrared light does not cause the same aversion response as laser light in the visible spectrum. Proximity to the laser and length of exposure also play a role in determining retinal injury. Case 1 briefly projected the green handheld laser into a mirror from a short distance, which produces virtually 100% reflectance. Boosten et al[12] described two cases of retinal injury that seem to be secondary to laser reflection from a mirror ball in a recreational laser light show.

Food and Drug Administration safety requirements include proper labeling of the specifications (power, wavelength, hazard class) of the laser device if Class 3A or greater, and a key switch and connector for remote interlock for Class 3B devices.[26] A study of 122 laser pointers labeled as Class 3A found that 90% of green and 44% of red laser pointers had power measurements exceeding the allowable 5-mW limit.[25] The FDA website states that it regulates all laser products, even handheld battery-powered lasers that are available for purchase from manufacturers, importers, assemblers, dealers, or distributors in the United States or its territories.[26] However, there is no regulatory body monitoring the accuracy of labeling of devices manufactured or obtained from outside the United States as are often obtained from the internet.

The potential for Class 3A green laser pointers to produce retinal damage if misused should no longer be disputed. In the last decade, there has been increased availability of Class 3B handheld laser devices that have similar output to lasers used for retinal photocoagulation: these are not FDA-approved laser pointers. Laser safety training is required for medical personnel who may be exposed to laser use in a hospital setting but is not required for the internet purchase of a 3B laser. The distinction between a 3A laser pointer and higher-output handheld lasers should be more clearly delineated. Labeling to include the potential for permanent vision loss if misused and exclusion of their use by minors at risk may be considered. Mandatory inclusion of protective eye goggles may increase public awareness of the potential for ocular harm. A brief search on the internet yields numerous websites selling inexpensive laser pointers and handheld lasers with minimal to no disclaimers regarding the potential dangers of incorrect use. The increased proliferation of these devices has made it more likely that individuals who are not familiar with appropriate safety precautions will use them. In the last 5 years, there are enough cases to cause concern regarding the internet availability of handheld lasers of increasing power and hazard class that are marketed to the public for amusement or to set fire to objects.

## Conclusion

Laser pointers and handheld lasers pose significant ocular risks when misused with the potential for permanent bilateral visual impairment. Evolution of SD-OCT findings are described and may provide information about visual prognosis based on the extent of central, foveal retinal changes. Anatomical changes are most prominent in the photoreceptor layers and may extend from Henle's fibers in the outer plexiform layer to the RPE. In addition to lasers in laboratory or industrial settings, handheld lasers purchased on the internet may not adhere to the ANSI standards or FDA regulations for laser pointers and have the potential to produce profound ocular injury.

**Key words:** eye injuries/diagnosis, eye injures/etiology, lasers/adverse effects, retina/injuries, retinal diseases/pathology, tomography, optical coherence.

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