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CUTTING-EDGE ADVANCEMENTS

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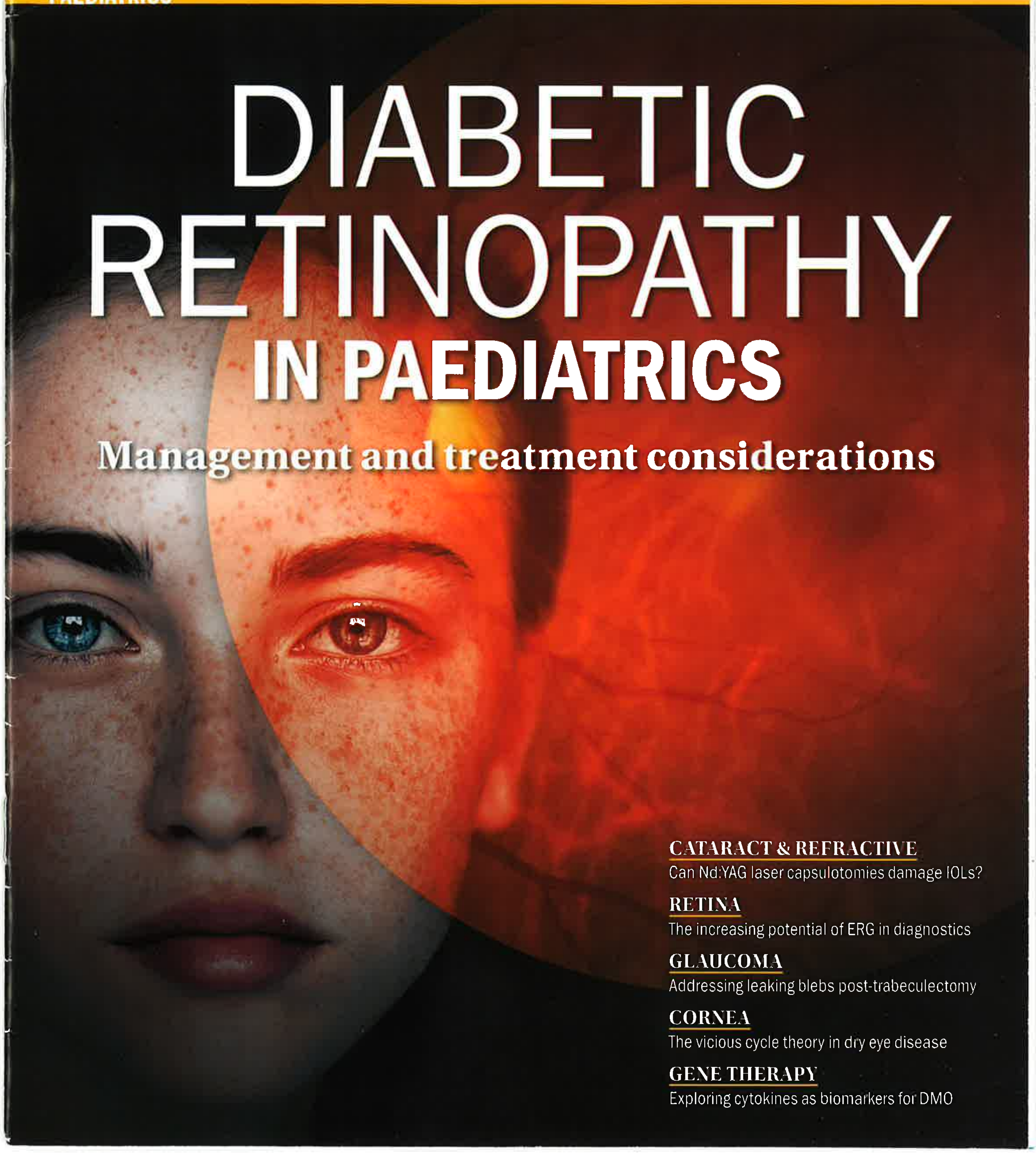
PAEDIATRICS



DIABETIC RETINOPATHY IN PAEDIATRICS

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Nd:YAG laser capsulotomy in intraocular lenses: Safe or dangerous?

Raman spectroscopy, electron microscopy, wavefront measurements offer clues

By Dr Andreas F. Borkenstein and Dr Eva-Maria Borkenstein


Dr Borkenstein

Neodymium:yttrium aluminium-garnet (Nd:YAG) laser capsulotomy is a safe, effective, quick and relatively easy gold-standard outpatient procedure for the treatment for posterior capsule opacification (PCO) following cataract surgery. It improves visual acuity and may also have positive effects on glare and contrast sensitivity in some patients.

However, there are reports of complications associated with the method such as corneal injuries; pupil blockage; iritis; increases in intraocular pressure (IOP); vitreous prolapse; retinal damage; and luxation/decentration of the IOL or damage to the IOL material (pitting). Pitting occurs in 15–33% of eyes during Nd:YAG laser posterior capsulotomy.

In the past, incorrect and inaccurate focusing of the laser beam was identified as the main cause of pitting. In several cases, time pressure could be determined as the main cause for these iatrogenic defects. Pitting is supposedly not visually significant, although rarely the damage may cause sufficient glare, straylight and image degradation to require the damaged IOL to be explanted (Figures 1–2).

Techniques

The two primary YAG types are the cruciate pattern and the circular pattern, and each has its benefits and downsides. In the cruciate method, the YAG laser is used to create a cross pattern, which then allows the resultant capsule flaps to retract out of the visual axis.

Laser spots are placed through the centre of the IOL. Therefore, care must be taken to properly aim the laser to avoid pitting the optic in the central visual axis.

The circular technique creates a circular cutout, which then allows for a round posterior capsular opening. With this method, laser shots do not need to be placed in the central optical zone but can instead be aimed at the periphery.

Thus, the chance of central pitting and negative effects on the optics is lower. Some data also found that the frequency of IOL damage depends on the specific IOL design. A design separating the posterior capsule from the IOL (ridge) is less prone to damage than lenses with a close apposition between the IOL posterior surface and the posterior capsule.

Current attempts to reduce or prevent PCO by having posterior capsule adhesion to the IOL might complicate laser treatment and increase rates of damage in the future. Nd:YAG rates commonly reported before 1992 were between 20% and 33%, while Nd:YAG rates for IOLs implanted 10 years later were below 17%. In the past, numerous studies on various IOLs showed very different, unsteady results of Nd:YAG and PCO rates (5–2%) 3–5 years after surgery.

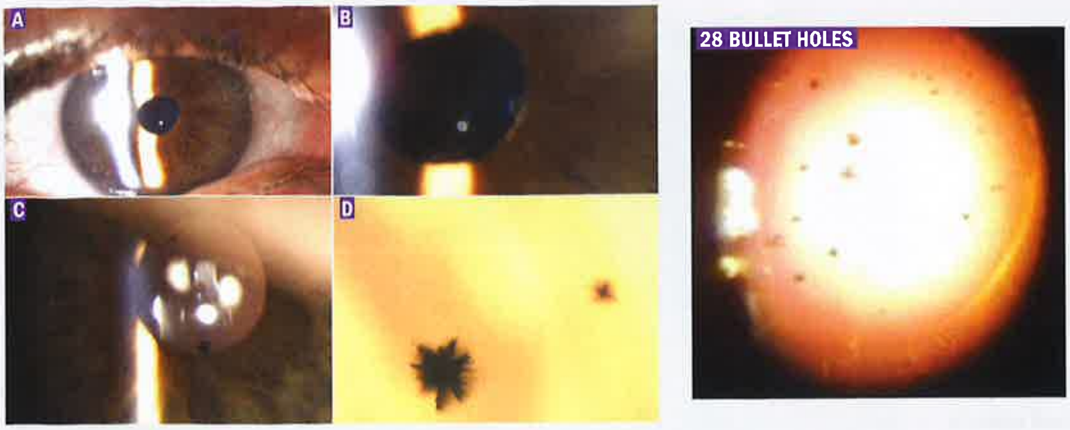
> It is important that patients are informed about all the potential dangers before they undergo a supposedly short and simple YAG procedure.

Comparison study

We recently conducted a study to assess differences in Nd:YAG-induced defects between hydrophilic and hydrophobic IOLs and describe optical and surface properties. The main aim was to increase awareness of the need to approach Nd:YAG laser

IN SHORT

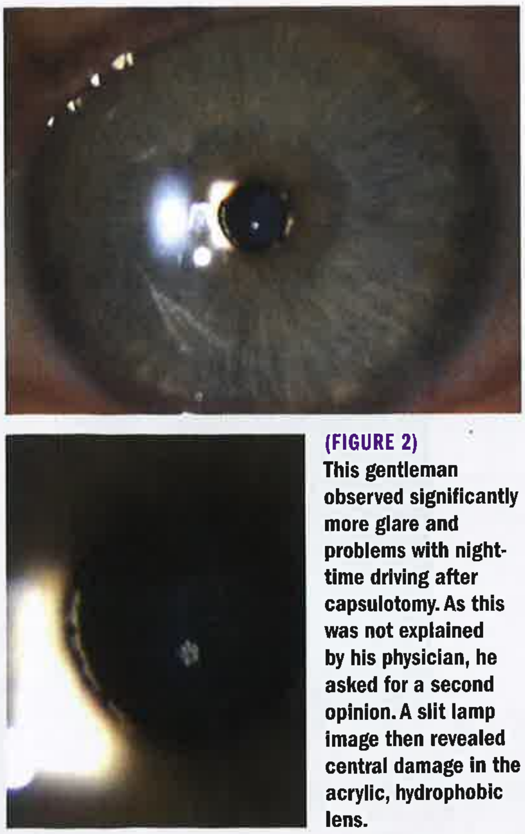
▸ ***Poorly focused YAG shots lead irrevocably to a permanent defect in the IOL material and thus to possible effects on the quality of vision with straylight or glare. In a recent study, the differing amounts of damage that Nd:YAG causes in a range of hydrophilic and hydrophobic acrylic lens materials was assessed.***



(FIGURE 1) **Slit-lamp examination of patients with YAG shots. Note: Some YAG shots are centred in the middle of the lens and visual axis. These patients complained about difficulties (straylight, glare) in night-time driving.**

capsulotomy with a greater level of caution. We recognised that hydrophilic and hydrophobic IOL materials seemed to be affected differently by Nd:YAG treatment according to wavefront aberrations and in slit lamp examinations.

A total of 12 different monofocal IOLs from nine manufacturers were evaluated. All five hydrophilic lenses had a refractive index of 1.46 and a water content of 26%. Of the seven hydrophobic IOLs, two were yellow and one had an additional heparin coating.



(FIGURE 2) **This gentleman observed significantly more glare and problems with night-time driving after capsulotomy. As this was not explained by his physician, he asked for a second opinion. A slit lamp image then revealed central damage in the acrylic, hydrophobic lens.**

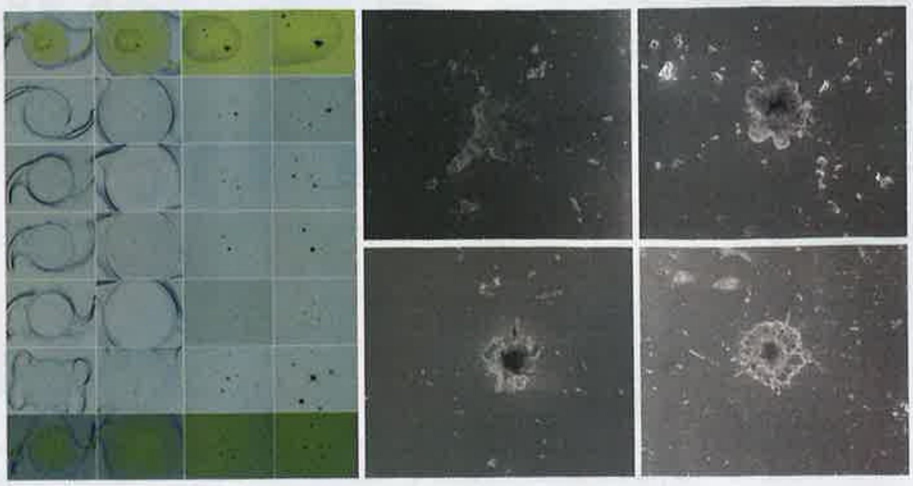
Refractive index varied between 1.47 and 1.55 and the water content was less than 1% except for one lens which was 4% water. All lenses were manufactured with a 360° sharp edge and had a spherical power of 21.5 dioptres.

Reflected-light microscopy and an environmental scanning electron microscope (ESEM) were used to visually analyse the defects. Additionally, wavefront measurements were taken for exact power mapping of the IOL optic and Raman spectroscopy was performed. Vertical and horizontal dimensions of the defects were analysed and compared, and Raman line scans assessed the chemical changes in the defect area and surrounding area.

In photomicrographs of the hydrophilic and hydrophobic IOLs after laser treatment, pits created by the laser were observed on both types of materials. The damage appeared to be bigger and more intense within the hydrophobic lenses than in hydrophilic ones. In the hydrophobic lenses the pits looked similar to the branches that appear when glass breaks and could be seen even with less magnification, while in the hydrophilic ones, they were not as visible.

These smaller zones of damage appeared like bullet holes with a smoother rim. An additional observation was that shots made directly next to already existing defects produced larger craters. This could be caused by a change in the material surrounding the defect (surrounding area).

The ESEM images confirmed the results and showed deeper and greater damage in hydrophobic materials than in hydrophilic. Damage to hydrophilic lenses seemed to be more circular while those in



(FIGURE 3) **Examples of the defects in hydrophobic and hydrophilic IOLs, as revealed by reflected light microscopy and scanning electron microscopy.**

hydrophobics were more frayed (Figure 3).

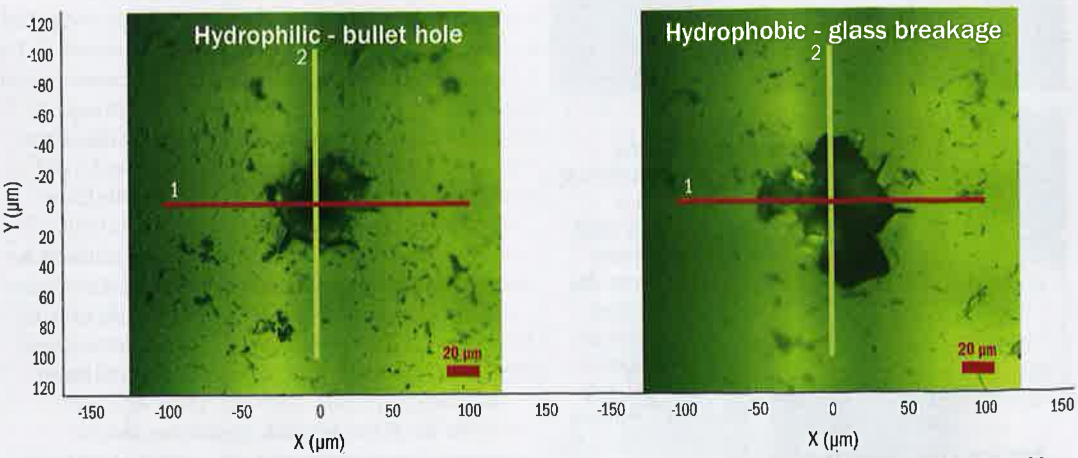
In Raman spectroscopy, defects were found to have different depths, with deeper pits seen in hydrophobic lenses (Figures 4–5). Raman line scans showed the area of defect in terms of chemical changes. These areas were found to be bigger than the visible defect area and, again, this effect was greater in the hydrophobic lenses.

Regarding the level to which the optical properties of the IOL changed after the treatment, a difference was noted within each group but it was not a significant one. Wavefront analysis revealed unusual white spots, besides the well-known colour map of the power of the lens. These spots occur when an area of the sensor has not been illuminated, since the light beam deflection at a defined point of the lens is so large that it no longer falls into the corresponding microlens, as in the case of damage and material defects.

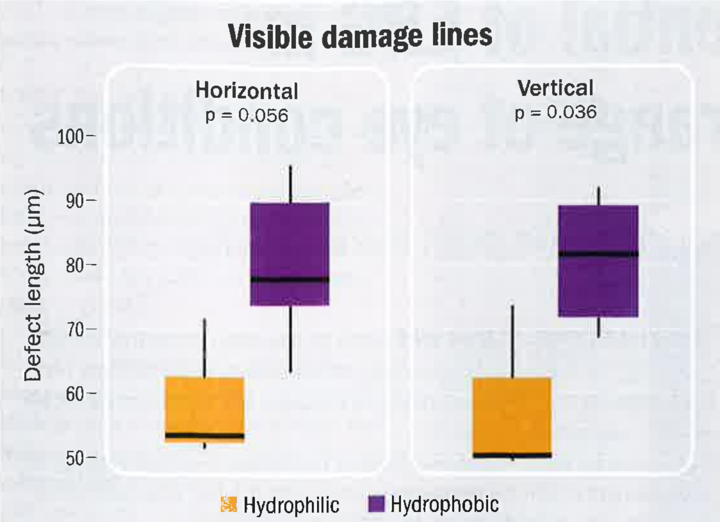
Our results may support the assumption that the differences between the materials are mainly due to the differing water content. Defects can be seen very well even within standard slit lamp examination.

We also found evidence that the material at the point of entry (area of the shot) and surrounding area changes chemically due to the procedure. These changes seem to be greater than what is visually observable.

If we analyse a hydrophobic lens as an example, the visible damage was measured at 81 µm (vertical) and 95 µm (horizontal), however, the chemical changes increased these to 120 µm (vertical) and 124 µm (horizontal), which was an enlargement of 48% and 31%, respectively. This means that the area of the defect in the IOL was not 7,600 µm² (visible area) but 14,800 µm²



(FIGURE 4) **Raman spectroscopy showing the different characteristics of the YAG shots in hydrophilic and hydrophobic materials.**



(FIGURE 5) Measuring the defect length showed differences in horizontal and vertical visible damage lines in hydrophilic and hydrophobic material. *(All images courtesy of Dr Andreas F. Borkenstein and Dr Eva-Maria Borkenstein)*

(actual area), which meant it was twice as large.

Despite modern, high-quality measurement methods, such as wavefront and other advanced technologies, it is currently difficult to measure just a small area. If, on the other hand, larger apertures and measuring areas with a diameter of 4, 5 or 6 mm are used, changes are still visible but no longer significant.

Nevertheless, it seems logical that the position of the defect plays a decisive role; if it is located centrally in the visual axis (pupil centre), the effects are greater than if it is located peripherally. Moreover, the IOL type and model plays another important role; it can be assumed that pitting in IOLs with bifocal, trifocal or enhanced depth of focus design lead more easily to clinically significant optical phenomena than in monofocal IOLs.

> Ophthalmologists should be as cautious as possible when performing laser capsulotomy.

The results of this study support clinical experience and show that iatrogenic-induced YAG shots in IOLs behave similarly to other defects and clouding/haze in such lenses, such as scratches (after improper folding of the IOL or incorrect manipulation with a spatula or forceps), glistenings or calcification in IOLs.

In all cases, the extent and severity as well as the position/area in the IOL optic is most important. When it comes to clinical symptoms, there is a wide variability, ranging from no effects or mild symptoms to severe clinically significant effects on the overall quality of vision.

Concluding thoughts and future perspectives

Ophthalmologists should be as cautious as possible when performing laser capsulotomy. In the worst-case scenario, an improper YAG-procedure can lead to major clinical effects and permanently influence the optical quality.

For such patients, explant of the IOL may need to be considered, but this has a further risk of complications. Therefore, it is important that patients are informed about all the potential dangers before they undergo a supposedly short and simple YAG procedure, and that the doctor is aware that these tiny defects could actually have a greater impact than is often thought.

Ophthalmologists should also consider the position of YAG laser. Laser shots do not need to be placed in the central optical zone but in the periphery, so the chance of central pitting and negative effects on the optic is lower. Moreover, the procedure should not be performed under time pressure.

If for any reason the lens is bombarded and defects do occur, the doctor should halt the procedure immediately. To continue operating would be irresponsible and could amount to an 'ophthalmic terrorist attack', which will certainly have clinical implications.

Further investigation via *in vitro* and *in vivo* studies is needed. Additional aids could be developed by companies to further minimise the risk. For example, an acoustic signal could be used to draw attention to a patient's head movements or warn that the focus of the laser beam is incorrectly adjusted. In addition, an ocular measuring device would help to avoid pitting the central, and most important, area of the lens and at the same time achieve a sufficiently large capsulotomy.

REFERENCE

1. Borkenstein AF, Borkenstein EM. Analysis of YAG-Laser induced damage in intraocular lenses: characterization of optical and surface properties of YAG-shots. *Ophthalmic Res.* 2020. DOI: 10.1159/000513203.

ANDREAS F. BORKENSTEIN, MD AND EVA-MARIA BORKENSTEIN, MD
E: *ordination@borkenstein.at*
Drs Borkenstein & Borkenstein are based at a private practice in the Privatklinik der Kreuzschwestern, Graz, Austria. They have no financial disclosures to reveal.