"Negative Dysphotopsia" and "Far Peripheral Vision"

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Millions of people receive intraocular lenses (IOLs) every year, and in addition to the removal of a cataract, the surgery can provide benefits like reduced refractive error, and reduced intraocular pressure. Visual results can be excellent, but there are occasional reports of "dark shadows" in the far periphery ("negative dysphotopsia")[1]. There is no clear consensus yet about the cause, but research into it has found that "far peripheral vision" as a whole is a neglected topic, with no previous evaluations using raytracing, and no clinical measurements near the limiting visual angle[2].

The primary cause of bothersome shadows is almost certainly "vignetting" at the IOL. Light no longer passes through the lens at large angles because it is much smaller than the natural lens, and rays traced in Fig. 1 illustrate how the main image goes dark, though light can also bypass the lens and illuminate the peripheral retina directly[3]. This can lead to a shadow with small pupils, which rapidly fades as the pupil opens up, in agreement with clinical data. Peripheral visual acuity is extremely poor, but text chart simulations help to illustrate (i) a distinct dark shadow with a small pupil, (ii) a fading shadow as the pupil opens, and (iii) a different magnification for the peripheral light, which also strikes the retina too peripherally[4-6]. The ray bundle at large angles splits, and the same region is actually seen twice. Light can also be scattered into the shadow by the natural lens capsule and other features, which is probably why it is not reported more often, and why it becomes less noticeable over time. Clinical measurements are needed to confirm this explanation.

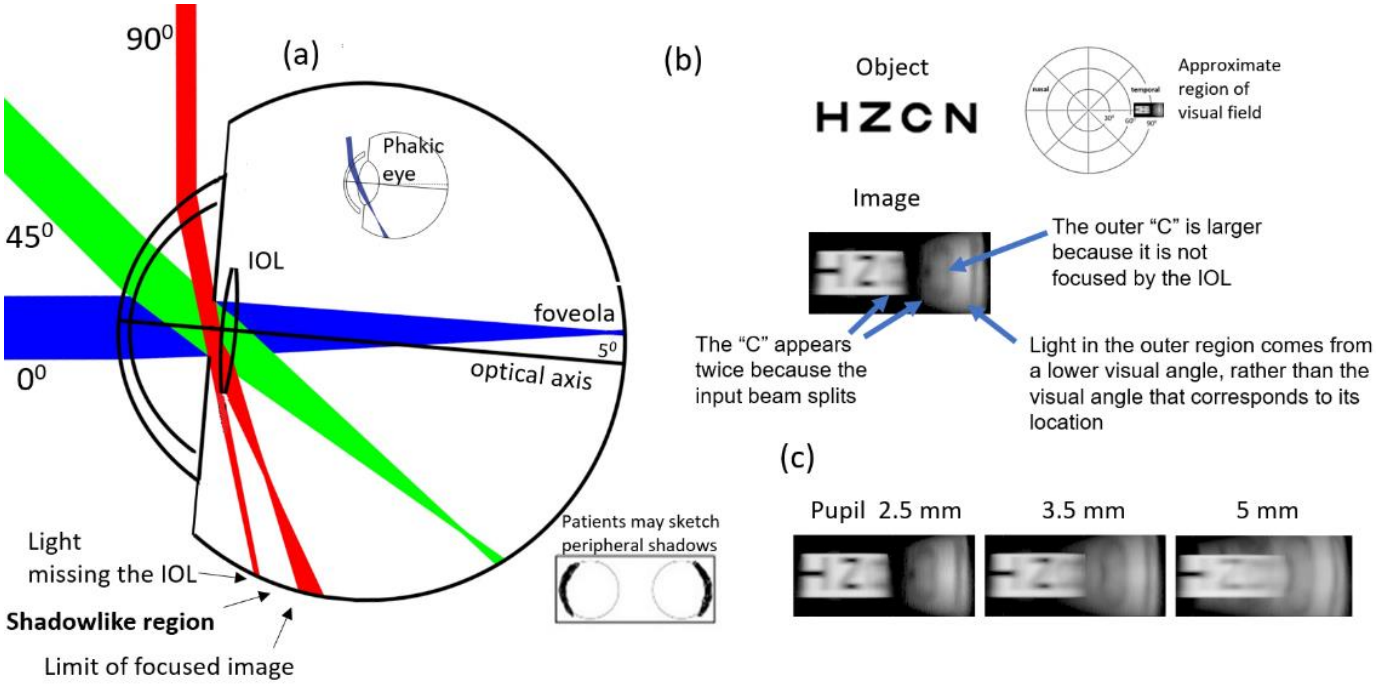

Figure 1. (a) Right eye from above. (b) Peripheral image. (c) Shadow fades as pupil increases.

These results are very unexpected after 50 years of IOL usage, with the pseudophakic eye being clearly different to the phakic eye in the far periphery. The raytrace plot depicts a clear hypothesis for "limiting" negative dysphotopsia, which can be tested clinically by measuring the shadow angle while monitoring the pupil. This may not be possible with a standard Perimetry test for the periphery, since the pupil diameter is usually neither controlled nor recorded, angles only extend to 90^0 (rather than 110^0), and the perceived location of the stimulus is not recorded. A simpler test is probably needed.

More broadly, the analysis raises questions about what exactly is seen in the far periphery by anyone. For example, what is the limiting visual angle in all directions, and how does it vary with refractive error, age, and race (specifically checking whether there is any link to myopia).

[1] Masket S, Fram NR, Pseudophakic Dysphotopsia: A Review of Incidence, Etiology and Treatment of Positive and Negative Dysphotopsia, *Ophthalmology* (2020).

[2] Simpson MJ. Mini-review: Far peripheral vision. Vision Research, 140C (2017), 96-105.

[3] Holladay JT, Simpson MJ. Negative dysphotopsia: Causes and rationale for prevention and treatment. J Cataract Refract Surg 2017; 43:263-275.

[4] Simpson MJ. Intraocular Lens Far Peripheral Vision: Image Detail and Negative Dysphotopsia. J Cataract Refract Surg 46; 451-8 (2020)

[5] Simpson MJ. Comment on: Distinct differences in anterior chamber configuration and peripheral aberrations in negative dysphotopsia. J Cataract Refract Surg 47; 139-140 (2021)

[6] Simpson MJ, Stanley D, Zhang X, Ellis SK, EP 2152202 B1, IOL peripheral surface designs to reduce negative dysphotopsia (2010) (Also US Patent Application 2008/0269886, and others with 81, 82, 89, 90, and 98 at end)

This is a brief summary of several years of work. A clear hypothesis is given for the cause of the bothersome peripheral dark shadows that are seen by some intraocular lens patients. This work also led to finding that there has been very little scientific evaluation at all of vision at very large angles (e.g. 80^0-110^0 temporally, but also the limit in all directions), even though this visual region is used all the time. This raises questions in turn about myopia, in case the growth of the young eye is unexpectedly influenced by signals from the limit of vision, in addition to defocus signals.

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