Presented at the 2010 American Academy of Ophthalmology Meeting

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Wavefront-Optimized Progressive Lens Design with Pupil Size Modeling Enhances Low-Light Vision for Presbyopes

— Marguerite B. McDonald, MD, FACS

Recent data shows that Varilux Physio Enhanced™ provides improved vision, particularly in low light.

Progressive addition lens wearers face a common problem: decreased acuity in dim lighting conditions. While everyone's vision is diminished in dark, low-contrast situations, progressive lens wearers have a unique predicament: As the pupil expands in dark settings, a larger beam of light enters the eye. This wider beam utilizes a larger area of the spectacle lens, and as more of the spectacle lens is utilized, more of the aberrations inherent in the lens cause wavefront distortions in the beam. This can result in reduced contrast sensitivity and diminished quality of vision.

Varilux Physio Enhanced™: A New Benchmark in Progressive Lens Design

At the annual meeting of the American Academy of Ophthalmology in October 2010, I presented on a poster on Varilux Physio Enhanced™, a new wavefront-corrected progressive lens design that incorporates pupil size modeling data for improved low-light vision. The full poster, "Factoring Pupil Size Changes into a Wavefront-Optimized Progressive Lens Design Improves Vision in Low Light Conditions," is included on the following pages.

Varilux Physio Enhanced™ uses W.A.V.E. Technology 2™ to identify and manage distortions. Built on earlier W.A.V.E. Technology™: Wavefront Advanced Vision Enhancement, which minimizes the amount of distortion caused by light passing through the lens, W.A.V.E. Technology 2™ incorporates pupil size modeling. This complex model allows designers to fine tune the design to provide the sharpest possible vision for all patients in all lighting conditions.

Cumulative results from a double-masked wearer study and optical bench testing suggest that, compared with progressive lens designs that do not incorporate pupil size modeling, the Varilux Physio Enhanced™ lens provides superior vision, with the greatest benefit seen in low lighting conditions.

The Importance of Contrast Sensitivity

These findings have important implications, as contrast sensitivity is a vital component of visual quality. Numerous everyday activities require the ability to discern objects, depth, and dimensions under low-contrast conditions. When driving in the rain, fog, or in the evening, for example, we rely on contrast sensitivity to distinguish forms that may blend in with the background, including pedestrians.

The ability to carry out more mundane tasks, such as reading a menu or dialing a phone in a dimly lit restaurant, also contribute to quality of life. Although some patients are more sensitive to changes in contrast sensitivity than others, the fact that we are now able to provide this added benefit marks a new achievement in progressive lens design.

Clearer, Crisper Vision, One Innovation at a Time

Progressive addition lenses have come a long way, with each incremental advance providing better vision for our patients. In addition to the breakthrough in pupil size modeling, Varilux Physio Enhanced™ lenses achieve higher levels of sharpness by customizing the design to patient prescription and viewing distance. This level of sophistication means that our patients can enjoy safer night driving and less strain during daily activities such as reading, television watching, and computer use. The design and quality of vision eases adaptation and helps ensure the one thing we all want: happier patients.

Marguerite B. McDonald, MD, FACS, is a cornea/refractive/anterior segment specialist with Ophthalmic Consultants of Long Island, Lynbrook, NY, and a pioneer in wavefront-based refractive correction. Dr. McDonald, who performed the world's first excimer laser vision correction procedure, also conducted the first wavefront-based laser surgeries in the USA.

Factoring Pupil Size Changes into a Wavefront-optimized Progressive Lens Design Improves Vision in Low Light Conditions

Marguerite B. McDonald, MD, FACS*, and the Essilor Study Group**

PURPOSE

Varilux Physio Enhanced™ (Essilor) is a new wavefront-corrected progressive lens that incorporates pupil size modeling data into its design. The study evaluates whether this lens provides better vision, especially in low light conditions, than other progressive lens designs.

Effects of Pupil Size on Progressive Lens Performance

A healthy pupil dilates and constricts in response to light levels and distance to the target of regard. This pupillary response is affected by patient-related factors, such as age and ametropia.[1,2] Natural fluctuations in pupil size pose a problem for progressive lens performance. When pupil size increases, as it does in mesopic and scotopic conditions, the wavefront received by the eye is more highly aberrated because the beam of light entering through an enlarged pupil passes through a larger area of the lens surface (Figure 1). This results from the fact that a level of higher order optical aberration, particularly coma, is inherent in progressive lens design. Thus, the greater the spectacle lens area utilized, the poorer the quality of the wavefront that reaches the retina. Spectacle lens-induced aberrations diminish contrast sensitivity and visual performance. The effect is most pronounced in dim light—in fact, progressive lens wearers' most common visual complaint is their quality of vision in low light conditions.[3]

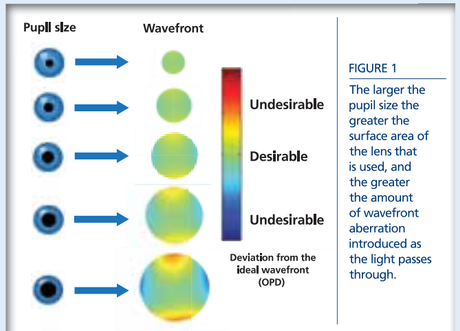


FIGURE 1
The larger the pupil size the greater the surface area of the lens that is used, and the greater the amount of wavefront aberration introduced as the light passes through.

Factoring Pupil Size Changes into Progressive Lens Design

To address performance issues posed by natural pupillary dynamics, a complex computer model was developed to predict pupil size for any given lens prescription and add power combination under a range of specific viewing distances and lighting conditions (Figure 2). For each pupil size, the model calculates the corresponding area of the lens surface that will be utilized. Then, taking the largest predicted pupil sizes (since these place the greatest constraints on progressive lens performance), the targeted areas of the original wavefront-optimized Varilux® Physio® lens are redesigned to minimize aberration in the area of the lens being used. The resulting design enhancement aims to minimize the spectacle lens aberrations associated with reductions in contrast sensitivity and visual performance.

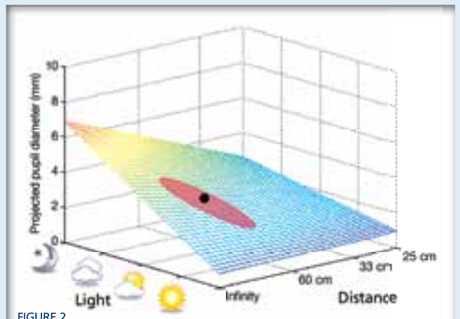


FIGURE 2
The area of the progressive lens surface that would be in use given the size of the pupil under the specific lighting level and viewing distance combination being modeled is represented in red. The model also takes into account the Rx, add power, and direction of gaze.

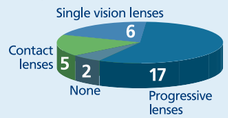
METHODS

A double-masked, randomized, non-dispensing wearer test compared the new Varilux Physio Enhanced lens to the original Varilux Physio wavefront-corrected design.

Subjects (N = 30):

- Average age: 52.9 years
- Spherical error: –6.25 to +3.25 D; average = –1.60 D
- Cylinder: up to 5.50 D; average = 0.70; 6 subjects >1.00 D
- Add: 0.75 to 2.75 D; average = 1.90 D
- BSCVA: 20/25 or better in each eye

Prior primary means of correction:



Test Protocol

Subjects received two pairs of identical eyewear, one with Varilux Physio Enhanced and one with Varilux Physio lenses. After testing with the first lens (randomized order), patients crossed over and tested the other lens design for comparison. Consistent fitting parameters were used (eg, monocular PDs, a minimum fitting height of 18 mm).

Subjects performed a series of real-world tasks in variable-controlled environments under both standard (100 cd/m²) and dim (25 cd/m²) lighting conditions (Table I). After concluding the tasks, subjects stated their "global overall" lens preference under each of the two lighting conditions.

TABLE I
Evaluative tasks conducted in standard (100 cd/m²) and dim (25 cd/m²) light

Vision type	Tasks	Functionalities assessed
Near	Accessing small-print features on: – digital camera – cell phone – restaurant menu	– Ease of use (camera, phone) – Clarity of vision (all) – Width of field (menu)
Intermediate	Reading and typing tasks: – LCD monitor set at 60 cm distance	– Clarity of vision – Width of field
Distance	Reading scrolling text at a minimum distance of 10 feet: – two LCD monitors, one positioned centrally, the other peripherally	– Sharpness of text – Ease of switching between central and peripheral monitor – Width of field
Changing Focus	– Near newsprint – Intermediate-distance LCD monitor – Far-distance LCD monitor	– Speed/ease of changing focus – Clarity of vision
Dynamic	Viewing while moving: – grocery shelves – stairs	– Finding items and reading labels (grocery shelves) – Confidence (stairs) – Maintenance of natural posture (stairs)

RESULTS AND DISCUSSION

Statistically Significant Preference for PAL that Uses Pupil Size Data to Optimize Wavefront

Subjects preferred the Varilux Physio Enhanced lens in both standard (71%; $P = 0.08$) and dim (82%; $P = 0.006$) lighting (Table II). The most frequently recorded subject comments referred to "better sharpness/clarity/focus" being experienced with the Varilux Physio Enhanced lens. A similar comparative study of 35 presbyopes confirmed that wearers experienced higher levels of visual performance for all measured criteria with the Varilux Physio Enhanced lens (Figure 3).

TABLE II
Subjects preferred the design (Varilux Physio Enhanced) that accounts for pupil dynamics

	Varilux Physio Enhanced	Varilux Physio	*P*-value
Standard Lighting (100 cd/m²)	71% (15)	29% (6)	0.08
Dim Lighting (25 cd/m²)	82% (18)	18% (4)	0.006

Note: Results for subjects who noted a lens preference in either the standard (21/30) or dim (22/30) lighting test scenario.

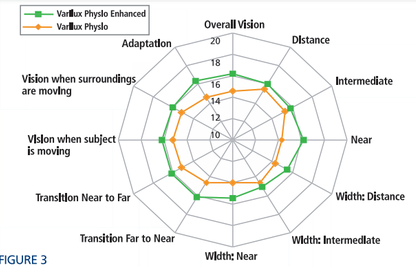


FIGURE 3
Subjects expressed higher levels of satisfaction with the Varilux Physio Enhanced lens for all performance criteria (as indicated by the wider diameter plot of mean responses in green) than for the Varilux Physio design (in orange). Scale: very poor (1) to very good (20)

Wearer Studies Confirm Optical Bench Test Findings

These wearer comparison outcomes corroborate optical bench test results that showed the Varilux Physio Enhanced lens exhibited reduced wavefront aberration levels (Figure 4) and improved contrast function (Figure 5) when compared to four other progressive lenses of identical prescription and material.[4] These tests showed Varilux Physio Enhanced offered:

- The lowest level of aberration in the portion of the lens utilized
- Highest modulation transfer function in dim and standard lighting

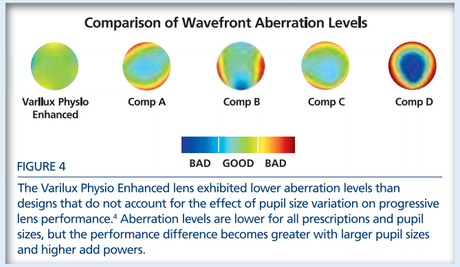


FIGURE 4
The Varilux Physio Enhanced lens exhibited lower aberration levels than designs that do not account for the effect of pupil size variation on progressive lens performance.[4] Aberration levels are lower for all prescriptions and pupil sizes, but the performance difference becomes greater with larger pupil sizes and higher add powers.

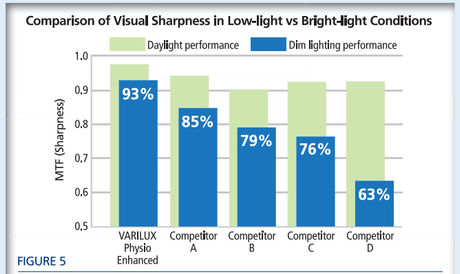


FIGURE 5
The Varilux Physio Enhanced lens maintained better contrast sensitivity in both low-light and bright-light conditions as indicated by a higher modulation transfer function (MTF). Evaluation based on a –4.00 D lens with +2.00 D add and pupillary diameters of 3 mm (bright light) and 8 mm (dim light).[4]

CONCLUSIONS

The Varilux Physio Enhanced design, which accounts for pupil dynamics, provides improved vision, particularly in low light.

Cumulative results from a double-masked wearer study and optical bench testing indicate that the Varilux Physio Enhanced lens, which is designed to account for the natural changes in pupil size that occur in response to lighting levels and the individual's accommodative state, provides improved vision in low light conditions when compared to progressive lenses that do not incorporate pupil size modeling data into their design.

The data show that the Varilux Physio Enhanced lens

- **Is globally preferred, with preference achieving statistical significance in dim light situations**
- **Has fewer aberrations than other progressive designs tested**
- **Preserves 93% of image sharpness in dim light for improved contrast sensitivity**

REFERENCES
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3. Nielsen on-line study of 300 interviewees in France and Germany, 2009. Data on file, Essilor International, S.A.
4. Comparative data were collected for the following progressive lens designs: Zeiss Individual™ (Lens A), Shamir Autograph II® (Lens B), Zeiss SOLAOne™ HD (Lens C), Hoyalux iD MyStyle (Lens D).

* The author has no financial interest in the products/companies referenced.

** The Essilor Study Group comprises independent researchers contracted to Essilor International, S.A.