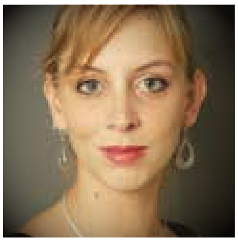
HIGH MYOPIA: THE SPECIFICITIES OF REFRACTION AND OPTICAL EQUIPMENT

The specific needs of highly myopic patients require special attention from eye care professionals. This article describes both the visual discomfort and main visual disorders associated with high myopia and explains the risks of visual impairment. It also discusses the specificities of refraction and the choice of optical equipment. In addition, it makes recommendations on frame selection and advise on the optimal selection of ophthalmic lenses.

Christian Franchi
Optician, Optique Vaneau,
Paris, France.

Christian Franchi graduated from the EOL (Ecole d'Optique et Lunetterie - School of Optics) in Lille, France, and trained at the ICO (Institut et Centre d'Optométrie – International College of Optometry) in Bures sur Yvette, France. He has practiced in Paris as an optician since 1979. Throughout his professional experience in tending to his wearers' visual health, Christian has continued to deepen his technical expertise. He was particularly interested in ophthalmic optical surfaces, their designing and implementation in optical equipment. With the advent of digital surfacing technologies in 2006, Christian has worked on methods of detecting a wearer's actual visual axes and on tracking the eye's center of rotation behind a corrective lens. He patented the OPHTAGYRE process in 2008. Christian Franchi is also a lecturer at several training seminars.



Adèle Longo
Research Manager,
Essilor Instruments,
Paris, France.

An optician and optometrist, Adèle Longo worked in an optical store while pursuing her studies at the Institut des Sciences de la Vision (Institute of Vision Sciences) in St Étienne, France, where she obtained her optometrist certification. In 2011, she joined the Research and Development department at Essilor International in the Low Vision Research Center within the Paris Vision Institute. In this context, she has worked to improve the functional assessment of patients with low vision. Currently with Essilor Instruments, Adèle is working on upstream studies and works as a low vision consultant at the same time in order to teach at the university and in centers for visually impaired patients.

Dominique Meslin
Director of Technical and
Professional Relations
Europe, Essilor International,
Paris, France.

Educated in France as an optician (Optical School of Morez) and optometrist (University of Paris Sud), Dominique has spent most of his professional career at Essilor. He began in Research and Development working on physiological optics and then held various positions in technical marketing and communication for Essilor International in France and also in the USA. He was the Director of Varilux University (now Essilor Academy Europe) for more than 10 years, and is now the Director of Professional Relations and Technical Affairs for Essilor Europe. Throughout his career, Dominique has facilitated numerous training seminars for eye care professionals worldwide. He is the author of several scientific articles and various technical publications for Essilor, including the "Ophthalmic Optics Files" series.

KEYWORDS
High myopia, pathological myopia, retinopathy, maculopathy, vision loss, visual acuity, contrast sensitivity, night vision, glare, recovery time from glare, quality of life, refraction, special lenses, lenticular lens, myopic rings, accommodation, minification effect.

"The specific needs of highly myopic people require special attention from eye care professionals."

In recent years, the prevalence of myopia has been increasing in all regions of the world. As reported in many studies, myopia's pandemic trends are putting researchers, clinicians and the industry of ophthalmic optics on the alert. Two aspects are emphasized in the mid-term projections: the number of people affected by myopia worldwide will increase steadily and, among them, the proportion of cases with high myopia is also going to increase. Thus, the prevalence of myopia (individuals with mild to high myopia) in the world's population could reach 25% by 2020 and nearly 50% by 2050, and the average prevalence of high myopia (over -5.00 D) would increase from 2.7% to almost 10% by 2050.[1] In other words, **myopic individuals would account for five billion people in 2050 and highly myopic individuals would account for one billion people** (Fig. 1). These figures show the significance of the phenomenon that is now considered a major public health problem, and compel us to better understand the day-to-day discomfort felt by slightly and highly myopic people so as to improve their eye care management.

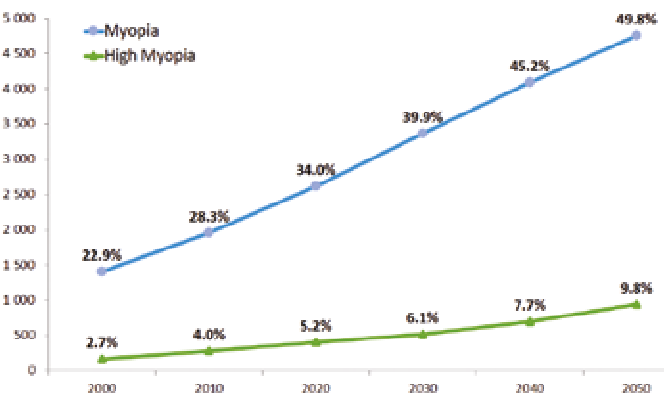


FIG. 1 | Number of individuals with myopia and high myopia, estimated by decade between 2000 and 2050. Adapted from Holden *et al.*[1]

1 Visual concerns of high myopia

1.1. Reduced visual acuity

One of the difficulties frequently encountered by highly myopic people is **the difficulty to read small print,** despite wearing optimal correction. Karen Rose[2] measured the maximum acuity attained by 120 subjects with various degrees of myopia, which was offset by their usual correction (contact lenses, eyeglasses, etc.). The results showed an average loss of two acuity lines on a logarithmic scale (0.2 on the Minimum Angle of Resolution [MAR] log) between medium myopia (-1.50 to -3.75) and high myopia (beyond -10.00 D), objectifying the subjects' problems.

1.2. Reduced contrast sensitivity

The Melbourne Department of Optometry and Vision Sciences[3] has measured the contrast sensitivity of various myopic subjects. Even after adjusting for the lenses' minification effect, the contrast sensitivity determined for the 10 most myopic subjects (greater than -4.00 D) appears worse than for the others (Fig. 2). **This explains the difficulty of deciphering low contrast characters**, which is necessary in everyday life – when reading certain forms or newspapers, for example. This shows us the importance of measuring contrast sensitivity during a patient's visual management in order to offer the proper solutions: for example, adding additional lighting can be useful, since it allows for an increase in the apparent contrast of objects viewed.

1.3. Deteriorated vision thresholds under low and bright lights

The study by Mashige[4] on 100 subjects tells us about the need to suggest lighting that is neither too weak nor too strong for these myopic individuals. To that effect, he measured night vision thresholds and vision thresholds under glare. For measuring night vision thresholds (light

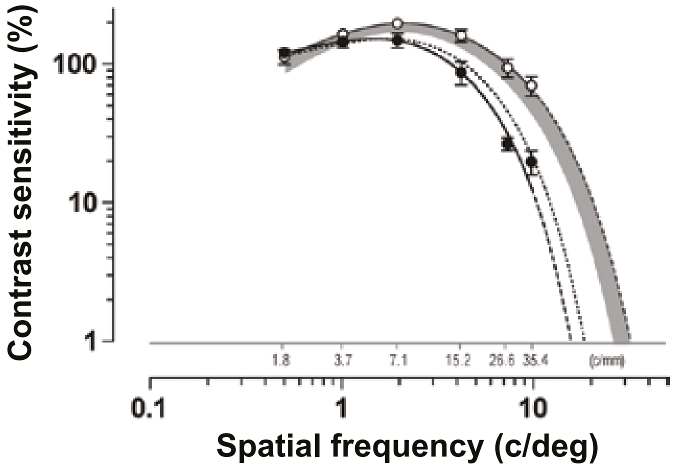


FIG. 2| The contrast sensitivity loss in high myopia occurred at high (but not low) spatial frequencies. The filled dots and empty dots, with black lines: these correspond respectively to the initial findings of highly myopic patients and control subjects. The gray shaded area: lower confidence limit at 95% of the contrast sensitivity function, modeled for control subjects. The black dotted curve: represents the position of the model for highly myopic patients corrected for the difference in image magnification compared with the control subjects.[3]

threshold level authorizing vision), he decreased ambient lighting until the subjects indicated that they could no longer see the target. The procedure to measure the thresholds of vision under glare was identical by simply adding a glare source. Results showed more significant vision thresholds for myopic than for hyperopic subjects (Fig. 3), which shows **a relative weakness in the adaptability of myopic subjects at different light levels.**

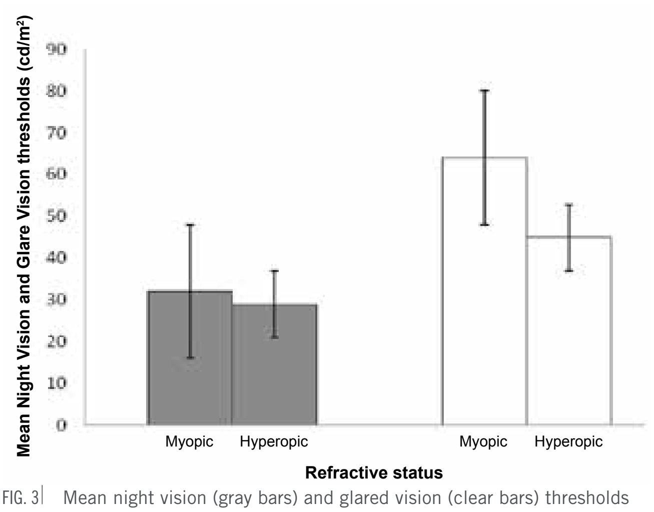


FIG. 3| Mean night vision (gray bars) and glared vision (clear bars) thresholds of myopic and hyperopic eyes.[4]

1.4. Increased recovery time after glare

In addition, the recovery time after glare, defined as the time required to regain the initial performance after being exposed to glare, is longer for myopic than for hyperopic subjects (Fig. 4), especially in subjects with a high degree of myopia. This shows, for example, **the difficulties experienced by these highly myopic at the exit of a tunnel**.

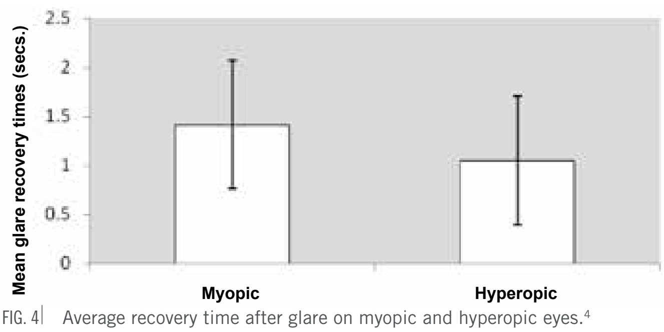


FIG. 4| Average recovery time after glare on myopic and hyperopic eyes.[4]

1.5. Decline in the quality of life and social impact

The VF-14 (result between 0-100) and the VQOL (0-5) are two questionnaires on quality of life that have been completed by subjects with different degrees of myopia.[2] The results showed that the highest myopia levels are directly associated with lower general satisfaction in the achievement of all day-to-day living activities due to **visual difficulties, particularly when driving**. The study of these questionnaires reveals that the difficulties are not only visual, but also **concern aesthetics, practical and financial aspects.** This decline in quality of life is essentially measured in subjects affected with high myopia (<-10.00 D). Accordingly, the **social and psychological impact,** resulting from their a**nguish of losing sight, is very significant**.

2. Risks of visual impairment in high myopia

2.1. Pathologic myopia (retinopathy and maculopathy)

A person with high myopia presents a **very significant risk of developing eye diseases**, which can sometimes cause serious retinal damage[5] leading to various eye complications and subsequent deficiencies in the visual field. Indeed, the excessive axial elongation of the highly myopic eye may cause the mechanical stretching of the outer layers of the eyeball, resulting in such various

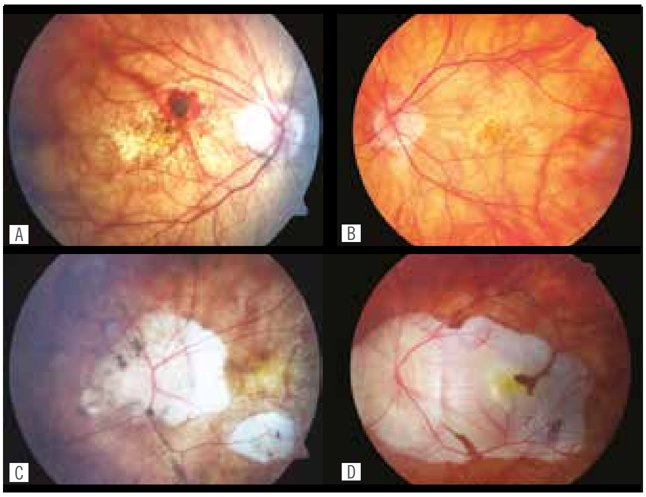


FIG. 5 | Photographs showing pathological changes on the fundus of four highly myopic eyes - (a) Myopic Choroidal Neovascularization; (b) Myopic Macular Degeneration; (c) Myopic Macular Degeneration with Staphyloma; (d) Geographic Atrophy Myopic Degeneration with Posterior Staphyloma.

pathological changes as staphylomas, atrophic lesions or chorioretinal cracks, choroidal neovascularization, and more (Fig. 5).[6] The choroidal peripapillary and sub-foveal thinning, scleral thinning, and irregular deformations of the eyeball have been associated with various lesions in the case of high myopia. Given the increasing prevalence of high myopia, **pathologic myopia (retinopathy and different categories of maculopathy[7]) is likely to increase dramatically in the coming decades**. Therefore, the detection of pathological changes should be evaluated early. Using advanced imaging technology could help identify people at risk and help in the management and monitoring of high myopia.

Beyond choroidal neovascularization and macular degeneration, high myopia has also been associated with the risk of other eye diseases, including glaucoma.[8] Regarding cataracts and the potential association with high myopia, the results diverge depending on the study.[9] Overall, high myopia is a major cause of visual impairment worldwide.[10, 11]

2.2. Management of visual impairment

Pathological or not, high myopia often leads to significant visual impairment. Magnification needs thus become much more significant. Very often, highly myopic people remove their glasses for near vision. This allows them to avoid viewing too small objects (reduced in size by their lenses), as well as bringing documents too close to their eyes to magnify them.

When the need for magnification is more significant due to visual impairment, it is interesting to suggest **a bright field magnifier**, an optical system that is placed directly on a document, thus allowing for magnification of the text and offering a high apparent contrast via concentration of light. Note that it is imperative to adapt the magnifier in relation to the focus distance of the myopic readers when they take off their glasses.

Electronic systems can, in the same way, meet even greater magnification requirements and are the only ones able to offer colorful image processing or reversed contrasts to optimize the vision of those with high myopia.

Significant light sensitivity as reported in high myopia and visual impairment involves testing **color filters** that can optimize vision while reducing the risk of glare. The analysis of lighting environments at work and at home, the elimination of sources of glare, and the addition of spotlights can help highly myopic people in achieving their daily tasks.

3. Specificities of refraction in high myopia

In the case of high myopia, it is important to practice **comprehensive measurements of visual functions** and to prioritize those functions that are the most impacted (e.g., visual acuity, contrast sensitivity, glare, etc.). Attention should be paid to day-to-day situations in which patients experience discomfort (low and bright lights, night vision, etc.). **The refraction of high myopia requires special precautions**[12], especially complete control of the distance between the glass and the eye (Fig. 6). It is therefore preferable for the prescription to be filled, or at least finalized, with trial frames. The lenses should be placed near the eye and, if possible, to the rear of the trial frame to ensure the closest simulation of the conditions in which the final frames will be worn. If the prescription is of a very high power and is beyond the capabilities of the refractor or the trial lenses, the refraction will be carried out over the

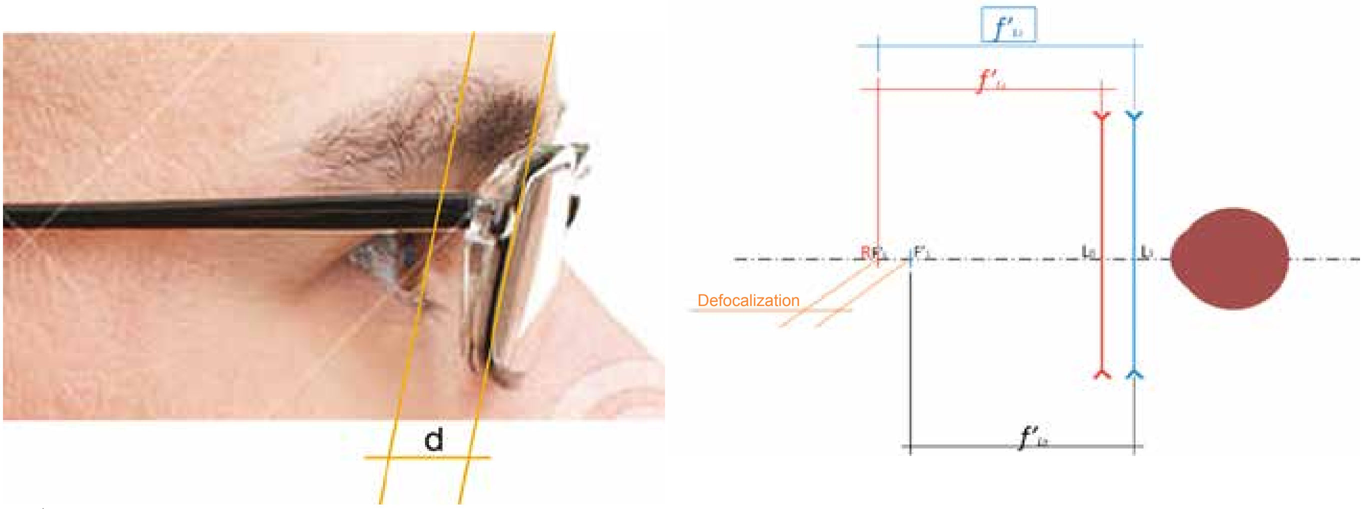


FIG. 6 | Variation in the correction of myopia with the vertex distance (d). The lens movement from L0 to L1 causes defocusing. The focal length of the corrective lens becomes $f'_{L1} > f'_{L0}$. To compensate myopia, the power should be decreased if the lens is closer to the eye.

patient's current glasses (over-refraction technique) with an additional lens support placed on the patient's frames. A person with high myopia often suffers from relatively low visual acuity and is therefore not very sensitive to small variations of sphere and a cylinder of 0.25 D; 0.50 D variations will thus be preferred during examination. As with any conventional refraction[13], it can be started with measurements from the autorefractometer's refraction or the prescription previously worn by the patient. To determine the sphere the fogging method can be used, with a high fog (+2.50 D) and larger increments of 0.50 D. To confirm the axis and the power of the astigmatism, a ± 0.50 D cross cylinder will be more efficient than a ± 0.25 D cross cylinder.

A very important aspect of the refraction of high refractive errors is **the inclusion of the vertex distance**: it can significantly alter the value of the prescription. The closest the lens is to the myopic eye, the lesser its power needs to be concave; the principle is to always match the lens' image focal point with the far point of the eye (Fig. 6). A person with -20.00 D myopia with a prescription based on a 12 mm vertex distance will thus need a prescription of -19.25 D if the lens is placed at 10 mm and of -20.75 D if it is placed at 14 mm.

Conversely, presbyopic people with high myopia can help their near vision by creating an additive effect by simply pushing their glasses farther away: for example, a person with -20.00 D myopia who pushes his or her glasses away by 4 mm thus creates an addition of about 1.50 D.

4. The importance of frame choice

The choice of frames is especially important with high myopia. The frame should be small to allow its positioning close to the patient's eyes and, if possible, with offset joints that reduce the size of the lenses and ensure proper distribution of the lenses around the eyes. The optician will adjust it to ensure that the lens is perpendicular to the direction of the gaze when the eye is in its primary position. The choice of the frame will also take into account the insertion height of the temples in the frame front according to the frame position on the nose and the ears; the temples will be adapted accordingly. Before measuring the right and left pupillary distances and heights, the final frame is to be perfectly adjusted to the patient's face. Finally, the vertex distance will be systematically measured or otherwise evaluated in order to confirm the refraction.

To remember:

A variation of 4 mm of the vertex distance requires an adjustment of the prescription according to the values shown in the table below. It is therefore imperative to take into account small changes in vertex distance starting at 10.00 D. In the absence of such precision, the correction is assumed to be determined for an eyeglass positioned 12 mm away from the eye. Ideally, the prescriber will indicate the distance at which the refraction was established on the prescription.

Corrective power	Vertex variation	Effect Power variation
10.00 D	4 mm	0.50 D
15.00 D	4 mm	1.00 D
20.00 D	4 mm	1.50 D

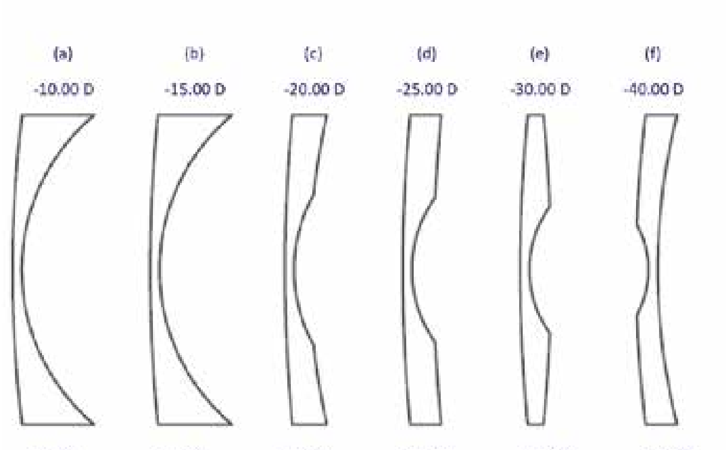


FIG. 7 | Special lenses for high myopia.

5. Special lenses for high myopia

To meet the needs of high myopia, manufacturers offer special lenses designed to reduce the edge's thickness, commonly covering a power range of up to -40.00 D in single vision and -25.00 D for progressive lenses. Different techniques are used, sequentially or simultaneously, to reduce the thickness at the edge of the lens (Fig. 7): **an increase of the refractive index** causes the flattening of the two surfaces, thereby thinning the lens' edge; for example, with an n = 1.67 index material, a -15.00 D lens can have a thickness that is close to that of a -10.00 D lens made of a classic material with an n = 1.50 index (Fig. 7a and b); **the reduction of the optical aperture** or a "lenticular" lens will allow the thickness to be reduced even more significantly. It involves the creation of a facet at the rear edge of the lens, which divides the lens into two parts – a central, "optical" zone and a peripheral "facet" – and considerably improves aesthetics (Fig. 7c to e). This facet can be optically concave (negative power), plano (no power) or convex (positive power), according to the desired thickness reduction (Fig. 7c, d, e). Moreover, the smoothing of the edge (Fig. 8) improves aesthetics and minimizes the image's doubling effect at the limit of the optical zone. It nevertheless creates a blurred vision zone that is often far enough to the side so as to avoid hindering the wearer whose lenses are placed close to the eye.

The higher the power of the prescription, the more the central optical zone is reduced (30, 25 and 20 mm) in order to achieve prescriptions of up to -40.00 D (Fig. 7f). For such a power, one can opt for bi-concave lenses whose power is negative on both sides and can achieve extreme power that can even exceed -100 D with a **bi-concave** and bilenticular lens![14]

The front faces of these lenses are very flat, generating lots of reflections that are very visible; it is therefore indispensable for their surfaces to be treated with antiglare (anti-reflective) coating as long as it is technically feasible.

5.1. Concave lenticular lenses

In order to achieve a high power lens with great aesthetics, manufacturers are producing so called "lenticular" lenses. They are composed of a central optical zone and a non-corrective annular zone on the periphery, called the facet. These two zones can be either separate, with a visible edge separation, or continuously connected via the smoothing of this edge (Fig. 8).

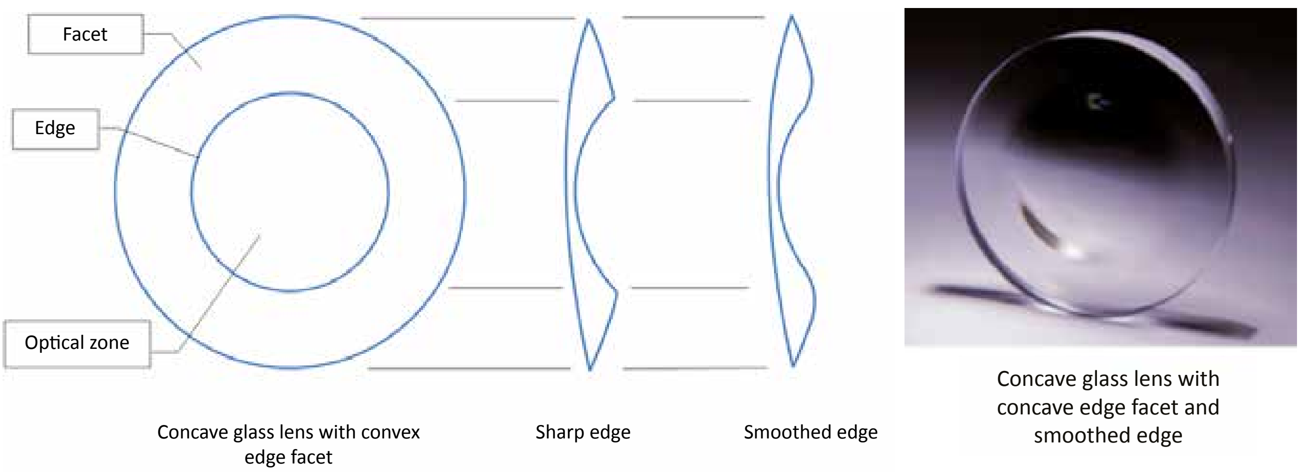
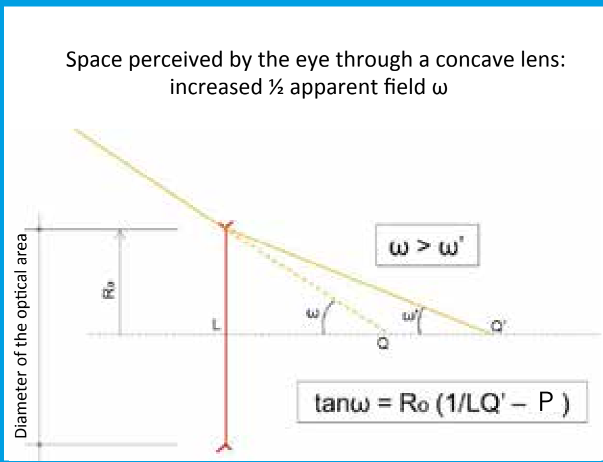


FIG. 8 | Concave lenticular lens

Lenticular lenses: optimum diameter of the optical zone

The goal of using lenticular lenses is to reduce the thickness of the lenses without limiting the visual comfort of the wearer. Indeed, optical apertures that are too small hinder visual comfort. Conversely, optical apertures that are too big unnecessarily increase thickness. To manage this compromise, it is useful to determine the optimum diameter for the optical zone.
The visual comfort is linked to the angular object field available behind the lens, which typically needs to be +- 30° for the central optical field. Depending on the wearer's individual habits, it is necessary to consider a certain margin when defining this central optical field.
Once determined, the target object half-field, the diameter of the useful optical zone, can be calculated. It is a function of the distance of the lens to the eye's center of rotation to the lens (LQ') and the power of the lens P. The results are summarized in Table I.
The temporal field is the most compelling: in case of astigmatism, the P power to be used for the calculation is the power of the 0°-180° meridian.



Lens Power (P)	-10.00	-15.00	-20.00	-25.00	-30.00	-40.0
Ø ZO with **ω** = 30°	23	21	19	18	16.5	14.5
Ø ZO with **ω** = 40°	33.5	30.5	28	26	24	21
Ø ZO with **ω** = 45°	40	36	36	31	28.5	25
Ø ZO with **ω** = 50°	48	43	40	36.5	34	30

Table I. Diameter that has to be given to the optical zone (ZO) depending on the lens power (P) to get an object half-field of **ω**.

6. Vision of a person with high myopia that has been corrected with ophthalmic lenses

During the optical correction of high myopia, several specific optical phenomena occur.[15, 16] They can be summarized as follows:

6.1. Lesser accommodation and lesser convergence
Through his or her ophthalmic lenses, a highly myopic person will accommodate and converge less than would an emmetropic or hyperopic person and less than if fitted with contact lenses. Indeed, the vertex distance plays a significant role, and its effects are all the more significant when the power is strong. For example, a person with -20.00 D myopia, who would apparently accommodate to 5.00 D to focus at an object 20 cm from his or her glasses, actually accommodates to approximately 3.10 D if the lens is placed at 12 mm from the eye. Similarly, although it seems as though such patients converge substantially to look 20 cm away, their convergence effort is actually much less due to the basic internal prismatic effects provided by their lenses at near vision.

6.2. Reduced visual acuity
With high myopia, the vertex distance causes a minification effect (reduction in size) in both the images seen by wearers through their lenses and the wearer's eyes as seen by other people. Due to this reduction in size, wearers with

$$M = \frac{1}{1 - d \times P}$$

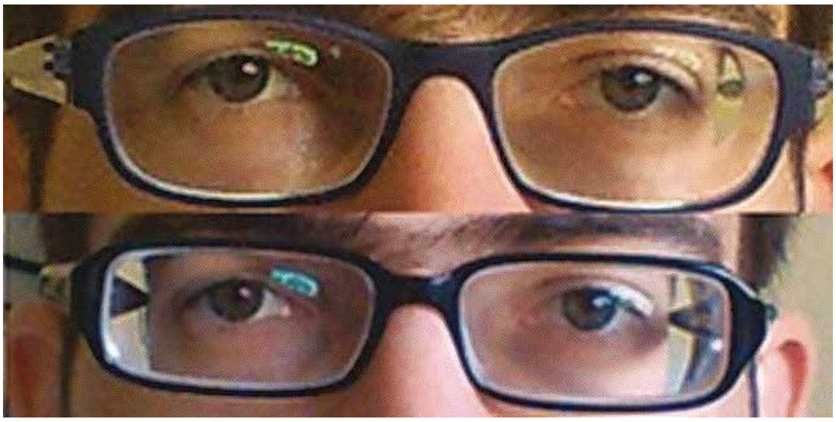


FIG. 9 | Calculation of the lens' minification effect (left) and perceived reduction of eyes' size in highly myopic wearers (right).

high myopia usually have significantly lower visual acuity with ophthalmic lenses than with contact lenses. The minification effect, mainly caused by the vertex distance, is given by the **following formula:**

$$M = 1 / (1 - d \times P)$$

where d = vertex distance and P = power of the lens (Fig. 9).

For example, for a -20.00 D lens placed at 12 mm, the minification effect is about 20%. Accordingly, if a patient's maximum acuity was 20/20 with contact lenses, it may only be 20/25 with eyeglasses simply due to this optical effect. That is one reason why opticians should always seek a frame that is positioned closer to the patient's eyes to minimize this effect as much as possible. As it has already been reminded, it is imperative to validate refraction specifically for that particular vertex distance.

To remember:

- The magnification/minification effect changes with the vertex distance.
- The closer the lens is to the eye, the weaker the effect is.
- Effect on visual acuity: VA is lower with eyeglasses than with contact lenses for someone with high myopia.

Minification effect for a lens power -10.00 D	Vertex distance (mm)	Minification effect for a lens power -20.00 D
0.909/-9.3%	10 mm	0.833/-16.7%
0.893/-10.7%	12 mm	0.806/-19.4%
0.877/-12.3%	14 mm	0.781/-21.9%
0.762/-13.8%	16 mm	0.757/-24.3%

6.3. Peripheral image duplication

Image duplication occurs at the edge of lenses with strong negative power. Indeed, the last beam of light passing through the lens is refracted towards the outside and the first external beam of light on the outside of the lens is not refracted. The same object is thus seen twice, once sharply within the lens and once blurred on the outside of the lens. For the wearer, this means that the peripheral image, or its perception, is doubled at the edge of the lens (or the edge of the central optical zone), especially if the edge of the frame is thin or missing (rimless frames or those with a nylon thread).

6.4. Phenomenon of the myopic rings

One of the particularities of the correction of high myopia with ophthalmic lenses is the emergence of unsightly rings on the periphery of the lens, which are more visible when looking at the wearer sideways. These rings are the images at the edge of the lens reflected multiple times on the front and back of the lens. Polishing the lens edge and/or reducing the optical aperture considerably decreases them.

7. The convenience of special lenses for high myopia

Surgical treatment or contact lenses cannot be used for all highly myopic patients, and ophthalmic lenses are still relevant for high myopia. A wide range of lenses with powers commonly reaching -40.00 D in single vision lenses and -25.00 D in progressive lenses are available, and the technical know-how of the lens manufacturer can go even further. Recently, a record -108.00 D myopia was corrected with ophthalmic lenses by an alliance of French-Slovak experts.[17] With careful, precise implementation by the optician, the wearer benefits from a comfortable visual experience. These special lenses, meant for extreme prescriptions, remain insufficiently known of and used by eye care professionals, and would be of great service to the highly myopic population, which continues to grow in numbers.

8. Conclusion

The number of young and old people with high myopia will increase in the future. Their care requires precise measurement of several visual functions and under various conditions in order to understand the origin of their discomfort. It is also necessary to carefully study all the parameters affecting the final refraction, from the visual exam to the adaptation of the optical equipment. Moreover, it seems imperative to study the difficulties patients encounter in their entirety in order to offer comprehensive, multidisciplinary care. •

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KEY TAKEAWAYS

- The specific needs of highly myopic people require special attention from visual health specialists.
- The main discomforts of those with high myopia include:
  - Reduced visual acuity
  - Reduced sensitivity to contrast
  - Deteriorated vision thresholds under low and bright lights
  - Elongation of recovery time after glare
  - Decline in quality of life and social impact.
- High myopia is often associated with risks of high visual impairment and eye diseases such as retinopathy and maculopathy (staphylomas, atrophic lesions, chorioretinal cracks, choroidal neovascularization, macular degeneration, glaucoma, etc.).
- The refraction of high myopia requires special precautions, comprehensive measures of visual functions and the inclusion of the vertex distance.
- The optical equipment of those with high myopia should be tailored to their needs. The practitioner will choose an appropriate frame and opt for special lenses in a range dedicated to high myopia.