Near refraction and aberrometry

Dr Dietmar Uttenweiler and **Christina Butz** discuss a Rodenstock system that allows near cylinder differences and high-order aberrations to be incorporated into the final lens

The question is often asked whether any potential improvement exists considering the high level of development of modern progressive lenses The answer is a clear yes! This is because there are three important influencing points that lead to improved vision: compensation for near astigmatism, taking high-order aberrations (HOA) into consideration and incorporating the latest aberrometric technologies With Eye Lens Technology (EyeLT) from Rodenstock, it is possible to address all three for the first time.

Near astigmatism

Near astigmatism is a known and important topic in ophthalmic optics, international studies and discussions in numerous textbooks.[1,2,3,4] However, in practice, compensation of near astigmatism has played a subordinate role in the past. The reason for this was that near astigmatism could only be corrected with a suitable single vision lens or special multi-vision lenses, but not with a progressive lens. Two years ago Rodenstock was successful at implementing different cylinders in one progressive lens. EyeLT from Rodenstock makes it possible for the first time to have full correction for distance vision and near vision for astigmatic prescriptions with a progressive lens.

There can be several causes for near astigmatism. The first cause is based on a physiological phenomenon: during eye movements the eyes adopt a torsion position defined by the line of vision, which is described as Listing's law. With astigmatic eyes this 'rolling' effect results in different cylinder axes, which may also require an adaptation to the cylinder axis of the lens. A lens that does not take these inter-relationships into account means the cylinder axis coincides with that of the eye only when looking straight ahead. As a rule of thumb, 3° deviation of the cylinder axis causes faulty cylindrical refraction of 10 per cent of the initial cylindrical value. Therefore, with a cylinder of 150 DC and an axis deviation of 5°, there is an astigmatic error of 025DC.

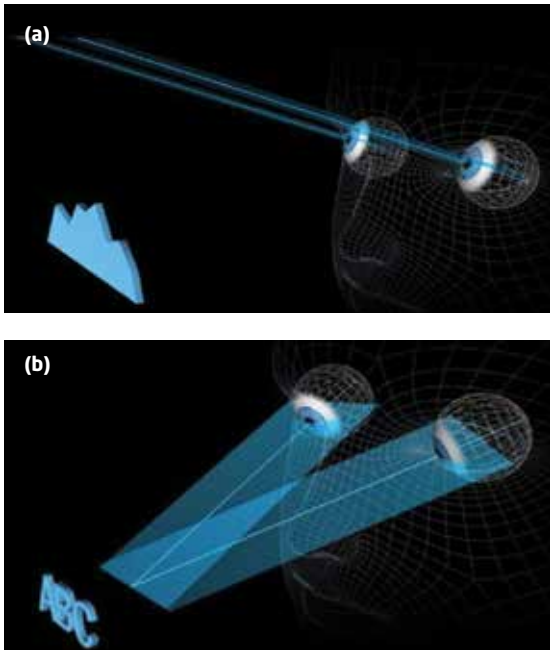


Figure 1 The torsion settings of the eyes differ for eye movements in the same direction (versions). (a) Listing's far vision) and eye movements in the opposite direction (vergences) (b) Listing's near vision

Rodenstock has been taking Listing's law into consideration for lens calculations since the introduction of the world's first individual progressive lens, Impression, in 2000. In its original form, Listing's law only applies to distance vision; however, significant modifications arise in near vision due to convergence (Figure 1).[5,6,7] Rodenstock takes these findings into consideration in the lens calculation with EyeLT. Here, an improvement to vision in medium and far distances can be achieved for all astigmatic prescriptions through an additional adaptation of the cylinder axis in near vision.

The second cause of near astigmatism is the so-called effective near astigmatism. This is a purely geometric-optical phenomenon caused by the distance between the lens and eye. Effective near astigmatism occurs with spectacle wearers with astigmatic prescriptions and under accommodation, and it increases the value of the required correction cylinder for near vision (Figure 2).

With the help of an advanced physiological model (EyeModel), Rodenstock has been able to take Listing's law for near vision and far vision as well as the effective near astigmatism into account in the lens calculation. Near objects are therefore once again projected clearly onto the retina.

The third cause is individual anatomical variation that can lead to near astigmatism due to astigmatic accommodation, for example due to tilting of the intraocular lens. However, anatomically induced near astigmatism cannot be reproduced in a physiological model and subjective near refraction is necessary to determine it, which requires checking the value and axis of the near cylinder in addition to the usual addition determination. With the Personal EyeModel option, this data is fed into the progressive lens calculation. The spectacle wearer benefits from considerably larger visual zones and clear near vision.

As visual demands at medium and close range increase due to the popularity of computers, tablet PCs and other new media, sharp and fatigue-free near and intermediate vision is becoming more and more critical. Improved vision promotes not only the satisfaction of the spectacle wearer, but also increases performance.

High-order aberration

Discussions about HOA have increased continuously over the past few years. It is generally necessary to differentiate between HOAs of the lens and those of the eye. Rodenstock has taken the intrinsic HOA of the lens (coma and spherical aberration) into consideration in lens optimisation since 2000.[8,9] In addition, the HOAs of the eye are fed into the lens calculation in two different ways in the newest generation of individual lenses from the Rodenstock Perfection category. This involves two complex calculation methods developed by the company: pupil-optimised correction, which is based on a physiological vision model, and DNEye optimisation, ie the calculation of the best sphero-cylindrical correction for each line of vision taking into consideration the individual aberrometric measurement data of the eye.

It is important to mention again that ▶

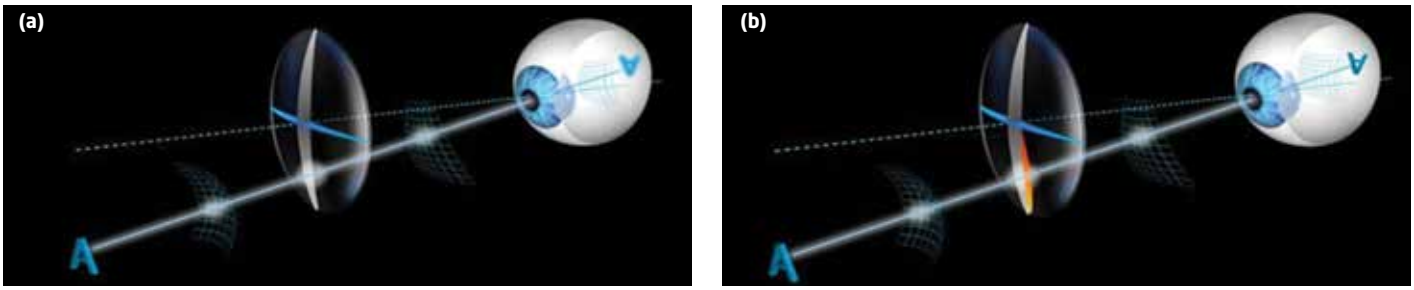


Figure 2 (a) The effective near astigmatism leads to an uncorrected effect of a cylindrical power in near vision. **(b)** To correct this, the cylinder effect must be increased in near vision

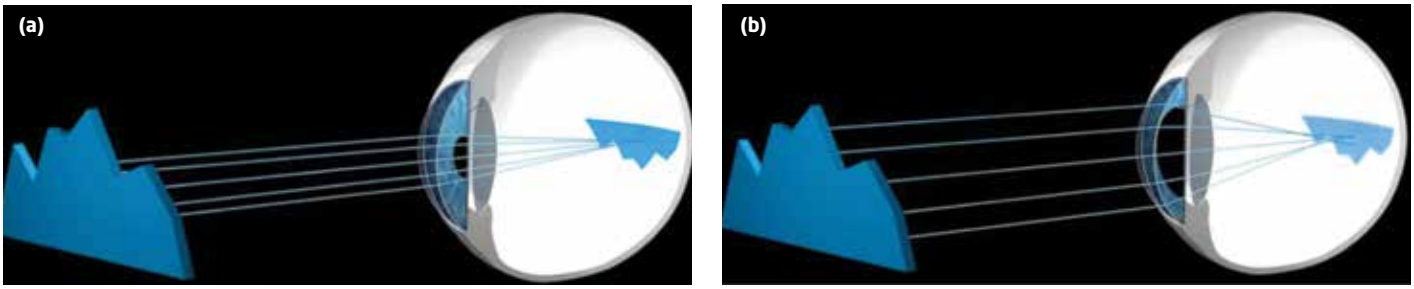


Figure 3a and 3b Spherical aberration: Rays at the edge of the pupil are usually refracted more than rays close to the axis

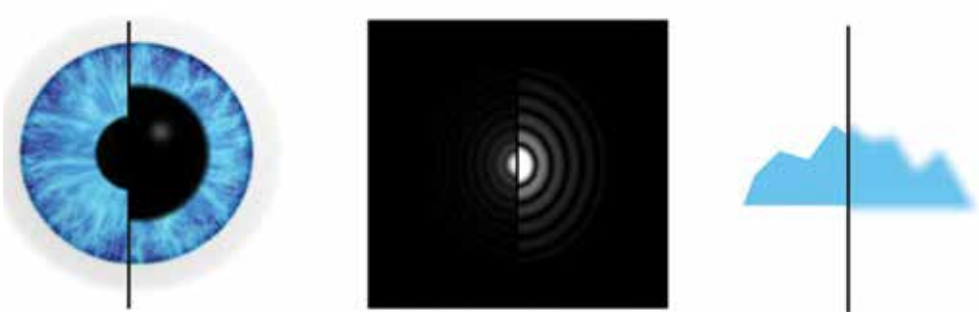


Figure 4 With a large pupil, the spherical aberration leads to a loss of contrast and an unclear image

it is generally not possible to correct the HOAs of the eye with a spectacle lens However, thanks to these two new developments, it is possible to take the effect of the HOA on the best sphero-cylindrical correction into consideration. An important characteristic value here is the pupil diameter HOAs have a greater effect with large pupils than with small pupils. Hence, the best sphero-cylindrical correction also varies with different pupil diameters.

In turn, the pupil size is affected not only by the ambient lighting, but also by the accommodation condition as well as the convergence position of the eyes. This coupling is referred to as accommodation reflex If the eyes are fixed on an object in the distance, then the pupils are larger than when they are fixed on a near object. However, the maximum pupil opening reduces with increasing age by an average of 0.4mm per decade.[10]

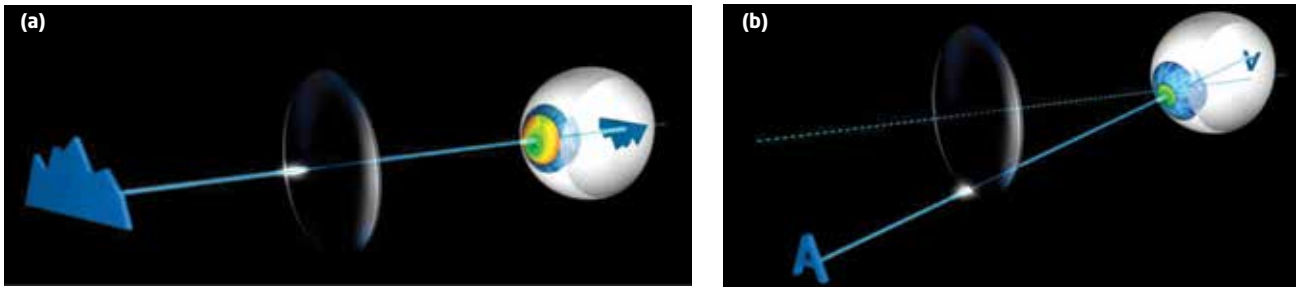
Since April 2013, pupil-optimised correction is one of the basic technologies of all individual lenses in the Rodenstock Perfection category. Here, the mean spherical aberration of the eye is fed into the lens optimisation – subject to the pupil size (Figure 3).

The spherical aberration of the eye is usually the most influential HOA In most cases light rays that hit the eye at the edge of the pupil are refracted more than rays close to the optical axis Hence, the point of the best image is no longer on the retina with a large pupil When the pupil size increases, it causes a type of myopia which results in an unclear image and loss of contrast (Figure 4).

As already mentioned, it is not possible to correct the spherical aberration of the eye with a spectacle lens. However, it is possible to minimise its negative effect on vision The foundation of pupil-optimised correction is an advanced physiological model upon which lens optimisation is based and which is based on standard values of the pupil size as well as the average spherical aberration of the eye. Each vision point of a lens can be assigned a specific object distance With the help of this newly developed physiological model and the findings on the correlation between the ordered addition and age, it is possible to determine the pupil play depending on the vision point. Hence, it is possible to calculate the spherical aberration of the eye depending on the pupil diameter and take it into consideration for lens optimisation. The spectacles wearer benefits from clear vision at all distances and in all light conditions.

The DNEye system allows the individual HOA profile for any individual to be reflected in their lenses. Through an additional aberrometric measurement, the vision system of the customer is analysed.[11] The DNEye Scanner measures the low and HOAs of the eye with high precision and completely automatically. Compared to conventional aberrometers, the DNEye Scanner records not only the aberrations of the eye for far vision, but also for near vision. This is because, just like the sphere and cylinder, HOAs are also dependent on accommodation. Furthermore, there is a measurement of the corneal topography as well as the individual pupil size with mesopic and photopic lighting.

The aberrometric measurement cannot replace the subjective refraction, because only the latter takes the processing of visual impressions in the visual cortex into consideration (perception). Nevertheless, it supplies important additional information about the visual system of the spectacles wearer. Within the framework of EyeLT, Rodenstock has developed a special algorithm that takes all these aspects into consideration up to the



Figures 5a and 5b DNEye optimisation takes into consideration the HOAs of the eye and the lens subject to the individual variance of the pupil size and thereby ensures the sharpest vision

Figure 6 Influence of EyeLT upon vision

Without EyeLT	With EyeLT EyeModel	With EyeLT Personal EyeModel + DNEye
No full correction in near vision for astigmatic prescriptions	Consideration of Listing's Law for near vision and effective near astigmatism	Consideration of the individual near refraction and the aberrometric measurement data of the eye
Limited vision areas and unclear vision in near and intermediate distances	Up to 25 per cent better near and intermediate vision	Up to 40 per cent better near and intermediate vision as well as 100 per cent exploitation of personal vision potential

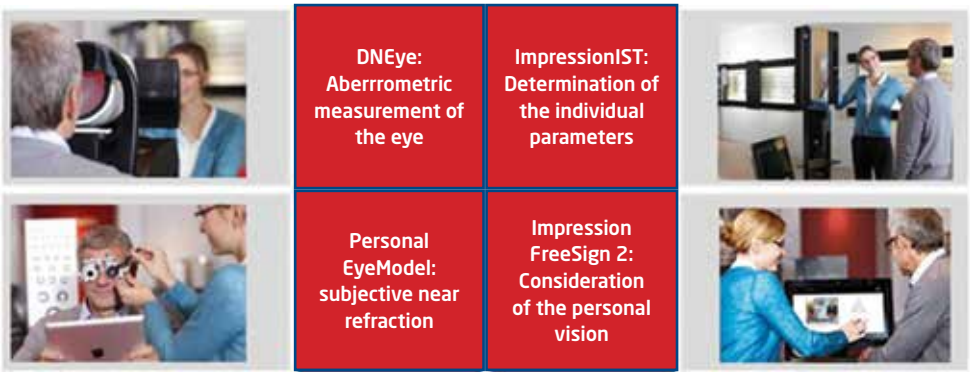


Figure 7 Important modules of the Rodenstock system of better vision

limit of that which is physically possible. The best sphero-cylindrical correction for each individual vision point is calculated on the basis of the aberrometric measurement data together with the subjective refraction data for far vision and near vision. It is then transferred to the lens through a unique, high-precision manufacturing process. Hence, every lens manufactured with DNEye data differs from other lenses.

To the spectacle wearer, this unique technology means an even more significant improvement in vision. A Swiss study provides the proof: Impression lenses with DNEye and Personal EyeModel give the spectacle wearer larger near vision areas in addition to noticeably increased visual comfort.[12]

The correction of near astigmatism as well as taking HOAs into consideration represent two important milestones on the way to optimum vision through spectacle lenses. Thanks to Eye Lens Technology, Rodenstock has been able to take these two aspects into consideration in lens optimisation. The DNEye option provides maximum individuality and is based on an extensive analysis of the customer's individual vision system. In the process, the individual parameters as well as the frame and centration data and also the aberrometric measurement data of the eye are incorporated into the lens in addition to the subjective refraction of far vision and near vision. Based on these parameters, Rodenstock calculates the best sphero-cylindrical correction for each vision point on the lens. Above and beyond this, the lens design can be adapted to the individual visual requirements with Impression FreeSign 2.

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