General Optical Council Approved CET For Optometrists
General Optical Council Approved CET For Dispensing Opticians

Freeform lenses

HOYA

Part 3

Paul Bullock describes the evolution in design of freeform progressive power lenses. C14632, one general CET point for optometrists and dispensing opticians

The progressive power lens (PPL) market is fiercely contested – the latest technology, designs and equipment are utilised; as well as significant resources in product research and development by lens manufacturers to provide the best product to the wearer.

Ever since the release of the very first commercially successful PPL in 1959 and the subsequent introduction of multiple PPL designs and manufacturers to the optical market, the manufacturers have tried to differentiate their product from their competitors. With early PPLs it was a relatively straightforward affair to have a significantly different design. Today it is much harder. The difficulty lies not so much with the imagination and expertise of the design team, but more so with the various restrictive covenants and patents protecting certain elements of PPL design and manufacture.

These 'industrial design restrictions' as they have come to be known have shaped the landscape of the PPL marketplace. PPLs launched within the past 18 months have, on average, had eight patents protecting elements of their design and manufacture.

The combination of industrial design restrictions and differentiation from competitors has led to different avenues or design directions for manufacturers to follow. This is nowhere more apparent than in the description of what constitutes a freeform progressive as previously discussed in Module 2 of this series (13.08.10). More recently there has been an interesting evolution in the design base theory of PPLs which will now be discussed.

Biometric individualisation

The advances in freeform lens technology not only allow us the facility to optimise for the wearer's prescription and facial parameters but also for their lifestyle and habitual characteristics. The ability to tailor-make the lenses to the patients' requirements offers the dispenser the option to deliver the highest level of patient care with an individual solution to the wearer's unique visual requirement.

One design direction that a modern PPL design has adopted is to categorise the wearer by their predilection to either move their head or eyes when viewing objects. The eye movers would require a wide, clear central viewing zone, so the design of the lens would purposely increase the strength of the surface astigmatism close to the umbilic both nasally and temporally, thereby increasing the size of the distance and near zones – in essence a harder design PPL. The head movers would require a design of lens with reduced surface astigmatism; in this case the PPL design would be focused around reducing the severity of the surface astigmatism by spreading it wider over the surface of the lens – in essence a softer design PPL. In order to determine the wearer's predisposition for eye or head movement the lens manufacturer supplies equipment to aid this categorisation.

Figure 1 Blue area viewed by eye movement, red area by head movements

In a totally non-scientific manner I decided to investigate my personal predisposition. This was done without the aid of equipment. I chose two of the aspects of my job that I spend a significant amount of time doing; general office work and motorway driving.

While driving I noticed that I was an eye mover for certain tasks. As my gaze passed from the road to my SatNav, across to my hands-free phone display screen, up towards my rear view mirror and across to my driver side wing mirror I did not change my head position, rather flicking my eyes to the required position. As displayed in Figure 1 by the blue arrow.

For other tasks such as looking at my passenger side wing mirror, checking the blind spot over my shoulders before changing lanes and reversing, it was very apparent that I was a head mover, as displayed in Figure 1 by the red arrow.

Testing this further, I noticed that my predisposition changed with the corrective method I was wearing at the time. While wearing contact lenses or high base, high curve prescription sunglasses, I tended to move my eyes more, as I enjoyed a larger peripheral field of view. When wearing traditional prescription spectacles I noticed that the smaller the eyesize of the frame I was wearing, the less I would move my eyes and I became more of a head mover due to the reduced field of view. I would also move my head more if I was wearing a frame with particularly thick sides which obscured my peripheral vision.

While undertaking office-based work, for close range, reading tasks and intermediate range tasks such as working on the computer screen, as displayed in Figure 2 by the blue arc, I noticed that I was very much an eye mover. If concentrating on a particular piece of printed text I found that I would, on occasion, use either my pen or finger to help with tracking my eyes

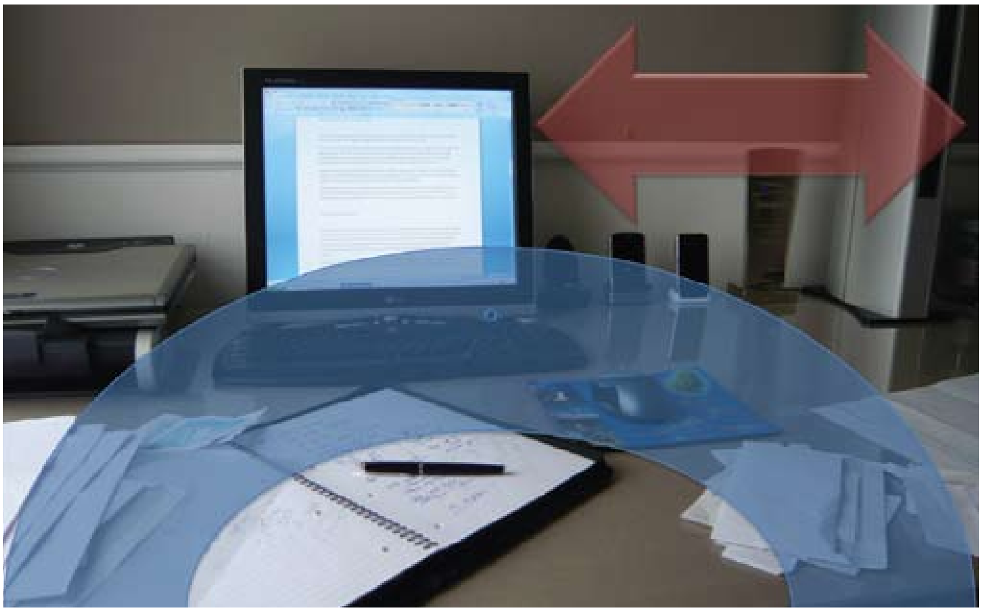

Figure 2 Blue, eye movements, red, head movements

along the page. My head would be entirely still during this time.

However, if I was typing from handwritten notes, with the text to the side of the screen or on the desk, I was a very apparent head mover, as displayed in Figure 2 by the red arrow. In my particular instance I could not determine whether I was a head mover or eye mover as it was less of a habitual usage rather than occupational and dependant on the method and characteristics of the optical correction I was using at the time.

An alternative design direction that a modern PPL design has adopted to determine the patients' requirements is to involve them in an active discussion regarding their visual and lifestyle requirements covering a broad range of activities and requirements and then using this information to influence the final individual lens design. Again, in order to aid this process the lens manufacturer supplies equipment and software (Figure 3).

Ethnic variations of freeform PPLs

Recently two major lens manufacturers have released versions of their freeform PPLs optimised for specific ethnic groups; specifically the Indian and Asian markets. These areas could be considered as the non-traditional markets for these particular manufacturers. The lenses are said to take into account the specific characteristics, anatomy and wearing conditions of the patient. The reasons and fitting conditions for one of the manufacturer's Asian optimised lens are as follows:

- The eye length is generally longer compared to the other population groups at 22-28mm
- A less pronounced face profile and nose bridge. Front face form angle 0°, pantoscopic tilt 6°
- Average pupil distance 63mm
- Average back vertex distance 12mm
- A higher degree of convergence
- A closer near working distance 373mm.

The same manufacturer in its Indian optimised freeform PPL accounts for the unique facial characteristics of the Indian features, the shorter eye length and different reading distance. No values for these fitting conditions could be determined during research.

Clinical study is required to determine the effectiveness and performance of these ethnically optimised freeform PPLs. The existence of the category of optimisation raises the question that does the normal, or global version of these PPLs offer reduced performance to a practice with a multicultural patient base?

Wavefront technology

Wavefront technology has been incorporated into freeform PPL design by several manufacturers. This technology has been adapted from successful utilisation in other industries, most notably laser refractive surgery and astronomical telescopes.

Looking into the night sky, the stars appear to twinkle. This is because of turbulence in the earth's atmosphere. Light from distant stars passes through various layers in the earth's atmosphere, and is refracted depending on the temperature and density of the air at that point. The light passes through one layer, refracted at one angle, then passes through another different layer and is refracted at a different angle. When you see a twinkling star, you are seeing the accumulated refractions from many different layers, which change the position and size of the star, many times a second.

This is why observatories are built at the top of mountains, where there is less atmosphere in between the telescope and the vacuum of space. During the 1960s astronomers developed methods to compensate for this thermal and atmospheric turbulence. A computer controlled deformable mirror compensates for wavefront deviations and measurements recorded using a wavefront sensor. This technology is known as adaptive optics.

The human eye is an imperfect optical system; light passing through the various optical media is also subjected to turbulence. The corrupted retinal images and the specific pattern of aberration are individual to every eye. These aberrations can be measured using a wavefront sensor, an aberrometer and classified using Zernike polynomials (Figure 4).

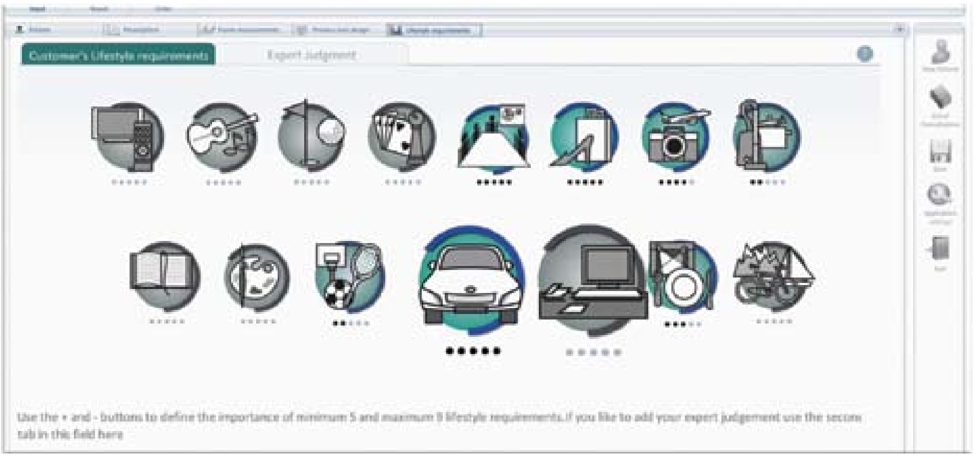

Figure 3 Manufacturer software

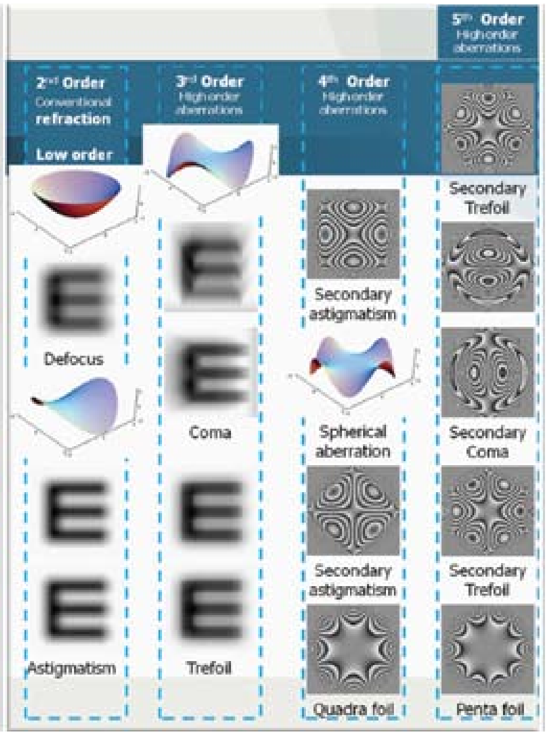

Figure 4 Zernike polynomials

During a normal refraction and correction, second-order Zernike polynomials: defocus and astigmatism, are corrected. These are classified as low-order aberrations, along with the 0th-order aberration: piston and the first-order aberration: tilt.

High-order aberrations include: coma, trefoil, spherical aberration and secondary astigmatism, anything above third-order aberrations.

There is confusion surrounding the application of this wavefront measurement technology to spectacle lenses. It is most important to determine whether the lens claims to reduce the high-order aberrations of the eye or from the progressive surface.

Some of the modern freeform design PPLs which utilise this technology lay claim to coma and higher-order aberration control. It is important to make the distinction between control and elimination. High-order aberrations cannot be eliminated, just in the same way you cannot eliminate unwanted surface astigmatism. Most modern PPL designs, whether they are freeform manufactured or conventionally produced, employ some level of higher-order aberration control as an integral part of the lens design to aid binocular function and reduce surface astigmatism. Even though the higher-order aberrations can be reduced, this will not improve the visual acuities of the wearer above the best corrected visual acuity – supernormal performance cannot be achieved through spectacle lenses.

PPLs produce a 'coma-like' aberration; different to the coma produced by the eye; this is due to the non-symmetrical change or variation in power and magnification across the progressive surface. This can be significant in specific regions of the lens, and with particular lens types. The effect will be more apparent in the areas where the surface astigmatism and power is changing the most and with short corridor PPLs and with higher additions. The optical aberration results from a variation in refractive power that causes the focus image point to spread or smear in one direction; similar to a comet's tail, instead of producing a sharp focus.

One manufacturer has a limited commercial release of producing a lens which corrects for the aberrations of the eye using a proprietary three-stage measurement and manufacture process. The patient is measured using their unique wavefront aberrometer, the measurement is then converted to a prescription using the manufacturer's patented algorithms and process control. The prescription information is then transferred to an epoxy polymer using an ultraviolet laser. This epoxy polymer is then sandwiched between two 1.6 refractive index cover plates and again a UV laser is used to cure the epoxy polymer to the cover plates seamlessly and to alter the refractive index of the polymer on a point by point basis, similar to programming a DVD to achieve the required refractive contour.

There is a significant drawback to this technology; this design can only correct high-order aberrations in one direction of vision and can only correct in a circle diameter of about 4-5mm from that vision direction. The lens essentially displays a restrictive 'straight-ahead' area of best vision. Also fully correcting high-order aberrations requires exact fitting parameters such as back vertex distance and pantoscopic tilt to be maintained, this is not easily done in real life usage conditions.

PPLs have always, and will continue to evolve, alongside technological advancements in computing technology to process more complex algorithms, advancements in understanding of the neurology and physiology of the visual pathway, the better understanding of the nature and theory of light and the expertise and development of surface generation with the latest computer numerically-controlled cutting machines. Freeform is the medium which lens manufacturers can realise designs and levels of performance and individualisation which were impossible with conventional manufacture.

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MULTIPLE-CHOICE QUESTIONS – take part at opticianonline.net

1 Which of the following is the average PD of Asian eyes?
A 60mm
B 61mm
C 63mm
D 64mm

2 What is the average near working distance of the Asian patient?
A 25cm
B 30cm
C 37.3cm
D 45.3cm

3 What is considered the average Asian face pantoscopic tilt?
A 0 degrees
B 2 degrees
C 4 degrees
D 6 degrees

4 Refraction during the eye examination measures which Zernike polynomials?
A First-order
B Second-order
C Third-order
D Higher-order

5 Of which order is tilt aberration?
A First
B Second
C Third
D Higher

6 Which of the following statements is not true?
A PPLs produce 'coma-like' aberration
B Higher-order aberrations are eliminated by careful design
C Secondary astigmatism is a higher-order aberration
D Supernormal acuity cannot be achieved by spectacle lens design

Successful participation in this module counts as one credit towards the GOC CET scheme administered by Vantage and one towards the Association of Optometrists Ireland's scheme.
The deadline for responses is October 7 2010