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

Freeform lenses

Part 1

In the first of a three-part series looking at freeform lenses, Paul Bullock describes the evolution of progressive power lenses as a backdrop to the introduction of freeform. Module C14211, one general CET point for optometrists and dispensing opticians

There is no better example of the lack of awareness on the part of the public about modern progressive lens options than an event which occurred only a few weeks ago.

My wife and I were in Budapest celebrating our seventh wedding anniversary. We took an open-top bus tour around this beautiful city; however, my attention was not on the architectural and natural wonders surrounding me, rather than on a fellow passenger and his curious spectacle arrangement. I was determined to take a picture of this gentleman which I am delighted to share with you (Figure 1).

From my subsequent discussions with him, his spectacle apparatus is thus:

- Pair 1 – single-vision distance, CR39, clear, uncoated
- Pair 2 – plano aviator style sunglasses, Glass, B15 tinted
- Pair 3 – single-vision near, CR39, clear, uncoated.

I explained that there were options to aid his visual experience and to improve his cosmetics and comfort. I demonstrated this by showing him the pair I was wearing at the time with the following specifications; -5.00DS, prism compensated, high index, high base, concave HMAR, flash mirror, polarising sunglasses.

Even though there was a significant language barrier the advice was warmly received and we may have another convert to progressive power lenses.

I am still surprised by the number of presbyopes who could benefit from the modern day technological marvels that are today's progressive power lenses (PPLs). They either decline to wear them, preferring to wear various optical apparatus with sometimes reduced success, or have not been offered the best fit solution to suit their lifestyle and visual requirements. I pondered this particular gentleman's plight as I researched this series. He, like most of our patients, would be surprised by the development, advancements and complexities of PPLs throughout history.

Figure 1 A novel approach to multi-focals

The progressive addition lens (PAL) concept

The ideal spectacle lens for presbyopia would be completely distortion free while providing a continuous progression in power for clear vision from distance to near, with wide fields of view for all distances. This has been the goal of the PAL designer since its inception.

Current PALs provide the wearer with zones for distance and near vision that are wide, free of distortions and stable in power. These areas are joined by a corridor of increasing plus power. This corridor of transitional power is generated by a gradual increase in the curvature of the lens surface.

A typical design PAL progressive surface can be represented by a series of conic sections stacked on one another. By joining these sections with their apices coinciding, an astigmatism-free corridor of increasing plus power is achieved.

This use of non-circular, aspheric cross sections, the conic sections, reduces the surface astigmatism in the lens periphery without compromising width of the viewing field.

From the distance to near zones, the conic sections vary from ellipses, to circles, to parabolas, to hyperbolas. Where these sections coincide, the resultant surface is free of astigmatism. Where the conic sections do not coincide, the front surface displays astigmatism.

The intensity and orientation of the astigmatism varies with the PAL design and the corridor length.

These concepts which we all take for granted today have taken much expertise, innovation and development since Benjamin Franklin first designed the bifocal lens in 1784.

Early PPL design

The optical principles of PPLs have long been understood. The earliest progressive lens patent was granted to British optometrist Owen Aves in 1907, co-founder of what is now known as the Institute of Optometry. The lens Aves designed used two aspheric cylindrical surfaces.

On one surface there was a section of an elliptic cylinder and the other a section of an inverted cone. Each surface contributed an equal cylindrical effect with the axes mutually perpendicular to produce a sphere of power from top to bottom. This was in essence a dual-surface progressive design; unfortunately the lens structure made it unable to correct for astigmatic prescriptions and Aves' design never went into production and instead was limited only to prototypes.

In the following years, many other PPL lens designs followed, including ones which used a parabolic concave back surface with an increasing radius of curvature from the geometric lens centre, decreasing the back surface power and increasing the total lens power. This lens orientation resulted in the central portion for distance vision with the periphery for near.

In 1914 Henry Orford Gowlland invented one of the first commercially available PPLs with the familiar umbilic design structure we recognise as a PPL today. The design was a single surface progressive using a section of a paraboloid on the rear surface. This designwasproducedcommercially,but without success. Limitations with the machining of the necessary surfaces, theopticallypoorperformanceofthese designsandtheresultingunacceptable aberrations are attributed to the classification of these early PPLs as a failure.

First-generation PPLs

In 1959 the first commercially successful lens was introduced by Essel, one of the founding members of Essilor. The progressive design, named Varilux 1, gave a large spherical distance and near zone linked along the main meridian, or umbilical line with orthogonal circular sections of decreasing radii. This design structure resulted in strong surface astigmatism in the periphery and to the nasal and temporal sides of the umbilical. The Varilux 1 was a symmetrical design with no inset. The lens could be used for either the right or left eye; the lens would be twisted nasally into the frame to create the inset required for the reading zone.

The design had no power variation in the upper half of the lens, a relatively short corridor, and a near zone of constant power approximately 22mm in width.

In the next few years several other manufacturers developed and released first-generation PPLs including Silor Super No Line and American Optical AO7.

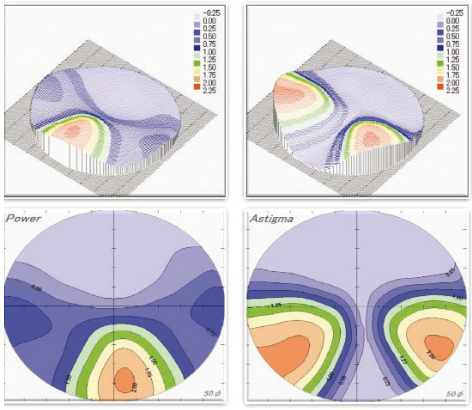

Figure 2 'Hard design PPL'

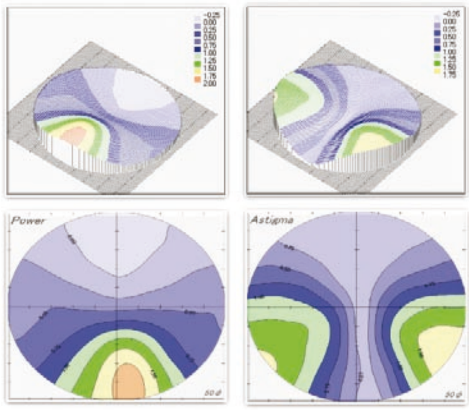

Figure 3 'Soft' design PPL

Second-generation PPLs

The development of commercially viable and successful PPLs represented a technological breakthrough in surface generation; the ability to control the angle of contact to produce the necessary surfaces was heralded by some as more of an innovation than the product produced.

With this new technology the lens designers had the ability to manufacture more complex designs to enhance the design performance.

First-generation designs had strong surface astigmatism; the next step in PPL development was to reduce this and to produce a softer design. Mathematic surface modelling was used to research ways to reduce this; however, the limitation was still in the capabilities of the manufacturing technology rather than the imagination and expertise of the lens designers.

The Varilux 2 design was introduced in 1972 with a change of design structure from orthogonal circular sections of decreasing radii to evolutive conic sections of changing eccentricities. This new design, termed 'horizontal optical moderation', coupled with an asymmetrical design with separate lenses for right and left eyes with inset near zones, produced a design optimised for binocular vision.

The Varilux 2 design possessed an aspheric progressive surface. The result of this was a reduction in the intensity of the surface astigmatism. Many similar designs were subsequently released using similar concepts, including: Silor New Super No Line, Rodenstock Progressiv R and Sola Graduate.

As more manufacturers entered the PPL market, great care was taken to differentiate their designs from their competitors. This was done by designing the lens around optimum performance for certain criteria. Some designs were focused around reducing the severity of the surface astigmatism by spreading it wider over the surface of the lens. Some designs purposely increased the strength of the surface astigmatism, thereby increasing the size of the distance and near zones.

Rodenstock in its Multigressiv design added an aspheric flatter base curve to its already aspheric progressive surface. This yielded better visual performance for higher astigmatic lenses.

Carl Zeiss in its Gradal HS design focused on binocular vision utilising

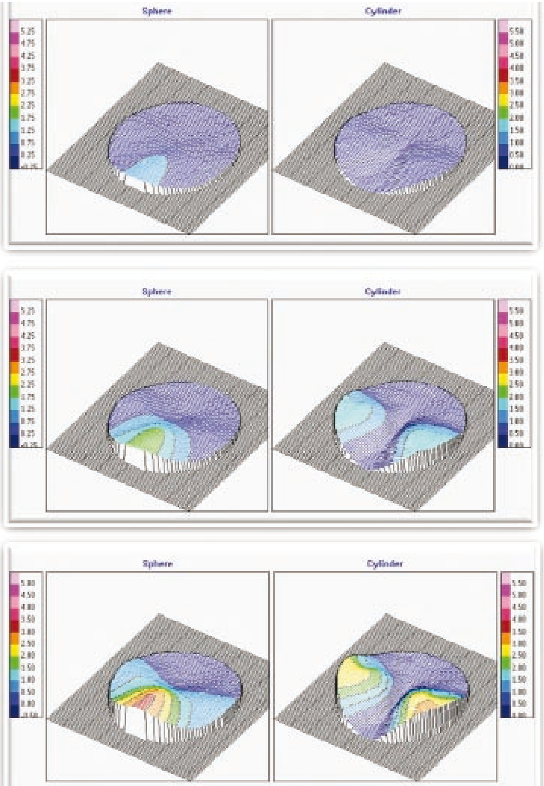

Figure 4 A multi-design PPL, changing from soft to hard design with increasing add

an asymmetrical design equalising acuities and prismatic effect across the horizontal zone.

Third-generation PPLs

This new generation, circa 1980, introduced the multi-design PPL. First-generation PPLs displayed strong surface astigmatism, now classified hard design PPLs (Figure 2). Second-generation PPLs displayed weaker surface astigmatism, now classified softer-design PPLs (Figure 3). Both these generations utilised the same basic lens design across all base curves and addition powers; this design is known as a mono-design.

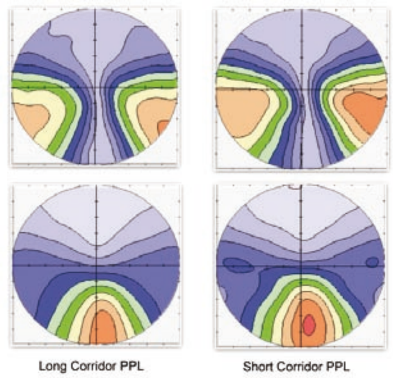

Figure 5 Shorter corridor PPLs were introduced in 1999

A multi-design PPL adjusts the lens design for each addition power. The design for an early presbyope would be a soft which became harder as the addition power increased. The multi-design PPL was aimed at vision comfort and ease of adaptation for each stage of presbyopia (Figure 4).

Several lenses of this era with this design profile include: American Optical M3, BBGR Selective and Hoya Hoyalux GP.

Further progressive power generations

Further generations of PPLs have been made possible due to significant advancements in lens design and surface manufacture. Advanced computer-numerically controlled cutting of the ceramic moulds used for forming the glass moulds for semi-finished PPLs has reduced manufacturing limitations

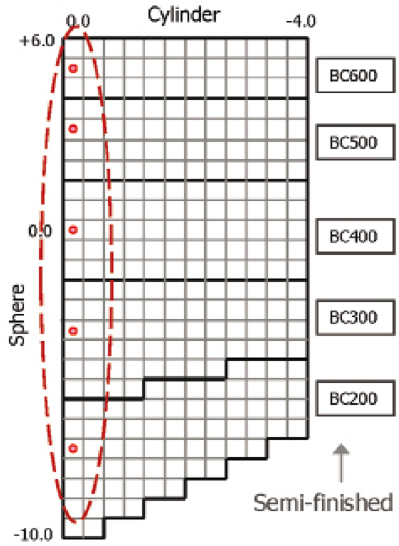

Figure 6 Conventional PPLs are only optimised for one target Rx per base curve

and mathematic surface modelling has become much more complex and efficient due to advancements in computer technology.

Fourth-generation PPLs, such as Varilux Comfort and Hoyalux Wide, were designed to offer more natural vision than previous generations. The design profile was thus that the wearer could obtain the near power in a fast, effective way while adopting a natural head posture.

Fifth-generation PPLs, such as Hoyalux Summit Pro, changed the orientation of the asphericity of the lens, matching the transmitted vertical and horizontal powers in a transmission-based design. Other key design characteristics include an ergonomic inset and horizontal asymmetric design. Other fifth-generation PPLs include the Varilux Panamic.

In 1999 American Optical released the first short-corridor PPL, the AO Compact in response to market demands. Eye sizes were becoming smaller throughout the 1990s and PPLs were not suitable for the shallow frames becoming fashionable at this time.

The near zone was positioned higher and the umbilical shortened, leading to a harder design profile. The wearer experienced a faster transition from distance to near and reduced intermediate field of view. The fitting height was reduced by 4mm compared to PPLs of the same era, more than adequate for the frame requirements (Figure 5).

Conventional design PPLs

Up to this point, all generations of PPLs could be classified as conventionally designed and manufactured. Conventional PPLs are privy to two major limitations, base curve restrictions and universal standard measurements.

Optional PPLs are produced from semi-finished blanks with a moulded progressive front surface and base curve. Each base curve is used for a range of powers but the design is only optimised for one target power per base curve, usually a simple spherical prescription. The design when a strong cylindrical power is required performs very differently to the optimised target power (Figure 6).

Due to the semi-finished nature of conventional PPLs with a moulded progressive surface, the progressive design was based upon assumptions regarding the target wearer. These universal standard measurements being:

- Pupillary distance of 63mm
- Back vertex distance of 15mm
- Pantoscopic tilt of 8°
- Front face form angle of 4°.

Any patient's Rx that lies outside of the optimised target power or frame and facial measurements that are outside of the universal standard measurements experiences a PPL considered as an acceptable compromise.

The ideal PPL would incorporate frame and facial measurements unique to the patient as well as lifestyle and method of use. The design would be calculated for every individual prescription rather than optimised for one target power per base curve, resulting in a personal design.

These new types of lenses will be discussed in the next article in this series, as will the improvements in the tools to design, manufacture and compute the complex surfaces required for the new generations of progressive power lenses, including the introduction of numerically controlled cutting and polishing machinery. The changing visual requirements of the presbyope will also be discussed.

• Paul Bullock is professional services manger at Hoya Lens UK

MULTIPLE-CHOICE QUESTIONS – take part at opticianonline.net

1 Which of the following is not a second-generation PPL?
A Sola Graduate
B Rodenstock Progressiv R
C Silor New Super No Line
D American Optical AO7

2 The Varilux I used a near zone of constant power of what approximate width?
A 18mm
B 20mm
C 22mm
D 24mm

3 Which of the following is not a third-generation PPL?
A Zeiss Gradal HS
B BBGR Selective
C Hoya Hoyalux GP
D AO M3

4 Which of the following best describes the Varilux Comfort?
A Second-generation PPL
B Third-generation PPL
C Fourth-generation PPL
D Fifth-generation PPL

5 Which of the following best describes the Hoyalux Summit Pro?
A Second-generation PPL
B Third-generation PPL
C Fourth-generation PPL
D Fifth-generation PPL

6 What front face form angle is suggested as a universal standard measurement?
A 2 degrees
B 4 degrees
C 6 degrees
D 8 degrees

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 August 5 2010