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Prescribing Multifocal Lenses

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INTRODUCTION

Multifocal spectacle lenses are primarily used in the treatment of presbyopia. Secondary usages include treatment of esophoria and pre-presbyopic accommodative dysfunctions such as reduced accommodative amplitude or accommodative infacility.

Until the early 1980s almost all multifocals were segmented bifocal and trifocal lenses. Since that time there has been steady growth in usage of progressive addition lenses (PALs) and approximately 50% of multifocals currently dispensed in the United States are of progressive design.

There are significant optical differences between and within the segmented and progressive multifocal lenses that affect the vision that is provided to the patient. The primary objectives of this chapter are to present and discuss those optical differences as they apply to meeting the viewing needs of individual patients and to the fitting, adjustment and adaptation to the lenses.

HISTORY

Benjamin Franklin is commonly credited with inventing bifocals in 1784. He simply cut his round distance and near lenses in half and bound them together in a frame to create a bifocal. Although it appears Franklin invented bifocals independently, S. Pierce (1760) and A. Smith (1783) also apparently independently invented them.[1] As might be expected, the two-piece lenses had poor structural integrity in the frame and debris accumulated at their junction. Schnaitmann (1837) produced and patented the first one-piece bifocal by grinding the top of a reading lens to produce the distance power in the upper portion of the lens. An unfortunate consequence, however, was poor optics resulting from a large amount of base-down prism in the top portion of the lens.

B.M. Hanna (1884) developed and patented the cemented bifocal, which consisted of a thin round reading lens cemented to the back surface of a distance lens with Canadian balsam. This lens had better optics than previous designs but still had the difficulties associated with two-piece lenses. Hanna (1886) also introduced the Perfection Grooved Bifocal, which was an improved two-piece lens similar to the Franklin bifocal. It had a half moon curved reading portion and also a bevel/groove interface between the two lenses that improved stability.

The modern multifocal era began with introduction of Kryptok, the first fused bifocal. It was invented in 1908 by John L. Borsch, a Philadelphia ophthalmologist and was a 22-mm round bifocal segment. The bifocal segment was made of flint glass (index 1.654, Abbe value 35) fused with heat (more than 1000°F) into a distance lens fabricated of crown glass (index 1.523). The Kryptok became a popular bifocal because it did not suffer from the instability of the cemented type, the segment was less conspicuous, and it eventually became the least expensive to produce. A one-piece bifocal (Ultex) was constructed in 1910 by Connor, an Indianapolis optician. This design involved grinding a round bifocal segment onto the distance portion of a single piece of glass. The result was a lens having a construction similar to that of the cemented bifocal but without any of the previously mentioned disadvantages. In 1915, the flat-top bifocal of fused construction was patented by Courmettes, a French citizen and resident of New York City. This was one of the segment styles introduced and manufactured by Univis Lens Company of Dayton, Ohio, in 1926. These newer fused bifocals used a barium glass for the segment (index 1.632, Abbe value 56) primarily because it has a better Abbe value and hence lower chromatic aberration compared to flint glass. The one-piece Franklin-style bifocal was introduced by American Optical Company in the early 1950s under the trade name Executive. This lens is based on the same principle as the first bifocal invented by Benjamin Franklin, with the optical centers of the distance and near portions placed adjacent to each other. Trifocals were introduced in 1826 by Hawkins of London. The first trifocal patents were taken out by Aves in England in 1907 and by Boness in America in 1911.

Throughout the history of multifocal lens development there has been an effort to devise a lens with an invisible segment. As early as 1916, Stead Optical Company made and patented a one-piece bifocal in which the boundary between the distance and near portions was rounded or blended. The most common method to accomplish this is with a progressive addition lens in which the power changes gradually from distance to near. The first PAL design was patented by Owen Aves in 1907. However, few advances occurred until 1951 when the Varilux 1 was developed by Maitenaz in France.[2] It was not until 1962 that Omnifocal became the first PAL available in the United States. The Varilux 1 lens was introduced in the United States in 1965, followed by the Varilux 2 in 1973. Since that time numerous PALs have been introduced to market.

SELECTING THE MULTIFOCAL FOR THE PATIENT

The many optical differences between the various multifocal designs create different visual environments for the patient. The differences between categories (bifocals versus PALs) and within categories are large and can significantly affect patient performance, comfort and acceptance. The patient's occupational and recreational pursuits should be identified and analyzed to determine unique viewing distances or viewing angles. Previous experience with multifocal lenses is instrumental in determining the new correction. Satisfaction with the current multifocal design nearly always predicts repeat success, however, it does not necessarily mean that the patient's vision cannot be improved with a different design. Many patients who currently wear bifocals appreciate the better vision and cosmetics of a PAL, or a patient successfully wearing one PAL design can often appreciate a different PAL design that suits their visual needs better.

DETERMINING THE ADD

Nearly all current multifocal lenses are constructed with the multifocal optics on the front surface of the lens. The curvature of the back surface is fabricated to provide the distance prescription of the patient. The power of the multifocal lens is "in addition" to the distance refractive power required for the patient and is specified in the optical prescription as the amount of plus power in the "add."

Most clinicians perform routine near-vision testing and determine the power of the add at a near-viewing distance of 40 cm or 16 inches. Each clinician establishes for him/herself a successful method for determining the appropriate add for the patient.

The most common methods of determining the 40 cm add are:

1. Remaining amplitude of accommodation. The basic tenet of this approach is that a patient can comfortably use only Y percentage (usually assumed to be 50%) of their remaining amplitude of accommodation (AA). The formula for this is:

   $$\text{Add} = 1/\text{viewing distance (M)} - Y \times AA$$

   For example, a patient has remaining accommodation of +1.50, a viewing distance of 40 cm, and assume the patient can use 50% of remaining accommodation. The calculation is $1/.4 - 0.5 \times 1.5 = +1.75$ D add.
2. Midpoint of the plus range. This procedure involves placing a target at the specified test distance (usually 40 cm) and determining the most and least amounts of plus that enable clear vision. The add amount is prescribed as the midpoint.
3. Binocular cross cylinder test. Patient views horizontal/vertical grid lines with cross cylinders placed with minus axis at 90 degrees. The add is the minimum amount of plus required to equalize appearance of the vertical and horizontal lines.
4. Trial lenses in free space. Measure the range of clear vision with trial lenses in free space. This method has advantage that it shows the patient what they will see with the prescription.

Any of the above methods can be used to determine the add power for 40 cm or other viewing distance. The viewing distance is incorporated into the equation for the first method, and the other methods can be used with the target placed at the particular distance required by the patient. The fourth method (i.e., placing an object at the viewing distance and determining the add power that provides the best range of clear vision), can be particularly successful for unique viewing distances.

BIFOCALS

As the name implies, bifocals provide two power zones. The primary lens contains the distance power and the add segment contains the near power. All bifocals provide a large distance viewing zone with homogenous power and most also provide a large near-viewing zone with homogenous power. However, the two viewing zones have a sharp demarcation. Cosmetically the line of demarcation is quite noticeable and can be particularly disturbing to patients who are sensitive to showing their age. Visually the line of demarcation represents a largely unusable portion of the lens. If the eye rotates so that the line of sight is near the line, then the pupil receives light from both viewing zones. This results in diplopia because of the prismatic effects of the segment and each image results from a different refractive power. The optical center of the add is not at the line (except in a Franklin-type segment, Fig. 1D), hence there is a base-down prismatic effect caused by the add at the top

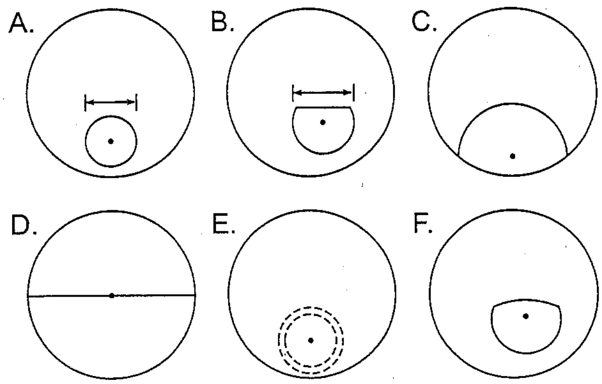

Fig. 1. Commonly used bifocal types. **A.** Round segment, available in diameters of 15, 22, 25, 28 and 35 mm. **B.** Flat top, available in diameters of 22, 25, 28, 35, and 45 mm. **C.** Ultex type, available in diameters of 38 and 40 mm. **D.** Executive bifocal. **E.** Round blended, diameter of 22, 25 and 28 mm. **F.** Curve top, available in diameters of 25 and 28 mm. For each bifocal type the dot designates the location of the optical center of the add. For all types (except D) the location of the optical center is at the center of the segment circle.

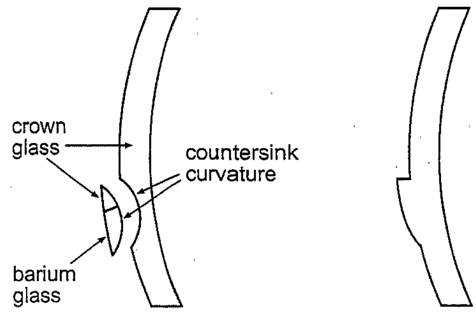

Fig. 2. On the left is fused flat-top bifocal. Fused bifocals are made only with glass material. On the right is a one-piece flat-top bifocal. All nonglass bifocals are one-piece.

of the segment. This prismatic effect is called image jump. The magnitude of the image jump (in prism diopters) is calculated by multiplying the power of the add (in diopters) by the distance from the top of the segment to the optical center of the add (in centimeters). The locations of the optical centers of the adds are indicated by the dots in Figure 1A to 1F and discussed further below. The magnitude of the image jump usually ranges from 0.5 to 4 prism diopters. Because of the double images and conflicting focus near the top of the segment, bifocal wearers habitually avoid fixating near the line and use saccadic eye movements to alternate between the distance and near viewing zones. Bifocal wearers experience a large zone of unusable visual space immediately below the primary gaze position, this is the primary visual compromise of bifocal lenses.

The shapes of the bifocal segments in the market today are essentially the same as those reviewed above from a historical perspective. All bifocals were initially developed in glass, today glass has a small market presence and most bifocals are made from plastic, polycarbonate, trivex or other resin materials.

By far the most commonly prescribed bifocal is the flat-top (FT) or D segment, directly derived from the Univis ''D'' segment developed in 1926. (There were also segment shapes designated ''A–C'' that were not as successful.) In glass products, then as today, the segment is formed by fusing a segment of barium glass (index of 1.623) to a crown glass (index 1.523) carrier lens as shown in Figure 2. The countersink curvature is calculated to provide the intended add amount and to enable the front curvature of the segment to match the curvature of the carrier lens. This results in a smooth front surface and the bifocal junction is indistinguishable by touch. Note in Figure 2 that the countersink is actually circular and the flat top is created by making the top part of the segment out of crown glass which seamlessly blends with the carrier lens. All nonglass bifocals are of one-piece construction, meaning that the entire lens is made from the same material and that the power difference between the distance and near portions is created with changes in curvature. The segment is formed (molded) as part of the lens and the power addition is created with a different curvature (Fig. 2). Because the surface has a discontinuity it is readily identified by touch, this is, the top of the bifocal segment forms a small ledge.

Available bifocal types are shown in Figure 1. The round segment (Figure 1A) has evolved from the Kryptok bifocal and classically has a diameter of 22 mm although other diameters are available. A chief advantage of round segments is that they are the least noticeable cosmetically, especially if a light tint (such as pink) is used. Disadvantages of the round segment are that image jump is fairly large because the distance from the top of the segment to the optical center of the segment is fairly large (i.e., half of the segment diameter). Also, because the top of the segment is curved, the top portion of the segment provides little width of near vision and is not very useful. This effectively enlarges the zone of unusable vision at the top of the segment. The 15 mm round segment is useful for patients engaged in activities such as golf or outdoor labor where a segment is considered bothersome yet the patient still requires some near vision. One successful solution for golfers is to use a monocular 15-mm round segment located superiorly or temporally on the same eye as the handedness of the golfer. Glasses with 15 mm round segments are usually for special usage and the patient will require a separate pair for other daily activities.

FT bifocal segments (Fig. 1B), sometimes still referred to as "D"-type segments, lessen the problems of the round segment at the top of the segment. By eliminating the top of the circle, useful near-field width is attained immediately below the top of the segment line. Also, because the optical center of the segment for FT bifocals is 5 mm below the top line, the magnitude of the image jump is less than for round segments. FT bifocals have become the standard bifocal because of visual advantages, even though they are more noticeable cosmetically than round segments. FT28 is the most common width, however, other widths can be used dependent upon the visual needs of the patient.

The Ultex-type bifocal (Fig. 1C) is characterized by very large amounts of image jump (the optical center is 19 to 20 mm below the segment top) and by limited distance zone in the lower portions of the lens. Because of these characteristics, the lens is not well-suited for general use. However, it is a very good lens for hyperopic patients who perform considerable near work such as at a desk. This is because the hyperopic patient obtains base-up prism with depressed gaze, hence requiring excessive depressed gaze to view typical near materials. Base-down prism from the Ultex bifocal counteracts the prism from the plus distance lens and reduces the amount of required gaze depression for near materials. The Ultex bifocal should be considered for this specialty use, but the large amount of image jump at the segment top and the minimal distance zone in the lower lens are detriments to prescribing the lens for general use.

The Executive bifocal (Fig. 1D), sometimes still referred to as a Franklin bifocal, has the advantages of an extremely wide near-viewing zone and no image jump at the top of the segment because the optical center of the add is on the segment line. Despite these advantages, the lens is limited in scope because of the lack of any distance zone in the lower portions of the lens. This is very bothersome for ambulation and general daily wear. The lens is best suited to meet extensive near-viewing needs such as at a desk. However, many practitioners prefer to use a FT35 or FT45 instead for these purposes.

The blended bifocal (Fig. 1E) is a variant of the round bifocal. The boundary between the distance and near zones is blended to produce an apparent seamless lens. Cosmetic appearance is the sole reason to use this lens because the blend area (2 to 3 mm wide) increases the area of unusable vision and decreases the diameter of the usable near vision zone. The curve top bifocal (Fig. 1F) is intermediary to the round and FT bifocals and also possesses intermediary properties. Although it can be a successful general usage lens, it has not enjoyed broad usage probably because of the larger visual advantages of FT bifocals.

PATIENT ADAPTATION

First-time bifocal wearers will go through an adaptation period. Some of the most common problems involve the altered location of objects through the bifocal segment, creating problems with stairs, curbs, and similar situations. First-time wearers should be counseled about these initial problems.

FITTING BIFOCAL LENSES

For good visual performance, it is important that the bifocal lenses be properly placed within the frame and the frame properly fitted to the face. Before making measurements of lens location, the frame should be selected and fitted to the patient's face and incorporating the appropriate pantoscopic tilt. Eyeglass frames with nose pad arms are preferred because they allow postfitting adjustment of the bifocal height.

SEGMENT HEIGHT

The segment height is specified as the vertical distance from the top edge of the segment to the level of the lowest portion of the lens. The person making the measurement should be located directly in front of the patient and at the same eye level. For most patients the best location of the top of the segment is approximately 1 mm below the lower limbal margin. Round segments should be fitted approximately 1 mm higher than FT segments. Consideration should be given to the location of the previous bifocals (if the patient has previously worn them) and the patient visual needs and preferences. Observe the segment height location in the current bifocals: if the location seems reasonable and the patient is satisfied then duplicate the location in the new spectacles.

Sometimes the current bifocal height is considerably lower or higher (less commonly) than ideal, yet the patient expresses no complaint. Observe patient behavior with the current bifocals to determine if awkward posture is required to use the segment and/or probe with questioning. Change the height only with caution, but do so (probably only partially) if it will result in better vision and patient satisfaction. The patient's particular viewing requirements should also be considered in determining the height of the bifocal. For patients with minimal near-viewing requirements the height should be lowered whereas patients with extensive near-viewing requirements should be fitted higher, perhaps even to the lower pupillary border. In nearly all cases, however, it is safer to err on the low side. Patient dissatisfaction occurs more readily with a segment that is placed too high.

SEGMENT INSET: THE NEAR INTERPUPILLARY DISTANCE

The major reference point (MRP) of the lens is the location that contains the prescribed refractive and prism correction; the MRP is the same as the optical center if there is no prescribed prism. The MRPs of the distance portions of the lenses should be separated in the frame by the same amount as the patient's inter-pupillary distance (PD). However, the bifocal segments should be separated by the same amount as the patient's near PD. The monocular difference between the distance and near PDs is the segment inset, or the horizontal amount by which the center of each segment is nasally displaced with respect to the MRP.

Major influences on the segment inset include the distance PD (Table 1) and the near-viewing distance that is largely driven by the amount of the add (Table 2). However, other influences include the fitting vertex distance (back lens surface to corneal apex) and the power of the distance lens because of the base-in and base-out effects of converging through minus and plus lenses, respectively. In order to determine the segment inset it is best to measure the near PD with the patient viewing the examiner's eye at the intended near-viewing distance and with the intended total lens power and vertex distance.

TRIFOCALS

As presbyopia advances, a bifocal-wearing patient is no longer able to see clearly at intermediate viewing distances. In early presbyopia, the patient can clearly see at intermediate distances either by using their remaining accommodation and viewing through the distance portion of the lens, or by viewing through the near portion of the lens because the add power is low. With advanced presbyopia the nearest point of clarity through the distance portion of the lens recedes because of the reduced amplitude of accommodation, and the farthest point of clarity through the bifocal comes closer because of the increasing add power. This results in loss of intermediate clarity.

The loss of intermediate clarity with a bifocal typically occurs with a near add of + 1.50 or greater. Intermediate viewing distances are important for shopping, general work around the home, computer work, viewing automobile instrument panels, card playing, playing musical instruments, etc. Trifocals are useful for many occupations. Many bifocal-wearing patients transparently adapt to this problem by adjusting their viewing distance to the object of regard or simply tolerating the problems. However, even if the patient is not aware of the clarity problem at intermediate distances, that does not mean they would not want a solution. Regardless patient awareness, consultation is indicated. One solution is to prescribe a PAL. Bifocal wearers can successfully change to a PAL. In the absence of desire to try a PAL, however, a trifocal lens is the appropriate solution.

Trifocal designs are variants of bifocal designs, three of which are shown in Figure 3A to 3C. If a patient has successfully adapted to a particular type of bifocal then the trifocal variant of that same design will likely be most successful. FT trifocals are the most commonly prescribed (Fig. 3A). The width of the segment can be chosen to match the current bifocal, or adjusted in size if necessary based on patient needs. The vertical dimension, or depth of the intermediate segment, is most commonly 7 mm. Larger depths are available and can be used for patients with extensive intermediate viewing needs such as at a computer. Similarly, there are executive trifocals (Fig. 3B), combination executive/FT trifocal (Fig. 3C), and round, curve-top, and Ultex trifocals (not shown). The features and benefits of the trifocal types mirror those of the bifocals as discussed above.

TABLE 1. Monocular segment inset as function of distance PD

Distance PD	Monocular inset
72	2.4
70	2.4
68	2.3
66	2.2
64	2.2
62	2.1
60	2.0
58	2.0
56	1.9
54	1.8
52	1.8
50	1.7

Assumptions: No distance power, vertex distance 14 mm, 40 cm viewing distance.
PD, prism diopter.

TABLE 2. Monocular segment inset as function of viewing distance.

Near add (D)	Viewing distance	Monocular inset
2.50	40.0	2.2
3.00	33.3	2.6
3.50	28.6	2.9
4.00	25.0	3.3
4.50	22.2	3.7
5.00	20.0	4.1
5.50	18.2	4.4
6.00	16.7	4.7
6.50	15.4	5.1
7.00	14.3	5.4
7.50	13.3	5.7
8.00	12.5	6.0

Assumptions: No distance power, vertex distance 14 mm.

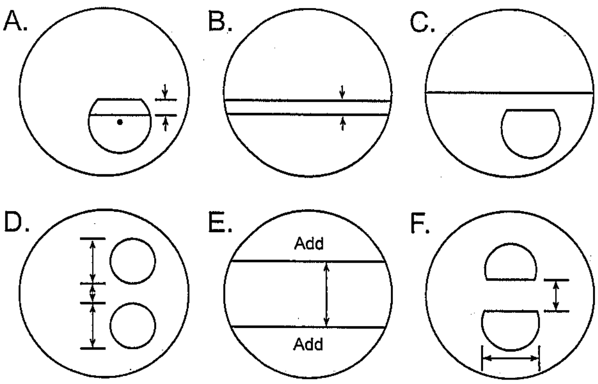

Fig. 3. **A.** Flat-top (FT) trifocal, specified by vertical dimenshon of the intermediate/largest horizontal dimension. Available as 7/25, 7/28, 7/35, 8/35, 9/35, 10/35. **B.** An executive trifocal, available with vertical intermediate dimension of 7 or 14 mm. **C.** E/D trifocal. Intermediate vertical dimension of 8 and FT width 25. **D.** Double-round segments. Vertical separation 14 and diameters 25. **E.** Double executive. Vertical separation 14. F. Double FT. Vertical separation 14 or 15. Segment diameter 25 or 28.

The fitting height of the trifocal is specified from the lowest edge of the lens to the top of the trifocal segment. The top of the trifocal segment is typically located at the lower pupillary margin but can vary slightly dependent upon patient needs as discussed above for bifocals. Compared to a bifocal, the depth of the intermediate segment, typically 7 mm, is at the expense of the distance and near-visual spaces. Larger intermediate depths (8 to 14) can be used for special purposes such as computer work, but often need to be fit somewhat higher. The larger trifocal depths (10 to 14) are usually reserved for special occupational needs and often do not serve well as general purpose lenses.

For most trifocals the intermediate add is 50% of the bifocal add, however intermediate add powers of 40% to 60% are also available in some designs. These other values can be used if there is reason to bias the intermediate viewing zone toward distance or near. For computer work a 60% intermediate portion can work better because the computer is typically located at the nearer end of intermediate vision.

DOUBLE SEGMENTS

Some presbyopic patients need to view overhead tasks at near or intermediate viewing distances. This can be true for car mechanics; painters and wallpaper hangers; some assembly line workers; pharmacists, librarians, and others with a need to view products on overhead shelves, etc. Typical bifocals or trifocals require the user to tilt the head severely to see these overhead objects. Double segments, samples shown in Figures 3D to 3F, are designed to meet such overhead viewing needs. The upper and lower segments usually have the same power. In some designs the upper segment is available in an add power that is intermediate to the bottom segment, of course designed for patients with overhead needs at intermediate distances. The typical separation between the top and bottom segments is 14 to 15 mm. The lens should be fitted by specifying the height of the lower bifocal segment as with standard bifocals; location of the upper segment is not specified.

PROGRESSIVE ADDITION LENSES

GENERAL

Since their introduction to the U.S. market in the 1960s,[3] PALs have steadily increased their share of the multifocal market. Several studies have shown a large percentage of patients prefer PALs compared to bifocal lenses.[4–6] PALs provide a continuous change of power from distance through intermediate to near that provides the wearer with a seamless visual space and eliminates the unusable area of visual space caused by the top line of a bifocal segment. A detracting feature of PALs is that the design necessarily results in unwanted astigmatism in the periphery of the lens, usually located in the lower diagonals relative to lens center.

PALs have both cosmetic and vision advantages compared to segmented multifocals. The cosmetic benefit results from the seamless design and is apparent. The vision advantage results from elimination of the bisecting region of unusable vision associated with the top of the bifocal segment, resulting in contiguous visual space from distance through intermediate to near. The vision advantage with PALs compared to bifocals is supported by a study that showed patient preference for PALs compared to a blended bifocal,[7] both of which are seamless. The strong preference for PALs compared to bifocals is further supported by another study[8] in which 265 habitual bifocal wearers were fitted with PALs: 92% of these patients preferred the PALs. Because progressive lenses have no image jump and no areas of intermediate blur, many wearers describe their vision with progressive lenses as more natural than with bifocals.

OPTICAL CHARACTERISTICS

Progressive addition lenses are designed to provide distance viewing in straight-ahead gaze, a gradual progression of power in an intermediate corridor, and the full addition power lower in the lens. The power change is accomplished by increasing the curvature of the front surface (i.e., decreasing the radius of curvature) along the corridor toward the bottom of the lens. Because the add must be spherical in nature, the curvature must increase equally in all meridians (i.e., it must increase in the horizontal as well as the vertical meridian). As result, the horizontal curvature is flatter in the upper portion of the lens and steeper in the lower portion of the lens. To reconcile the curvature disparity and to make a seamless lens, surface curvature must be altered in the lower quadrants of the lens. This results in the unwanted astigmatism. Therefore, a necessary and undesirable side effect of the gradual progression of power is unwanted astigmatism in the periphery of the lens. The pattern of unwanted astigmatism is a defining characteristic of individual PAL designs.

The unwanted astigmatism limits the error-free viewing zones of the PAL, resulting in considerably narrower error-free distance, intermediate, and near-fixation fields than typical bifocal lenses. The magnitude and location of unwanted astigmatism are worse with higher adds (greater change in curvature required) and when the distance and near centers are closer to one another (curvature must change over a shorter distance). Primarily as a result of the latter, the near zone of a PAL is lower in the lens than for a FT bifocal. Whereas a very wide near zone is attained with a FT bifocal with approximately 16 to 20 degrees of ocular depression, most PALs require gaze depression of 30 to 35 degrees to obtain the near zone, one that is also considerably narrower than provided by a FT bifocal.

A common method to represent the optics of PALs is with contour plots of the spherical equivalent and unwanted astigmatism powers as shown in Figures 4 and 5. Because of the complex nature of the optics there are literally an infinite number of possible PAL designs and dozens of different designs are currently available. Although most current PALs defy clear categorization, it is instructive to consider the differences between a "hard" and "soft" design. The lens in Figure 4 shows characteristics of a hard design. Relatively speaking, a lens of hard design has wider error-free distance and near-viewing zones, the area of the lens with unwanted astigmatism is relatively small, and the magnitude of the unwanted astigmatism is large. The separation between the distance and near centers is shorter and the rate of power change along the corridor is greater. The lens in Figure 5 shows soft design characteristics: narrower error-free distance and near-viewing areas, larger area of unwanted astigmatism but of lower magnitude, distance and near centers are farther apart, and a lower rate of power change in the corridor.

To accommodate the convergence that occurs with viewing at closer distances, the central power corridor is nasally angled toward the bottom of the lens to accommodate ocular convergence at near-viewing distances. Older PAL designs used the same lens for right and left lenses but angled in opposite directions. This approach resulted in the pattern of zone widths and unwanted astigmatism being different to the two eyes. Most current PALs use different lenses for right and left (essentially mirror images of one another) in order to present the same optical characteristics to each eye.

The width and area of the error-free distance, intermediate, and near viewing as well as the magnitude and distribution of unwanted astigmatism can vary significantly across lens designs.[9,10] There is considerable interdependence of the sizes and locations of the viewing

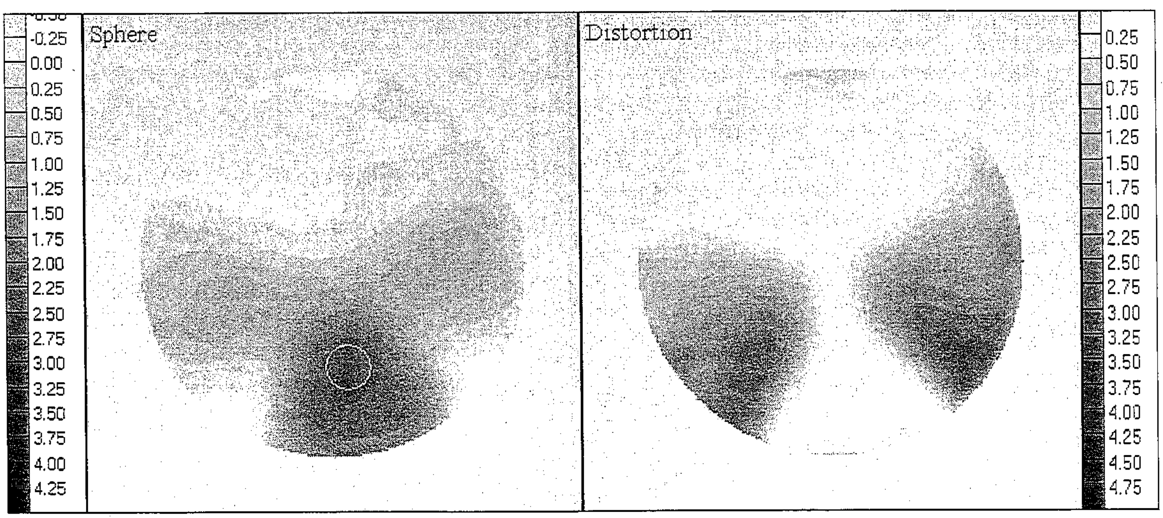

Fig. 4. Contour plots of spherical equivalent power (*left*) and unwanted astigmatism (*right*) for SOLA VIP, plano distance power, +2.00 D add. Contours in 0.25 D steps.

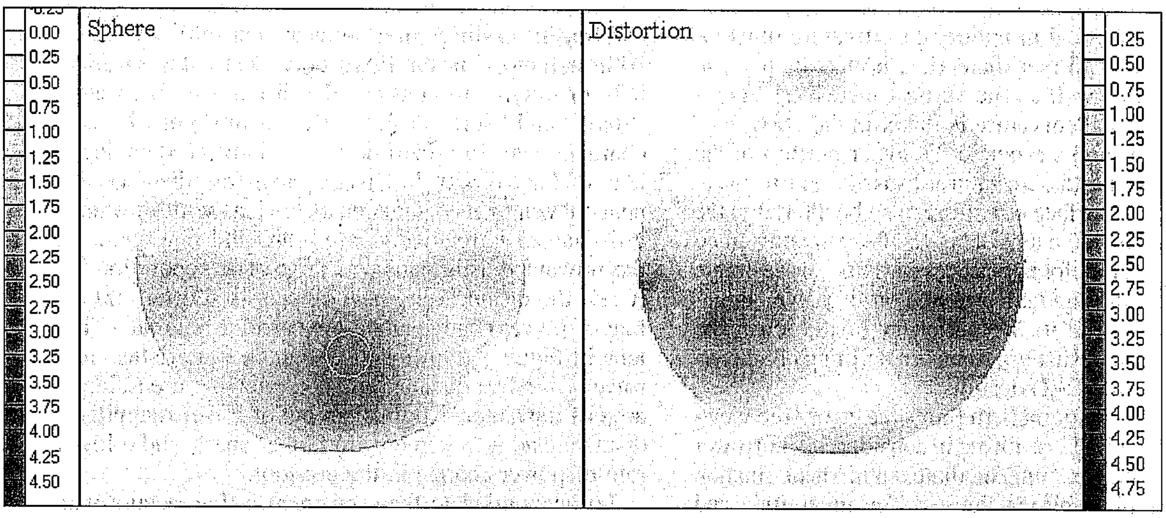

Fig. 5. Contour plots of spherical equivalent power (*left*) and unwanted astigmatism (*right*) for Varilux Comfort, plano distance power, +2.00 D add. Contours in 0.25 D steps.

zones and the magnitude of unwanted astigmatism that make it currently impossible to design a lens that is optimized for all optical attributes. Hence, a particular PAL design may optimize one viewing zone or characteristic, but it is at the expense of the other zones or characteristics.

The widths and areas of the three viewing zones (distance, intermediate, and near) and the magnitude of unwanted astigmatism have been reported.[11] The mean measurements are shown graphically in Figure 6. Analysis showed that even the largest intermediate and near error-free zones are smaller than those required to view a typical computer screen or standard paper respectively,[11] and also smaller than the normal amount of ocular rotation used to view noncentral targets.[12] This means that the PAL wearer must learn to move their head more and their eyes less in viewing noncentral objects and/or tolerate some blurof typical noncentral foveally fixated objects. It is most likely that the head and eye movement patterns are altered by PAL wearers,[13] but the high acceptance and preference rates for PALs also indicate that patients fairly readily are able to do so.

PRESCRIBING PROGRESSIVE ADDITION LENSES

For most patients a PAL satisfies general vision needs better than a segmented bifocal. PALs should be considered a first option for general visual use, unless cost is a consideration or the patient has specific occupational or other visual needs that require the wider error-free fields provided by segmented bifocals.

Current successful bifocal or trifocal wearers will remain successful with same lens design, although they would likely prefer the advantages of a PAL. A large percentage of successful bifocal wearers prefer a PAL if given the choice,[8] although there is some risk in making the change. Determine if the bifocal-wearing patient has specific occupational or other vision needs that preclude recommending change to a PAL. Otherwise, the patient can be advised of the vision and cosmetic differences between the lens types in order to decide upon a possible change.

For a first-time PAL wearer, selection of the particular PAL design should consider the patient's specific visual needs. If a patient is successfully wearing a particular design of PAL, they will likely continue to be successful with the same design. However, consideration should be given to a different PAL design if it better meets their specific visual needs.

As a direct result of the trade-offs in PAL design and the fact that the various designs utilize different trade-offs, some PALs can be expected to provide better vision at distance, intermediate, near or various combinations of those distances. Ratings of 28 PAL designs based upon the widths and areas of the distance, intermediate and near-viewing zones and also the magnitude of unwanted astigmatism are presented in Tables 3 to 7.[11] These tables identify those lenses that can best meet the specific visual needs of particular patients. Just as there is a range of optical characteristics among PALs, there is also a range of visual needs among patients. The clinical task is to match the two.

Table 3 shows lens ratings along the single attributes of distance zone, intermediate zone, and astigmatism. These ratings are useful for those patients for whom

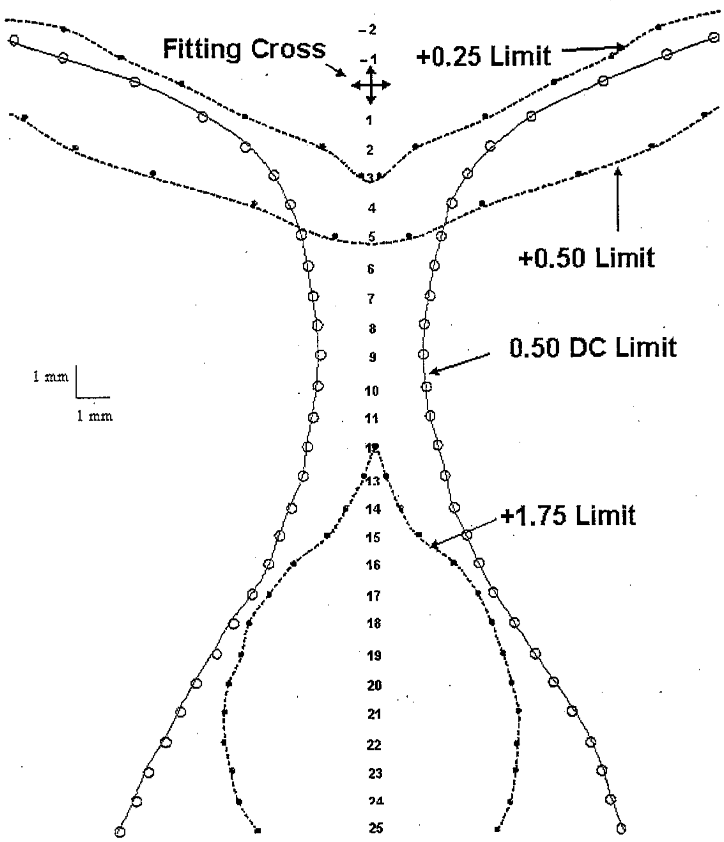

Fig. 6. Mean contours of 28 progressive addition lenses with nominal add of +2.00; data acquired in 1-mm vertical steps. Contour for +1.75 add shown because of greater consistency across lenses. For conversion to visual fixation through the lens, 1 mm is approximately 2 degrees of eye rotation.

there is a single over-riding need for one of those attributes. For example, the distance rankings are used for patients who drive a lot or are involved in outdoor work and have only occasional need for intermediate and near vision. The intermediate rankings are used for patients who want a general purpose PAL but whose primary need is viewing a computer or performing a manufacturing task at intermediate viewing distances. However, such patients may benefit even more from an occupational progressive lens (see section on occupational progressive lenses [OPLs]). The rankings based on astigmatism are used for those patients who are very sensitive to unwanted astigmatism and for whom this is the most important lens attribute.

Table 4 shows ratings based only on the near-viewing zone. These ratings are useful for those patients for whom near vision is the single overriding need. This includes patients who perform extensive near tasks yet also desire a general purpose PAL. It also includes emmetropic patients who intend to use the lenses primarily as reading glasses but also desire a general purpose PAL. An OPL should be considered for these patients. The near ratings in Table 4 are directly derived from width and area magnitudes. As result, the ratings generally increase with greater fitting height because a greater fitting height necessarily results in a larger near-viewing zone for all lenses. The larger ratings for greater fitting heights represent the fact that the patient will have a larger and wider near-viewing zone with a greater fitting height. Only a few lenses provide any near addition for a fitting height of 16 mm. Note also that the lens rankings change somewhat as a function of the fitting height. This is because the manner in which the near zone changes toward the bottom of the lens is different for the various lenses

The ratings in Table 5 combine viewing zones and are based on equal weightings of the distance and intermediate ratings and the intermediate and near (fitting height of 22 mm) ratings. The two columns on the left do not consider the amount of unwanted astigmatism, whereas those on the right include a 25% weighting of astigmatism. The distance/intermediate ratings apply to patients with primary visual needs at those two distances and for whom near viewing is not as important. This includes drivers or those with outdoor occupations and recreations who have distance and intermediate viewing needs but for whom near viewing is not as important. The intermediate and near category applies to patients

TABLE 3. Calculated ratings for the distance zone, intermediate zone, and unwanted astigmatism.

		Specialty usage—calculated ratings			
Distance	**Rating**	**Intermediate**	**Rating**	**Astigmatism**	**Rating**
SOLA Percepta	88.1	Zei Gradal Top	91.3	J&J Definity	93.3
Younger Image	87.4	J&J Definity	91.1	Varlx Panamic	70.0
Shamr Genesis	83.6	Pentx AF Mini	87.2	AO Pro 15	69.3
Ess Spr No-lne	83.2	Sig Nav Precsn	84.6	AO Compact	66.7
Vis Ease Outlk	77.2	AO Pro 15	84.6	Rdnstk Life AT	66.0
AO b'Active	69.3	HoyaLux ECP	83.6	Pentx AF Mini	61.3
Sig Kodak	67.1	Rdnstk Life AT	82.7	Pentx AF 150	61.3
Zei Gradal Top	65.4	SOLAMax	76.7	AO b'Active	60.7
Ess Natural	54.6	AO b'Active	74.8	Sig Kod Precise	60.7
J&J Definity	53.0	Sig Kodak	71.0	SOLAMax	59.3
SOLA VIP	47.9	Hoya Sum CD	70.0	Shamr Genesis	55.3
Rdnstk Life XS	47.8	Ess Adaptar	62.0	Younger Image	54.0
HoyaLux ECP	47.4	SOLA XL	61.7	Shamr Piccolo	54.0
Pentx AF 150	43.5	Younger Image	61.0	Ess Adaptar	48.0
Varlx Panamic	39.3	Ess Natural	60.8	Hoya Sum CD	47.3
Sig Kod Precise	37.3	Varlx Panamic	60.2	Rdnstk Life XS	46.7
AO Pro 15	36.4	Pentx AF 150	59.1	Sig Kodak	43.3
Ess Adaptar	35.3	Shamr Genesis	58.9	Vis Ease Outlk	42.0
Varlx Comfort	34.7	Hoya GP Wide	57.8	Varlx Comfort	39.3
Hoya Sum CD	30.1	Varlx Comfort	45.4	Ess Natural	38.7
Sig Nav Precsn	29.1	Vis Ease Outlk	44.0	Hoya GP Wide	38.0
SOLA XL	24.9	Shamr Piccolo	43.2	Zei Gradal Top	37.3
Hoya GP Wide	24.5	Sig Kod Precise	42.3	HoyaLux ECP	35.3
AO Compact	23.6	SOLA VIP	35.9	SOLA XL	31.3
Shamr Piccolo	23.1	AO Compact	31.9	Sig Nav Precsn	30.0
Rdnstk Life AT	17.6	SOLA Percepta	30.7	SOLA Percepta	30.0
Pentx AF Mini	16.2	Rdnstk Life XS	27.6	SOLA VIP	8.0
SOLAMax	7.1	Ess Spr No-lne	10.8	Ess Spr No-lne	−29.3

Higher ratings indicate larger and wider areas of vision and lower astigmatism magnitude. These ratings are useful for patients with a single over riding need for distance vision, intermediate vision, or reduction of unwanted astigmatism. (Reprinted with permission of *Optometry*.)

who largely work indoors and primarily perform visual tasks at those viewing distances and for whom distance vision is not as important. The ratings that include astigmatism weighting apply to patients with sensitivity to unwanted astigmatism.

The ratings in Table 6 apply for general usage needs. They combine ratings for distance, intermediate, and near-viewing zones or only distance and near zones; ratings are provided based on fitting height of both 18 and 22 mm. The ratings based upon all three zones apply for patients with general viewing needs at all three distances. If the intermediate viewing zone is not particularly important to the patient, then the ratings based on distance and near apply. Unwanted astigmatism is not factored into the ratings in Table 6. The ratings in Table 7 are the same as in Table 6 except that unwanted astigmatism is factored into the rating. These are for patients with general viewing needs and for whom reduced astigmatism is also important.

FITTING PROGRESSIVE ADDITION LENSES

Both the vertical and horizontal positioning of the PAL within the eye of the frame are critical. Because the near addition in a PAL is relatively low in the lens, a frame with a relatively large B (vertical) dimension should be selected, preferably larger than 30 mm. Frames with adjustable nose pads are also advisable, to enable post-dispensing adjustment of the location of the lenses before the eyes. The frame must be properly adjusted to include pantoscopic angle, vertex distance, and vertical wearing position prior to measuring the lens location.

PALs are designed to have the fitting cross placed directly in front of the pupil with normal straight-ahead gaze. For each design this provides the optimal location of the viewing zones and the optimal binocular use of the lenses. The vertical height of the fitting cross should be measured from the pupil down to the lowest edge of the lens in the frame. The ratings in Table 4 show that considerably greater near areas and widths are attained with greater fitting heights. Only a few PALs provide a near-viewing zone with a fitting height of 16, and a fitting height of 22 provides considerably greater near zone than a fitting height of 18 for all of the lenses. Small frames, which result in shorter fitting heights, require careful selection of PAL design (far left columns of Table 2).

Even with a properly selected short-corridor PAL,

TABLE 4. Calculated ratings for near zone

Near specialty use—calculated ratings							
Fit height 16	**Rating**	**Fit height 18**	**Rating**	**Fit height 22**	**Rating**	**Fit height 26**	**Rating**
Shamr Piccolo	28.0	Shamr Piccolo	45.1	Shamr Piccolo	76.8	SOLA VIP	111.3
Rdnstk Life XS	27.2	AO Compact	41.1	SOLA VIP	76.2	SOLAMax	106.9
AO Compact	24.0	Rdnstk Life XS	40.2	SOLAMax	74.0	Shamr Piccolo	103.8
SOLA VIP	22.5	SOLA VIP	38.8	Rdnstk Life XS	71.9	Rdnstk Life XS	102.9
Hoya Sum CD	17.1	SOLAMax	38.3	AO Compact	65.9	Hoya GP Wide	98.3
SOLAMax	16.3	Vis Ease Outlk	30.4	Ess Spr No-lne	63.3	Ess Spr No-lne	80.1
Sig Kod Precise	14.8	Ess Spr No-lne	29.8	Hoya GP Wide	59.2	Hoya Sum CD	80.1
Vis Ease Outlk	13.0	Sig Kod Precise	28.6	Sig Kod Precise	57.3	Varlx Comfort	80.1
Hoya GP Wide	3.4	Varlx Comfort	26.6	Varlx Comfort	56.9	HoyaLux ECP	78.1
J&J Definity	0.0	Shamr Genesis	25.7	Shamr Genesis	54.2	Sig Nav Precsn	77.2
Varlx Panamic	0.0	Hoya Sum CD	23.2	Sig Nav Precsn	52.0	Sig Kod Precise	74.4
AO Pro 15	0.0	SOLA XL	22.8	Vis Ease Outlk	52.0	AO Compact	71.9
Rdnstk Life AT	0.0	Varlx Panamic	21.6	SOLA Percepta	50.1	SOLA Percepta	67.0
Pentx AF Mini	0.0	SOLA Percepta	20.8	SOLA XL	48.7	Shamr Genesis	63.2
Pentx AF 150	0.0	Pentx AF Mini	20.2	Hoya Sum CD	46.6	Pentx AF 150	62.9
AO b'Active	0.0	Ess Adaptar	19.7	Sig Kodak	46.3	Sig Kodak	61.4
Shamr Genesis	0.0	HoyaLux ECP	15.5	AO b'Active	44.8	SOLA XL	61.3
Younger Image	0.0	AO b'Active	14.6	Ess Adaptar	43.9	Ess Adaptar	60.6
Ess Adaptar	0.0	Sig Kodak	14.1	Rdnstk Life AT	43.6	Vis Ease Outlk	59.5
Sig Kodak	0.0	Rdnstk Life AT	13.1	Varlx Panamic	42.6	AO b'Active	58.3
Varlx Comfort	0.0	Sig Nav Precsn	13.0	Pentx AF Mini	41.9	Varlx Panamic	56.4
Ess Natural	0.0	Younger Image	12.5	HoyaLux ECP	41.1	Rdnstk Life AT	56.2
Zei Gradal Top	0.0	AO Pro 15	9.8	Pentx AF 150	41.0	Zei Gradal Top	55.6
HoyaLux ECP	0.0	Hoya GP Wide	9.4	Younger Image	40.8	Pentx AF Mini	54.9
SOLA XL	0.0	Pentx AF 150	8.7	AO Pro 15	40.0	AO Pro 15	49.5
Sig Nav Precsn	0.0	J&J Definity	5.4	Zei Gradal Top	35.0	Younger Image	45.3
SOLA Percepta	0.0	Ess Natural	0.0	J&J Definity	24.9	J&J Definity	12.8
Ess Spr No-lne	0.0	Zei Gradal Top	0.0	Ess Natural	20.0	Ess Natural	9.8

These ratings are useful for those patients for whom near vision is the single overriding need. Ratings increase with greater fitting heights commensurate with the greater near viewing zone sizes thereby attained. (Reprinted with permission of *Optometry*.)

fitting heights shorter than 18 necessarily result in some compromise of the near-viewing zone and the patient should be advised of such. The compromised near zone will be noticeable in conditions of low illumination (menu in a restaurant) because of a larger pupil, high reading demands (office work or reading a book in the evening), or viewing small print (phone book). Many patients consider these as reasonable trade-offs for the fashionable small frame. Separate reading glasses or OPLs can be prescribed for specific near-viewing tasks.

Accurate measurement of the PD is particularly critical for successful wearing of a PAL. This is because of the narrowness of the intermediate channel that is directly below the fitting cross. The narrowest portion of the average PAL (Fig. 6) is approximately 3 mm, or about the same size as the pupil of the eye. If the pupils of both eyes are to be able to simultaneously view through the channel, there is essentially no tolerance for error in the separation of the two lenses. Any error in the separation of the lenses relative to the PD of the patient results in one of the eyes viewing through an edge of the channel when the other is centered in it. Improper measurement of PD may be the largest reason for patient nonacceptance of PALs.

PD measurement with a pupillometer is probably the most accurate method. Accurate measurement of the total PD is the most important, however, it is also advisable to specify the split, or monocular components of the PD as enabled by a pupillometer.

ADAPTATION TO PALS

Some patients have difficulty adapting to PALs. However, this problem has lessened considerably with newer designs and the high acceptance rates of PALs indicate this problem is becoming uncommon. Adaptation problems can be related to spatial distortion resultant from the pattern of unwanted astigmatism in the lower quadrants of the lens. Such patients will report swimming sensations, spatial disorientation, warped appearance of lines, or vague complaints. Other patients may have difficulty with the width of the distance, intermediate, or near-viewing zones. Distortion is less and zones are wider for lower adds, therefore, adaptation is easiest for the beginning presbyope. Adaptation to a PAL will be more difficult for a first-time wearer with a higher add. As with most spectacle lens adaptation, it may take up to 2 weeks of continuous wear for adaptation.

TABLE 5. Combination ratings for distance/intermediate, and for intermediate/near (fitting height of 22 used in rating)

Specialty usage combinations: Without astigmatism weighting				With 25% astigmatism weighting			
Distance and intermediate	Rating	Intermediate and near (FH 22)	Rating	Distance and intermediate	Rating	Intermediate and Near (FH 22)	Rating
Zei Gradal Top	78.4	SOLAMax	75.4	J&J Definity	77.4	SOLAMax	71.4
Younger Image	74.2	Sig Nav Precsn	68.3	AO b'Active	69.2	J&J Definity	66.8
J&J Definity	72.1	Pentx AF Mini	64.5	Younger Image	69.1	AO Pro 15	64.0
AO b'Active	72.1	Rdnstk Life AT	63.1	Zei Gradal Top	68.1	Rdnstk Life AT	63.9
Shamr Genesis	71.3	Zei Gradal Top	63.1	Shamr Genesis	67.3	Pentx AF Mini	63.7
Sig Kodak	69.1	HoyaLux ECP	62.3	AO Pro 15	62.7	AO b'Active	60.0
HoyaLux ECP	65.5	AO Pro 15	62.3	Sig Kodak	62.6	Sig Nav Precsn	58.7
Vis Ease Outlk	60.6	Shamr Piccolo	60.0	HoyaLux ECP	58.0	Shamr Piccolo	58.5
AO Pro 15	60.5	AO b'Active	59.8	Vis Ease Outlk	56.0	Zei Gradal Top	56.7
SOLA Percepta	59.4	Sig Kodak	58.7	Varlx Panamic	54.8	Shamr Genesis	56.2
Ess Natural	57.7	Hoya GP Wide	58.5	Rdnstk Life AT	54.1	Varlx Panamic	56.0
Sig Nav Precsn	56.9	Hoya Sum CD	58.3	Pentx AF Mini	54.1	HoyaLux ECP	55.6
Pentx AF Mini	51.7	J&J Definity	58.0	Pentx AF 150	53.8	Hoya Sum CD	55.6
Pentx AF 150	51.3	Shamr Genesis	56.5	Ess Natural	52.9	Sig Kodak	54.8
Rdnstk Life AT	50.1	SOLA VIP	56.0	SOLA Percepta	52.0	Hoya GP Wide	53.4
Hoya Sum CD	50.1	SOLA XL	55.2	Sig Nav Precsn	50.2	AO Compact	53.3
Varlx Panamic	49.7	Ess Adaptar	52.9	Hoya Sum CD	49.4	Pentx AF 150	52.9
Ess Adaptar	48.6	Varlx Panamic	51.4	Ess Adaptar	48.5	Sig Kod Precise	52.5
Ess Spr No-lne	47.0	Varlx Comfort	51.2	SOLAMax	46.3	Ess Adaptar	51.7
SOLA XL	43.3	Younger Image	50.9	Sig Kod Precise	45.0	Younger Image	51.7
SOLAMax	41.9	Pentx AF 150	50.1	Hoya GP Wide	40.4	SOLA XL	49.2
SOLA VIP	41.9	Sig Kod Precise	49.8	SOLA XL	40.3	Rdnstk Life XS	49.0
Hoya GP Wide	41.2	Rdnstk Life XS	49.7	Rdnstk Life XS	39.9	Varlx Comfort	48.2
Varlx Comfort	40.1	AO Compact	48.9	Varlx Comfort	39.9	Vis Ease Outlk	46.5
Sig Kod Precise	39.8	Vis Ease Outlk	48.0	Shamr Piccolo	38.4	SOLA VIP	44.0
Rdnstk Life XS	37.7	SOLA Percepta	40.4	AO Compact	37.5	Ess Natural	39.9
Shamr Piccolo	33.1	Ess Natural	40.4	SOLA VIP	33.4	SOLA Percepta	37.8
AO Compact	27.7	Ess Spr No-lne	37.0	Ess Spr No-lne	27.9	Ess Spr No-lne	20.4

The distance/intermediate ratings apply to patients with primary visual needs at those 2 distances, near viewing is not factored. The intermediate and near category applies to patients that primarily perform visual tasks at those viewing distances and for whom distance vision is not as important. The ratings that include astigmatism weighting apply to patients with sensitivity to unwanted astigmatism. (Reprinted with permission of *Optometry*.)

Adaptation difficulties can often be managed by adjusting the pantoscopic angle, the vertex distance, or the fitting height (if the frame has adjustable nose pads). Verify that the distance between lens centers matches the patient's PD; mismatch can certainly cause adaptation problems. If the patient difficulties concern the width or area of one of the viewing zones, consult Tables 3 through 7 to determine if the complaints match the lens characteristics and whether another PAL design would resolve the problem. If the problems cannot be resolved, common industry practice is to replace the PAL lenses with bifocals with no additional charge to doctor or patient.

OCCUPATIONAL PROGRESSIVE LENSES

DESIGN AND OPTICAL PROPERTIES

OPLs utilize progressive power optics and are designed primarily to meet typical indoor viewing needs of presbyopic patients. OPLs provide near vision in the lower portion of the lens, a wide field of intermediate vision in the straight-ahead position, and far intermediate vision in the top of the lens. OPLs are not designed to meet typical distance viewing needs and they are not intended to meet general vision needs. The need for this type of lens has been driven by the large numbers of people working in offices and at computers. However, OPLs also meet the viewing needs of many people who work in other indoor environments.

As with PALs there is wide variation in OPL designs. Stylized designs of both a PAL and an OPL are shown in Figure 7 to demonstrate the principal differences between the two. Most OPL designs do not include any distance correction whereas a wide clear field of distance vision is important to PAL design. OPLs are designed to provide a wide field of intermediate vision, contrasted with the narrow intermediate vision provided by PALs. The unwanted peripheral astigmatism that necessarily accompanies any lens with progressive op-

TABLE 6. General usage combination ratings—no weighting for unwanted astigmatism

General usage combinations—no astigmatism weighting							
Distance, intermediate & near (FH 18)	Rating	Distance, intermediate & near (FH 22)	Rating	Distance and near (FH 18)	Rating	Distance and near (FH 22)	Rating
Shamr Genesis	56.1	Shamr Genesis	65.6	Ess Spr No-lne	56.5	Ess Spr No-lne	73.3
Younger Image	53.6	Zei Gradal Top	63.9	Shamr Genesis	54.7	SOLA Percepta	69.1
AO b'Active	52.9	Younger Image	63.1	SOLA Percepta	54.4	Shamr Genesis	68.9
Zei Gradal Top	52.2	AO b'Active	63.0	Vis Ease Outlk	53.8	Vis Ease Outlk	64.6
Sig Kodak	50.8	Sig Kodak	61.5	Younger Image	49.9	Younger Image	64.1
Vis Ease Outlk	50.5	Vis Ease Outlk	57.7	Rdnstk Life XS	44.0	SOLA VIP	62.0
J&J Definity	49.9	HoyaLux ECP	57.4	SOLA VIP	43.3	Rdnstk Life XS	59.8
HoyaLux ECP	48.8	J&J Definity	56.4	AO b'Active	42.0	AO b'Active	57.0
SOLA Percepta	46.5	SOLA Percepta	56.3	Sig Kodak	40.6	Sig Kodak	56.7
AO Pro 15	43.6	Sig Nav Precsn	55.3	Shamr Piccolo	34.1	Zei Gradal Top	50.2
Sig Nav Precsn	42.3	AO Pro 15	53.6	Sig Kod Precise	33.0	Shamr Piccolo	49.9
Ess Spr No-lne	41.3	SOLA VIP	53.3	Zei Gradal Top	32.7	Sig Kod Precise	47.3
Pentx AF Mini	41.2	SOLAMax	52.6	AO Compact	32.4	Varlx Comfort	45.8
Hoya Sum CD	41.1	Ess Spr No-lne	52.4	HoyaLux ECP	31.5	AO Compact	44.8
SOLA VIP	40.9	Rdnstk Life XS	49.1	Varlx Comfort	30.7	HoyaLux ECP	44.3
SOLAMax	40.7	Hoya Sum CD	48.9	Varlx Panamic	30.4	Pentx AF 150	42.2
Varlx Panamic	40.3	Pentx AF Mini	48.4	J&J Definity	29.2	Hoya GP Wide	41.8
Ess Adaptar	39.0	Rdnstk Life AT	48.0	Ess Adaptar	27.5	Varlx Panamic	40.9
Rdnstk Life XS	38.5	Pentx AF 150	47.9	Ess Natural	27.3	SOLAMax	40.6
Ess Natural	38.5	Shamr Piccolo	47.7	Hoya Sum CD	26.6	Sig Nav Precsn	40.6
Rdnstk Life AT	37.8	Varlx Panamic	47.3	Pentx AF 150	26.1	Ess Adaptar	39.6
Shamr Piccolo	37.1	Hoya GP Wide	47.2	SOLA XL	23.8	J&J Definity	39.0
Pentx AF 150	37.1	Ess Adaptar	47.1	AO Pro 15	23.1	Hoya Sum CD	38.4
SOLA XL	36.4	Varlx Comfort	45.7	SOLAMax	22.7	AO Pro 15	38.2
Sig Kod Precise	36.1	Sig Kod Precise	45.6	Sig Nav Precsn	21.1	Ess Natural	37.3
Varlx Comfort	35.6	Ess Natural	45.1	Pentx AF Mini	18.2	SOLA XL	36.8
AO Compact	32.2	SOLA XL	45.1	Hoya GP Wide	17.0	Rdnstk Life AT	30.6
Hoya GP Wide	30.6	AO Compact	40.5	Rdnstk Life AT	15.3	Pentx AF Mini	29.0

Distance/intermediate/near ratings useful for patients with general visual needs, distance/near ratings useful for patients without intermediate needs. Ratings calculated for fitting height (FH) of 18 and 22, representative of low and high fitting heights, respectively. (Reprinted with permission of *Optometry*.)

tics is typically located higher in the lens in an OPL compared to a PAL because indoor office work comprises more downward viewing than typical outdoor environments. The magnitude of the unwanted astigmatism will typically be less with an OPL than with a PAL. This is because the power change in an OPL is less (the OPL typically does not include the full distance power) and the poles of the power extremes are farther apart than for a PAL. Both of these factors serve to reduce the amount of unwanted astigmatism.

OPLs are commonly prescribed by writing the typical distance prescription with near addition and specifying an OPL design. The laboratory fabricates the lens to have the prescribed near power in the bottom of the lens. This is atypical because all other lenses are fabricated to have the prescribed distance power at a designed location near the center or upper portion of the lens. The powers provided in the middle and upper portions of the OPL are determined by the lens design relative to the near prescription.

Because the near power is used as the fabrication reference for OPLs, the power change that occurs in an OPL is specified from the near reference. This results in specification of a negative power progression that occurs with increasing height in an OPL, exactly the opposite manner of specifying power change in a PAL. This power change in an OPL is referred to as a power "degression."

The amount of degression in an OPL, along with the add power, determines the power and hence the amount of distance blur in the top portion of the lens. Most of the OPL designs have a power degression less than the near add, which results in an add of 0.25 to 0.75 D in the top of the lens. This amount of plus in the top of the lens is usually acceptable for an indoor environment. Although a full distance power in the top of the lens may be needed for some patients, it may not be the best correction to meet the needs of many other patients and, in some ways, degression to the full distance power defeats some of the advantages of the OPL design. The lower degression (compared to the full degression to accomplish full distance power) enables a wider corri-

TABLE 7. General usage combination ratings

General usage combinations—25% astigmatism weighting							
Distance, intermediate & near (FH 18)	Rating	Distance, Intermediate & near (FH 22)	Rating	Distance and near (FH 18)	Rating	Distance and near (FH 22)	Rating
J&J Definity	60.7	J&J Definity	65.6	Shamr Genesis	54.8	Shamr Genesis	65.5
Shamr Genesis	55.9	Shamr Genesis	63.0	Younger Image	50.9	Younger Image	61.6
AO b'Active	54.8	AO b'Active	62.4	Vis Ease Outlk	50.8	SOLA Percepta	59.3
Younger Image	53.7	Younger Image	60.8	SOLA Percepta	48.3	Vis Ease Outlk	58.9
AO Pro 15	50.0	AO Pro 15	57.6	AO b'Active	46.6	AO b'Active	57.9
Sig Kodak	48.9	Zei Gradal Top	57.3	J&J Definity	45.3	Rdnstk Life XS	56.5
Zei Gradal Top	48.5	Sig Kodak	56.9	Rdnstk Life XS	44.7	Sig Kodak	53.4
Vis Ease Outlk	48.4	SOLAMax	54.3	Sig Kodak	41.3	J&J Definity	52.5
Varlx Panamic	47.8	Vis Ease Outlk	53.8	AO Compact	40.9	Shamr Piccolo	50.9
Pentx AF Mini	46.2	Varlx Panamic	53.0	Varlx Panamic	40.3	Sig Kod Precise	50.6
HoyaLux ECP	45.5	Rdnstk Life AT	52.5	Sig Kod Precise	39.9	AO Compact	50.2
SOLAMax	45.4	HoyaLux ECP	51.9	Shamr Piccolo	39.1	SOLA VIP	48.5
Rdnstk Life AT	44.8	Pentx AF Mini	51.6	Ess Spr No-lne	35.1	Varlx Panamic	48.2
Pentx AF 150	43.2	Pentx AF 150	51.2	Pentx AF 150	34.9	Ess Spr No-lne	47.6
Hoya Sum CD	42.7	SOLA Percepta	49.7	AO Pro 15	34.6	Pentx AF 150	47.0
SOLA Percepta	42.4	Sig Kod Precise	49.4	SOLA VIP	34.5	Zei Gradal Top	47.0
Sig Kod Precise	42.2	Shamr Piccolo	49.3	Zei Gradal Top	33.9	AO Pro 15	46.0
Shamr Piccolo	41.3	Sig Nav Precsn	48.9	Varlx Comfort	32.8	SOLAMax	45.3
Ess Adaptar	41.2	Hoya Sum CD	48.5	Ess Adaptar	32.6	Varlx Comfort	44.2
AO Compact	40.8	Rdnstk Life XS	48.5	HoyaLux ECP	32.4	HoyaLux ECP	42.0
Rdnstk Life XS	40.6	Ess Adaptar	47.3	SOLAMax	31.9	Ess Adaptar	41.7
Sig Nav Precsn	39.2	AO Compact	47.0	Hoya Sum CD	31.8	Hoya GP Wide	40.9
Ess Natural	38.5	Hoya GP Wide	44.9	Ess Natural	30.2	Hoya Sum CD	40.6
Varlx Comfort	36.5	Varlx Comfort	44.1	Pentx AF Mini	29.0	Rdnstk Life AT	39.5
SOLA XL	35.2	Ess Natural	43.5	Rdnstk Life AT	28.0	Sig Nav Precsn	37.9
SOLA VIP	32.6	SOLA VIP	42.0	SOLA XL	25.7	Ess Natural	37.6
Hoya GP Wide	32.4	SOLA XL	41.6	Sig Nav Precsn	23.3	Pentx AF Mini	37.1
Ess Spr No-lne	23.6	Ess Spr No-lne	32.0	Hoya GP Wide	22.2	SOLA XL	35.4

Same as Table 4 but with 25% weighting for unwanted astigmatism. Same use as Table 4 but for patients with sensitivity to unwanted astigmatism. (Reprinted with permission of *Optometry*.)

dor of clear intermediate vision and lower magnitude of unwanted astigmatism. Selection of the amount of degression involves a trade-off between clarity of distance vision and the usable field of intermediate and near vision.

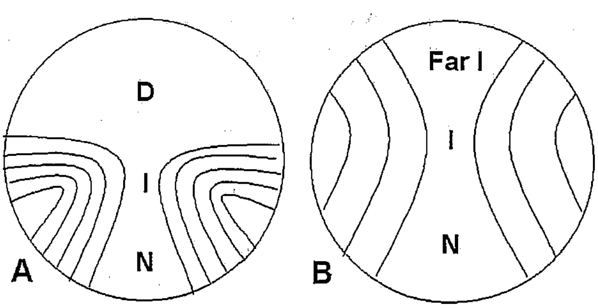

Fig. 7. Stylized contour plots of astigmatism with viewing zone locations for: (**A**) progressive addition lens and (**B**) occupational progressive lens.

PRESCRIBING OCCUPATIONAL PROGRESSIVE LENSES

An important factor in the success of most OPLs is the far-intermediate power in the top of the lens. With far-intermediate correction in the top of the lens the patient can navigate hallways, recognize co-workers, attend meetings, etc. This is important because the patient does not need to remove the glasses each time they leave their desk as they would need to do with reading glasses. Most patients will not use computer glasses that need to be removed each time the leave their desk. The intermediate and near-viewing areas of an OPL enable the patient to function at their desk and computer, whereas the far intermediate zone in the top of the lens enables the patient to navigate the office while wearing the lenses.

Work at a computer is the most common task for which OPLs are designed and prescribed. Bifocals and PALs do not work well for computer users who require a lens addition for viewing intermediate distances. Early presbyopic patients with near adds of approximately

1.50 D or less have enough remaining accommodation to focus on the computer display through the distance portion of the lens. However, once the patient requires an add for intermediate viewing, they can no longer comfortably use a bifocal or PAL. A bifocal lens is usually prescribed for a 40-cm viewing distance and the bifocal segment is located for a downward viewing angle of approximately 25 degrees. The computer is typically at a distance of 50 to 70 cm and a downward viewing angle of 10 to 20 degrees. The bifocal wearer must awkwardly tilt the head back and lean toward the computer display to see the screen clearly through the near portion of the lens. A progressive addition lens is likewise limiting at the computer because the area of the lens containing the intermediate power is small and narrow, thereby requiring head instead of eye movements to scan the computer screen. An OPL has a wide corridor of usable intermediate power that is located well for computer viewing.

OPLs meet visual needs in many other situations in addition to computer use. They work well for many indoor needs such as housework, manufacturing facilities, medical offices, indoor sales, etc. They also work well instead of bifocals for pediatric patients. For pediatric patients, the OPL should be designed to provide some distance vision in the top of the lens for viewing the front of a classroom. OPLs are also a good substitute for single vision reading glasses, because they provide a good reading area but also far-intermediate vision in the top of the lens for viewing objects such as a television across the room.

Several OPLs are available in a series of discrete degression amounts. These include Access (SOLA International, San Diego, CA), Cosmolit Office (Rodenstock, Munchen, Germany), Office (Shamir Insight, Inc., aka Desktop by Hoya, San Diego, CA). The degression amounts available for each are shown in Table 8. The specific degression power is typically selected by the optical laboratory based on the near add power in the prescription as indicated in Table 8. The amount of add remaining in the top of the lens is shown in the right column of Table 8. The clinician can specify that the laboratory provide a nonstandard degression if patient viewing distances and intended usage vary significantly from typical indoor usage. For example, it is often possible to select a degression amount that matches the patient's near add, thereby providing the distance power in the top of the lens. This may be desirable for a child in a classroom or for a stockbroker to see the ticker display across the room. Although this approach provides a small area of distance correction in the top of the lens, it is too small in area to meet nonindoor distance viewing requirements.

TABLE 8. Occupational progressive lenses that are available in a limited series of degression values

	Degression	Add range	Add power in top
Access	0.75	1.00 to 1.50	0.25 to 0.75
	1.25	1.75 to 2.50	0.50 to 1.25
Cosmolit Office	1.00	1.00 to 1.75	0.00 to 0.75
	1.75	2.00 to 2.50	0.25 to 0.75
Office	0.75	1.00 to 1.50	0.25 to 0.75
	1.25	1.75 to 2.00	0.50 to 0.75
	1.75	2.25 to 2.50	0.50 to 0.75

Each degression value serves a small range of near addition powers, the resulting range of add power in the top of the lens for the add range is shown in the right column.

Gradal (Carl Zeiss Optical, Inc., Chester, VA) is an OPL that has a full range of degression powers in 0.25 D steps; the degression amount is selected by the laboratory so that +0.50 D add remains in the top of the lens, unlike the lenses in Table 8 in which the amount of add in the top of the lens varies dependent on near add.

Two OPLs, Tact (Hoya) and Technica (American Optical, New York, NY) are designed to have a small area of distance power in the top of the lens (i.e., the degression amount equals the add amount). The distance viewing area is small and located high in the lens. These lenses can be used for patients with limited but critical distance viewing needs while in an indoor environment.

ANISOMETROPIA—VERTICAL IMBALANCE AT NEAR

Any spectacle-wearing patient with anisometropia will obtain different amounts of prism to each eye when viewing away from the optical center. For example, what differential prism is generated when the following patient depresses their gaze 20 degrees to read?

OD: −2.00 DS
OS: −5.00 DS

When the patient depresses their eyes 20 degrees, this represents viewing through a lens location that is 10 mm from the optical center (2 degrees = approximately 1 mm). By Prentice's rule, the amount of prism (in prism diopters or Δ) is equal to the distance from the optical center (in centimeters) multiplied by the power. Hence, the prism at that lens location in the right eye is 2Δ base-down (1 cm × 2 D) and in the left eye it is 5Δ base-down. This is a net of 3Δ base-down in the left eye.

This amount of induced differential prism might be expected to cause significant difficulty for the patient, but this is not always the case. It has been shown that most anisometropic patients will measure orthophoria in both straight-ahead and in down-gaze through spectacles.[14] This seems to indicate that binocular eye movements can adjust to the differential prism demands. If the patient is wearing single vision lenses, the patient can also adjust to this problem by using more head movement than eye movements when viewing peripheral objects thus maintaining fixation close to the optical centers of the lenses and avoiding the differential prism effects. However, when a patient is prescribed multifocals, they are now required to view through a peripheral portion of the lenses in order to use the near portion of the lens. The bifocal-wearing patient cannot avoid the induced prism problem by using head instead of eye movements. Some bifocal wearing patients have difficulty with this and resultant discomfort while reading.

It can be determined if this is a problem for a particular patient by having them view downward through their spectacle lenses at a typical reading angle, interpose corrective vertical prism before their eyes (in the example above, this would be 3Δ base-up in the left eye), and note if the patient is more comfortable. Vertical phoria or fixation disparity can also be tested in down gaze through the glasses. Observe if the patient is a head mover with their glasses, this is an indication that differential vertical prism may be a problem.

One method of solving this problem is to prescribe a separate pair of reading glasses with the optical centers placed lower in the frame allowing the patient to read without encountering much differential prism.

The most common method of solving this problem is with bicentric grind, or what is referred to as "slab-off." This is a special grinding technique applied to the back surface of one of the two lenses by the optical laboratory. Essentially the laboratory grinds the back surface with two different grinding centers, one higher than the other. This results in a horizontal line of demarcation that extends across the entire lens. There is a sudden prism jump at that line, and the amount of the prism jump is calculated to eliminate the induced differential prism at a given reading level. The amount of prism in the slab-off can be specified in the laboratory order, or the practitioner can specify the reading level at which prism equalization is desired and the laboratory will calculate the amount. The line is normally placed to be colocated with the top of the bifocal or trifocal segment. This procedure can also be performed on a PAL.

FUTURE OF MULTIFOCAL LENSES

Multifocal lenses are, by far, the most common clinical treatment of presbyopia. Although newer surgical corrections of presbyopia will certainly gain usage in the future, it is likely that multifocal lenses will be a mainstay for quite some time. Progressive addition lenses will continue to gain market share and segmented multifocal lenses will become less common. Newer designs of progressive addition lenses will result in better visual function and special purpose PALs will also become more common.

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