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Progressive addition lenses—measurements and ratings

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Abstract

BACKGROUND: This study is a followup to a previous study in which the optics of several progressive addition lens (PALs) designs were measured and analyzed. The objective was to provide information about various PAL designs to enable eye care practitioners to select designs based on the particular viewing requirements of the patient.

METHODS: The optical properties of 12 lenses of the same power for each of 23 different PAL designs were measured with a Rotlex Class Plus lens analyzer. Lenses were ordered through optical laboratories and specified to be plano with a +2.00 diopters add. Measurements were normalized to plano at the manufacturer-assigned location for the distance power to eliminate laboratory tolerance errors. The magnitude of unwanted astigmatism and the widths and areas of the distance, intermediate, and near viewing zones were calculated from the measured data according to the same criteria used in a previous study.

RESULTS: The optical characteristics of the different PAL designs were significantly different from one another. The differences were significant in terms of the sizes and widths of the viewing zones, the amount of unwanted astigmatism, and the minimum fitting height. Ratings of the distance, intermediate, and near viewing areas were calculated for each PAL design based on the widths and sizes of those zones. Ratings for unwanted astigmatism and recommended minimum fitting heights were also determined. Ratings based on combinations of viewing zone ratings are also reported.

CONCLUSIONS: The ratings are intended to be used to select a PAL design that matches the particular visual needs of the patient and to evaluate the success and performance of currently worn PALs. Reasoning and task analyses suggest that these differences can be used to select a PAL design to meet the individual visual needs of the patient; clinical trials studies are required to test this hypothesis.
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Use of progressive addition lenses (PALs) has increased steadily since their introduction to the marketplace. Approximately 50% of currently dispensed multifocal lenses are PALs.[1]

The optics of PALs are complex and vary from design to design. In theory, there can be an infinite number of PAL designs. Despite the large variability among PAL designs, the optical information that is provided to eye care practitioners is largely limited to the location on the lens that the manufacturer recommends be fitted before the patient's pupil (fitting cross) and the locations on the lens at which the distance and near prescriptions can be verified. Manufacturers also provide a recommended minimum fitting height, but there are no established guidelines by which the minimum fitting height is related to the optics, nor do any standards address the minimum fitting height. ANSI Z80.1[2] specifies a reference method by which the spherical equivalent and astigmatism values across the lens can be measured; however, manufacturers generally do not report such contour plots for their lenses.

Two previous articles have reported the optics of a wide

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selection of PALs using systematic methods.[3,4] One[3] reported the optical measurements of 28 PAL designs; contour plots were measured and analyzed for magnitude of unwanted astigmatism and the widths and areas of the distance, intermediate, and near viewing zones. Visual task analyses indicated that the measured variances in the sizes of the viewing zones would affect vision; therefore, comparison of PAL designs based on the measured zone sizes had reasoned validity. A lens rating system was developed for distance, intermediate, and near viewing zones based on the measured characteristics for each lens compared with the measured range across lenses. A rating for unwanted astigmatism was also developed. The ratings were on a scale of 0 to 100 and were intended to be used by eye care professionals to improve the visual care of their patients by enabling them to select a PAL design with viewing zone and distortion characteristics that match the viewing needs of the particular patient. Postpublication feedback to the author indicates that numerous clinicians use the ratings for that purpose.

There was also a strong, but mixed, response from the ophthalmic industry to the publication.[3] In the past, PALs have been marketed largely with nontechnical messages intended to develop brand loyalty among eye care practitioners. The study results and the intended use of the reported ratings have potential to change the method by which clinicians select PALs for their patients and hence to change the marketing paradigm. Some companies have embraced the results of the previous study, whereas others have not.

The methods for measuring the sphere and cylinder powers used in the previous study[3] and in this study are straightforward. The methods of analyzing those measurements and the rationale for developing the ratings are discussed and specified. However, there can certainly be other methods of measuring, comparing, and analyzing the various PAL designs.

The current study is a followup to the previous one,[3] in which one limitation was that only 1 lens of each design was measured and analyzed. We have subsequently developed software that enables us to analyze lenses in less time. Consequently, in this study, we are able to report mean and standard deviations based on measurements of several lenses of each design. The mean value is a better representative of the PAL design than the value based on a single lens. Measurement of multiple lenses of each design also allows statistical testing of the differences between the measurements and ratings of the various PAL designs. Also, the standard deviation of the measurements and ratings is a representative of the manufacturing consistency. Manufacturing consistency is important for clinical care. Inconsistency can negatively affect vision in terms of matching the characteristics of the right and left lenses, ordering a new prescription of the same PAL design for a patient, or replacing a single lens for a patient.

In the current study, the measurement methods and analysis criteria are the same as those used previously.[3] Results are reported as the mean and standard deviation based on measurements of 12 lenses comprised of 6 right/left pairs acquired separately through laboratory channels. Several of the measured PAL designs are newly introduced since the last study, and some of the measured designs are the same as in the previous study.

Methods

Measurement method

The lens measurement method was identical to that previously reported.[3] All lenses were measured using the Rotlex Class Plus lens analyzer to provide sphere, cylinder, and axis values across the surface of the lens. The lenses were measured by aligning the prism reference line markings appropriately in the instrument. All of the measurements were made using the Rotlex "DST" mode; hence, all measurements were normalized to an assigned power of plano at the location recommended by the manufacturer.

The criteria for determining zone width and area were also the same as in the previous study,[3] but the implementation was different. In the previous study, the Rotlex software was used to analyze each lens file. Widths were measured by an operator who recorded each width in 1-mm steps up and down the corridor. Areas were calculated by summing the widths, thereby integrating area in 1-mm steps. In the current study, the ASCII data file for each lens was exported into a parser software program developed for this purpose. The data file contained X and Y coordinates and sphere, cylinder, and axis values in a 1/2-mm grid. Linear interpolation was performed to create data points in a 1/32-mm grid. The data file could be parsed according to specific values or ranges of each of the values (X, Y, sphere, cylinder, or axis) separately or in combination. The data files were parsed using the same criteria as in the previous study[3] to define zone widths and areas.

The distance zone widths and areas were constrained by 1.5 mm above the fitting cross, and by +0.25 dioptersphere (DS) and 0.50 dioptercylinders (DC). The intermediate zone was constrained by adds of +0.75 DS and +1.50 DS and by 0.50 DC. The near zone was constrained by +1.75 DS and by 0.50 DC.

Determining sample size

It was necessary to determine the number of lenses of each design that would be required for testing to achieve a desired level of confidence. There are 2 sources of variability when measuring several lenses of the same design: the method variability is variability as determined by measuring and analyzing the same lens repeatedly and the manufacturing variability is the variability in lenses of the same design and prescription. The method variance was tested by measuring and calculating ratings twice for each of 10 different PALs. The 10 PALs were AO b'activ, Hoyalux ECP, Pentax AF Mini, Rodenstock Life XS, Signet-Armorlite Navigator Precise, Shamir Genesis, SOLA XL, SOLAMax, Vision Ease Outlook, and Younger Image. The manufacturing variance, i.e., across lenses of the same design, was evaluated by measuring and analyzing 3 pairs each of 5 different designs: AO Compact, Hoyalux ECP, Shamir Genesis, SOLA VIP, and Varilux Panamic. Each lens pair was obtained from a different optical laboratory to minimize possible batch effects. All lenses were plano distance with a +2.00 diopters (D) add. The order of lens measurement and analysis for both variance tests was randomized and data files coded so that the experimenter was not aware of the lens being analyzed.

Reliability is the consistency of measurement as determined by the correlation coefficient using data from a mixed model repeated measures analysis of variance. The method covariance was determined from the data obtained by measuring each of 10 lenses twice. The manufacturing correlation coefficient is the covariance between lenses of the same design divided by the sum of the manufacturing covariance plus the method covariance.

The methods for measuring and analyzing data had reliability values of 0.95 or better for all measurement categories except the intermediate width and intermediate rating, which had reliabilities of 0.943 and 0.926, respectively. Only 2 lenses of each design are required to obtain at least 0.95 method reliability. The manufacturer reliability data are considerably lower than the method reliability data, ranging from 0.892 to 0.930 for the intermediate and near measures and ratings and from 0.346 to 0.538 for the distance measures and ratings. Only 3 lenses are required to obtain at least 0.95 manufacturer reliability for the intermediate and near measures and ratings; however, 11 lenses are required for 0.90 manufacturer reliability for the distance rating. Therefore, 12 different lenses (6 pairs) of the each design were measured.

Lens acquisition

The lenses were ordered from optical laboratories as if for a patient with a prescription of plano distance and a +2.00 D add. The add amount was verified by checking lens markings. Six pairs each of the following lens designs were ordered from an optical laboratory: AO Compact, AO Easy, Pentax AF, Pentax AF Mini, Rodenstock Life AT (poly), Rodenstock Life XS, Shamir Genesis, Shamir Piccolo, Signet Armorlite Kodak, Signet Armorlite Kodak Concise, Signet Armorlite Kodak Precise, Signet Armorlite Navigator Short, SOLAMax, SOLA One, Varilux Comfort, Varilux Ellipse, Varilux Liberty, Varilux Panamic, Vision Ease Illumina (poly), Vision Ease Outlook, Younger Image, Zeiss Gradal Brevity, and Zeiss Gradal Top. Each pair of a particular design was ordered from a different optical laboratory, because 2 pairs simultaneously ordered from the same laboratory would have a high chance of coming from the same manufacturing batch. The following laboratories provided lenses for the study: Walman Optical, Minneapolis, Minnesota; Diversified Ophthalmics, Cincinnati, Ohio; Hoya Vision Care, Cleveland, Ohio; Interstate Optical, Mansfield, Ohio; Optical One Inc., Youngstown, Ohio; Select Optical, Columbus, Ohio; Toledo Optical, Toledo, Ohio; and Top Network, Columbus, Ohio. Because of limited availability, the Vision Ease Illumina lens was obtained as follows: 2 pairs were received from 2 different laboratories each but with significant time between orders, and 2 other pairs were received directly from the manufacturer. All lenses were made in CR-39 except Rodenstock Life AT and Vision Ease Illumina, which were only available in Polycarbonate. PAL lenses from Hoya and from Johnson & Johnson could not be attained in sufficient numbers across our laboratory network to be included in the study.

Results

The criteria for measuring and reporting the zone width, zone area, astigmatism measurements, and ratings are identical to those used in the previous study.[3] The rationale for selecting the particular criteria are reported in the previous publication and are not repeated here. Likewise, the validity of the measured widths and areas insofar as they are related to the performance of everyday tasks was discussed in the previous publication and is not presented here.

Distance viewing zone

The widths and areas of the distance viewing zone for the 23 PAL designs are shown in Figures 1 and 2, respectively. The width values are for the zone width at the level of the fitting cross—hence they represent the width that the patient receives in the straight-ahead gaze position when fitted as recommended by the manufacturer. The zone width is limited on both sides by 0.50 DC or +0.25 DS, whichever occurs first. The area of the distance viewing zone includes the area up to 1.5 mm above the fitting cross. The side and lower boundaries of the distance area are constrained by 0.50 DC or +0.25 DS.

Intermediate viewing zone

The widths and areas of the intermediate viewing zones are shown in Figures 3 and 4, respectively. The width and area are both constrained by 0.50 DC. The zone width reported in Figure 3 is at the vertical location at which the add power is +1.25 D in the center of the corridor. The area of the intermediate zone is constrained by 0.50 DC and by add amounts of +0.75 D to +1.50 D.

Astigmatism

The maximum amount of astigmatism on each lens is shown in Figure 5. It has been shown that the maximum amount of astigmatism on the lens correlates highly with the amount of

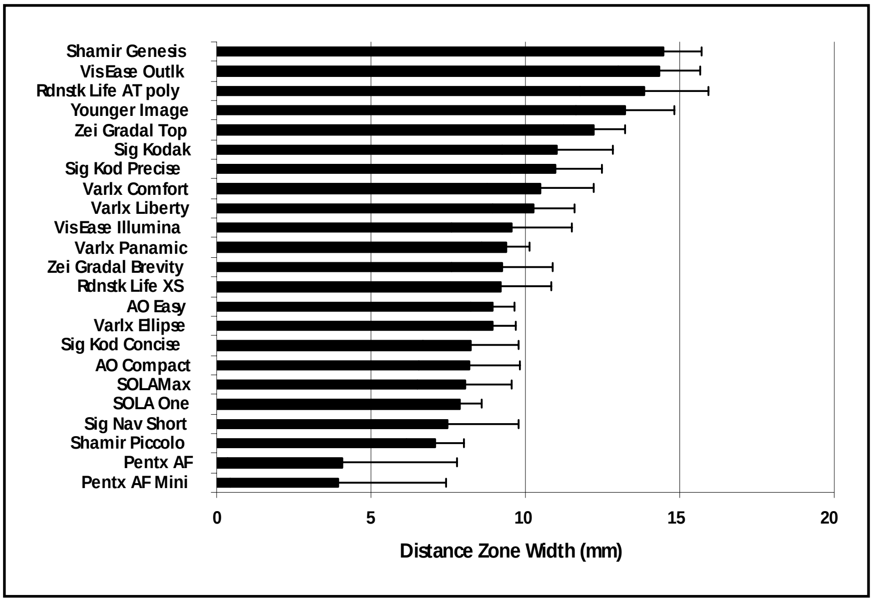

Figure 1 Width of the distance zone (error bar is standard deviation) at the level of the fitting cross.

astigmatism elsewhere on the lens and that the magnitude of unwanted astigmatism is a fundamental measure of the lens design.[5]

Near viewing zone

The widths and areas of the near viewing zone are shown in Figures 6 and 7, respectively. The near widths and areas are constrained to have less than 0.50 DC and also to have more than a +1.75 D add. An add level of +1.75 D was used instead of the nominal add power of +2.00 D, because many lenses do not attain an add amount of +2.00 D.[3] The near zone width and area values depend on the downward distance from the fitting cross.

In practical use, the amount of the near zone available to the patient depends on the fitting height of the lens in the spectacle frame. Because any given PAL design can be fitted over a range of fitting heights, the widths and areas shown in Figures 6 and 7 are reported for 3 representative distances from the fitting cross. Fitting height, however, must also include additional height for the frame bevel and to allow for some pupil coverage. Therefore, 2 mm is added to the distance from the fitting cross to derive fitting height values.

Minimum fitting heights

The manufacturer specifies the minimum recommended fitting height for each PAL design. The specific methods for

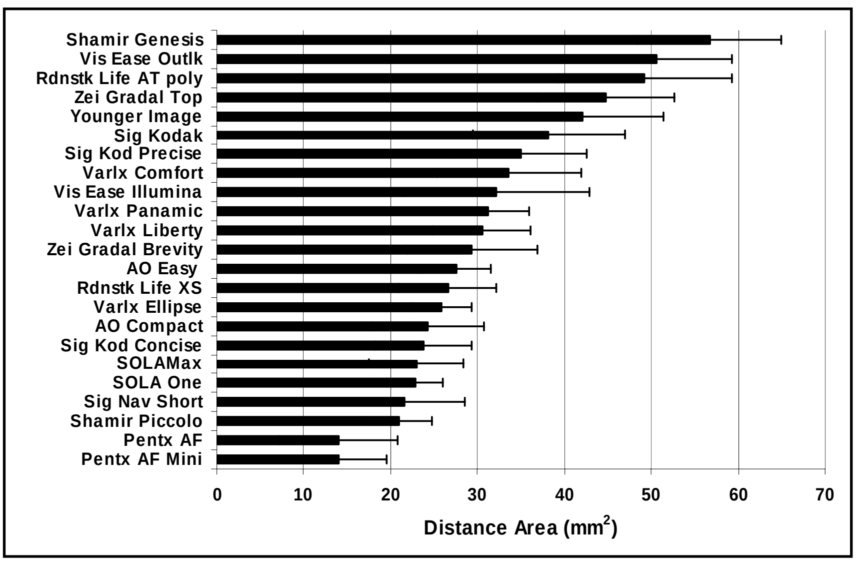

Figure 2 Area of the distance viewing zone.

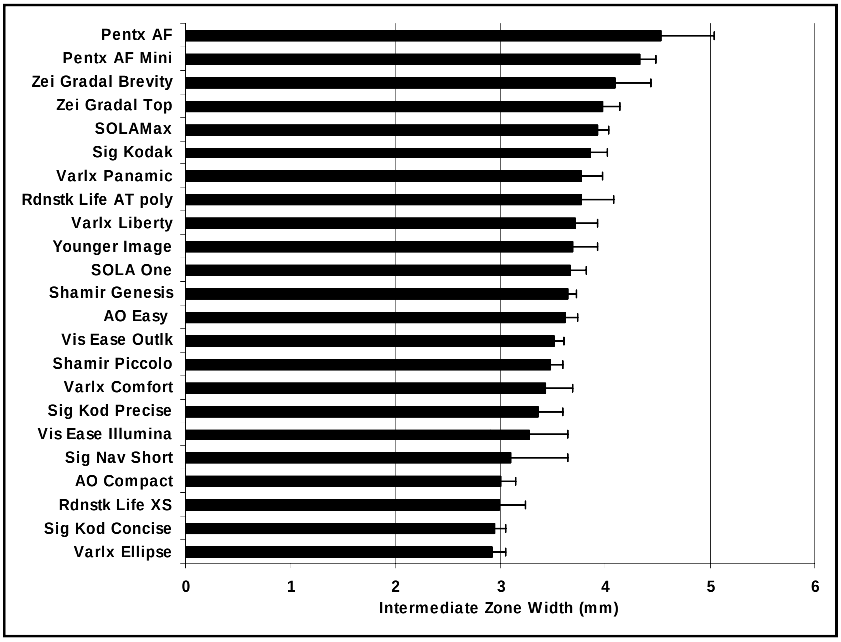

Figure 3 Width of the intermediate zone (error bar is standard deviation).

determining the minimum recommended fitting height are not revealed by the manufacturer nor are there standards or commonly recognized methods that apply to determining the claimed minimum fitting height.

In this study, we measured the highest level at which +1.75 D add occurred in each lens design. Of course, the minimum fitting height will be greater than the highest occurrence of the +1.75 D add because of the frame bevel and the fact that some minimum amount of the near zone must be exposed above the frame to enable a minimum level of functional near vision. To determine the amount by which the minimum fitting height should exceed the highest occurrence of the +1.75 D add, we subtracted the highest occurrence of the +1.75 D from the manufacturer recommended minimum fitting height across all designs. Across all designs, the average difference was 4.1 mm. Therefore, the criterion we used to develop our recommended minimum fitting height was to add 4.0 mm to the highest occurrence of the +1.75 D add. In this manner, the minimum fitting heights recommended herein are, on average, the same as those currently recommended by manufacturers, but the minimum fitting height recommended for any particular design is related to the measured highest occurrence of +1.75 add for that design. The recommended minimum fitting heights based on measurements herein, along with the manufacturer recommended minimum fitting heights are shown in Figure 8.

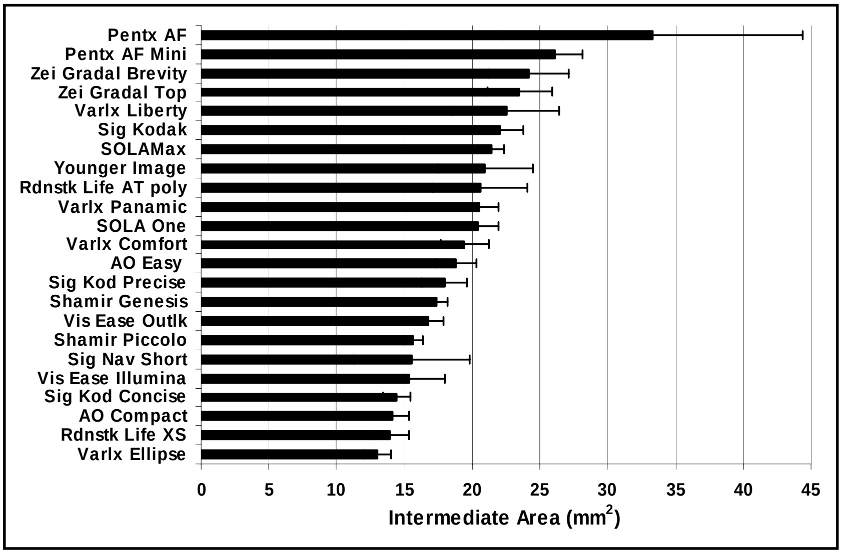

Figure 4 Area of the intermediate zone (error bar is standard deviation).

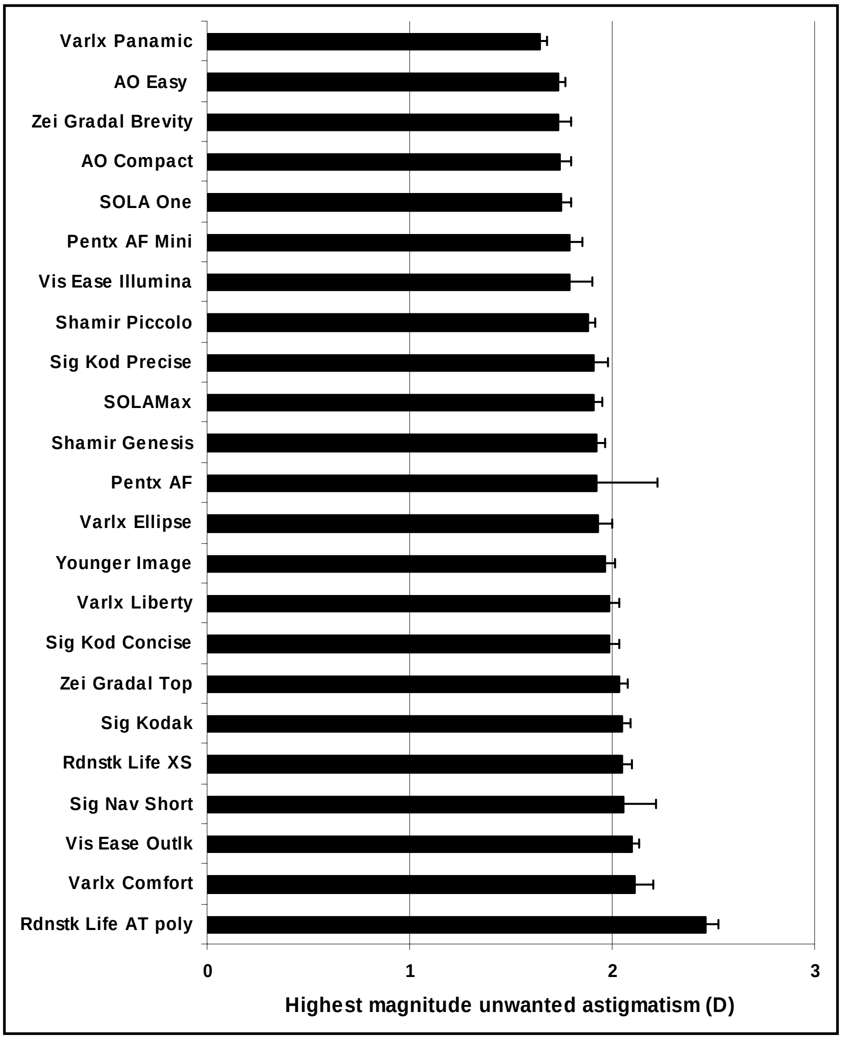

Figure 5 Greatest magnitude of astigmatism (error bar is standard deviation).

Single attribute lens ratings

Ratings for the distance, intermediate, and near viewing zones and also for astigmatism were derived for each measured lens from the data shown in Figures 1 through 7. The basis for establishing the ratings are identical to those from the previous study[3] and are summarized in Table 1. The viewing zone ratings are comprised of equal parts width and area. For each the width and the area, a rating on a scale of 0 to 100 is calculated based on the location of the measured value within the range shown in Table 1. Ratings greater than 100 or less than zero are possible when the measured value is outside of the range shown in Table 1. The ratings for width and area are averaged to determine the rating for the viewing zone. The 0 to 100 rating for astigmatism is entirely based on the location of the measured value within the range specified in Table 1. Lower amounts of astigmatism result in higher rating values. Further details about the conversion of measurements to ratings have been reported previously.[3]

The single-attribute ratings for various aspects of PALs are presented in Tables 2 through 4. Each table also shows the lens ratings, which, based on the measurements on 12 lenses of each design, are not statistically different from one another. Lenses in those tables with nonoverlapping symbols (black circle) were significantly different at $p < 0.05$ as measured by adjusted Tukey B paired comparisons.[6]

The ratings for the distance and intermediate viewing zones are shown in Table 2. Near ratings for fitting heights of 16 and 18 mm are shown in Table 3 and for fitting height of 22 in Table 4. The same 0 to 100 ranges are used for near width and area regardless of the fitting height. As a result, the ratings can also be compared across fitting heights, i.e., the increased ratings for higher fitting heights reflect the fact that more near viewing zone is attained with the greater fitting height. Astigmatism ratings are shown in Table 4.

The PAL designs that are the “highest” and “lowest” rated in each category are shown in bold in Tables 2 through 4. Lens designs are categorized into the highest-rated group by either exceeding the grand mean by more than 1 standard deviation or by being in a grouping of lenses at the top of the ratings that are not statistically significantly different from one another. The lowest category is determined similarly except for being lower than 1 standard deviation from

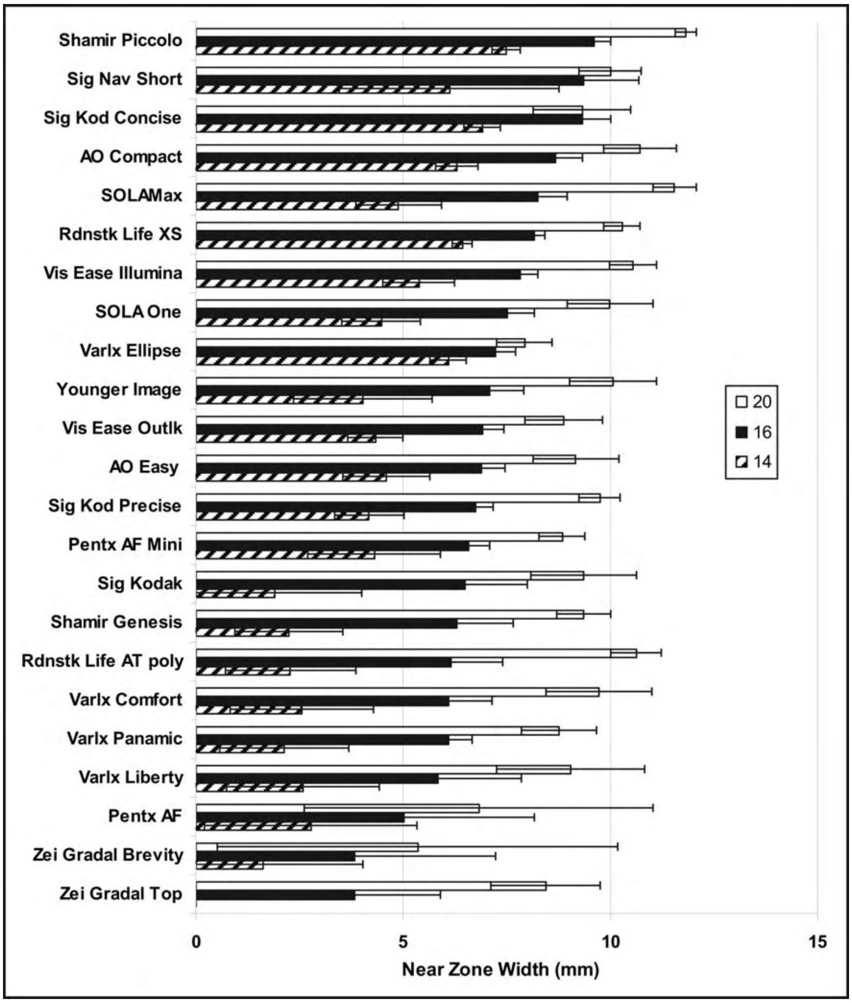

Figure 6 Width of the near zone at 14, 16, and 20 mm below the fitting cross (error bar is standard deviation). These data are used to calculate near ratings for fitting heights of 16, 18, and 22, respectively.

the grand mean or not significantly different from others at the bottom of the list.

Combination categories

It is possible that optimal lens selection for individual patients might be best accomplished by taking into account the ratings in more than one of the above attributes. These patients will benefit from good characteristics in more than one viewing zone. For this reason, the single-attribute ratings in Tables 2 through 4 were combined to create the following combined categories: (1) Distance and intermediate vision (Table 5); (2) intermediate and near vision (Table 6); (3) general purpose—distance, intermediate, and near vision (Table 7); and (4) general purpose—distance and near vision (Table 8).

For each combined usage category, a rating value based on an average of the component ratings (distance, intermediate, near, and/or astigmatism) appropriate to that usage category was calculated for each lens. Astigmatism was weighted 25% in those categories for which it is included. The mean and standard deviation for each lens design within each category was computed. This resulted in calculated means, standard deviations, and ranges of nonsignificant differences similar to the data presented in Tables 2 through 4. The lens ratings, the results of statistical testing, and calculations of those with the highest and lowest ratings in each of Tables 5 through 8 are calculated and presented in the same manner as in Tables 2 through 4.

Discussion

The measurements and analyses of the PALs in this study are performed with the goal of providing clinicians with information that will assist them in providing appropriate treatment options for their patients. There are tradeoffs in the design of a PAL[5]; therefore, no single design can be optimized for all characteristics. The measurements in this study show that the balance of tradeoffs can vary widely for the various PAL designs in the market. Previous analyses of common visual tasks show that the measured variances in the widths and areas of the distance, intermediate, and near

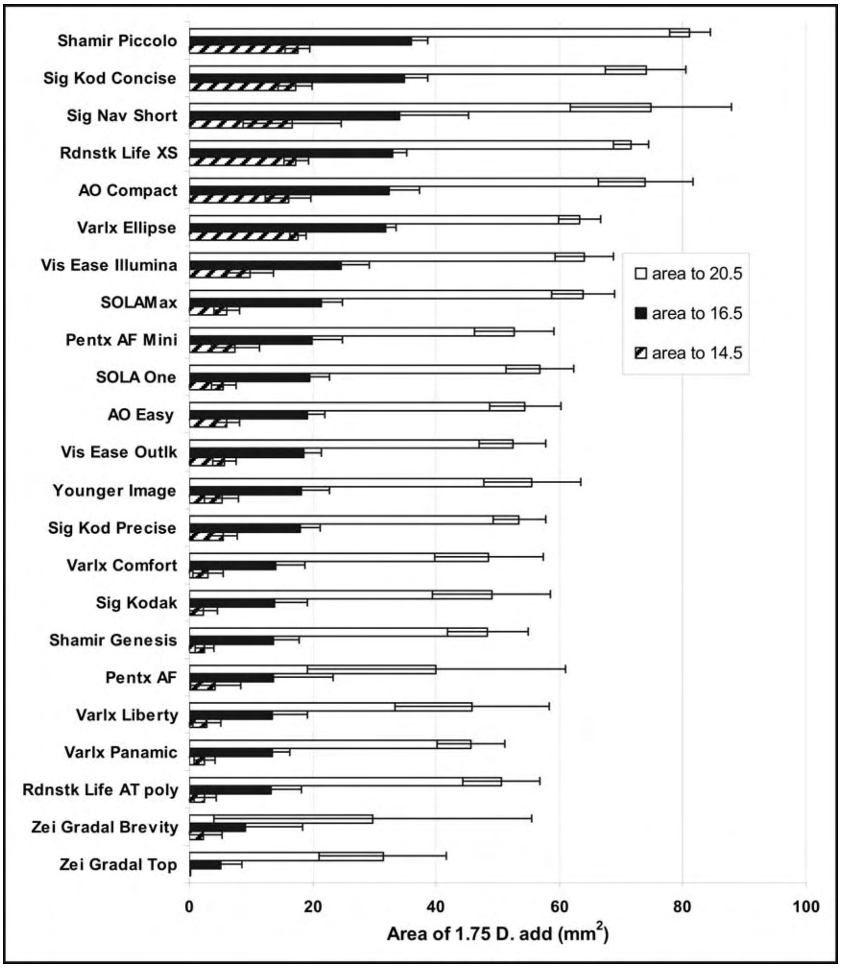

Figure 7 Area of the near zone down to 14.5, 16.5, and 20.5 mm below the fitting cross (error bar is standard deviation). These data are used to calculate near ratings for fitting heights of 16, 18, and 22, respectively.

viewing zones can be expected to affect visual task performance,[3] i.e., patients should notice the differences in the zone widths and areas across lens designs.

The measurement and analysis methods used in this and the previous study[3] are well defined and have been reasoned to be valid. However, other methods of mea-

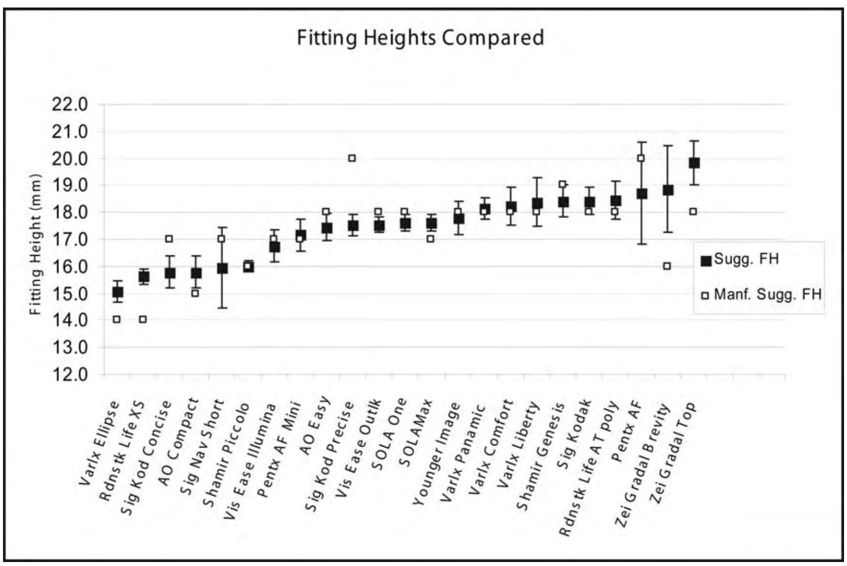

Figure 8 Minimum suggested fitting heights based on the measurements (error bar is standard deviation) and as suggested by the manufacturer.

Table 1 Criteria for calculating ratings from measured values

Rating Category	Derivative Measures	0 to 100 Scale
Distance zone	50%— width at fitting cross	5 to 20 mm
	50%—area from 1.5 mm above fitting cross	15 to 60 mm^2
Intermediate zone	50%—width at 1.25 D add	2 to 5 mm
	50%—area from 0.75 to 1.50 add	10 to 30 mm^2
Near zone*	50%— width at Y	0 to 15 mm
	50%—area to Y +0.5 mm	0 to 100 mm^2
Astigmatism	Largest magnitude	2.75 to 1.25 D

*Near zone ratings reported for a specified fitting height. Fitting height determined by adding 2 mm to the Y value.

surement and analysis could certainly be developed. Ultimately, the true test of any PAL assessment system will be patient performance and acceptance. Plans are underway to test both performance and lens preference in a clinical trials study.

Methodology

Because of the measurement methodology, the measurements represent the PAL optics that are "in addition" to the intended prescription and, therefore, can reasonably apply to all distance prescriptions fabricated from the base curve that was tested. Only one base curve was tested in this study (the base curve that is used for a plano prescription); therefore, consistency of design across base curves was not tested.

The data in the current study are based on 12 lenses of each design; this offers advantages over the data in the previous study, which were based on measurements of 1 lens of each design.[3] First, values based on an average of 12 lenses enables a better estimate of the population mean, i.e., it gives a truer measure of the design characteristic. Also, multiple lenses of each enables statistical testing to determine if measurements and ratings of one lens design are significantly different from others. The results of such statistical testing are shown in the ratings presented in Tables 2 through 8 and have also been used to help identify the highest and lowest rated lenses in each category.

The standard deviations shown in Tables 2 through 4 indicate the spread of the data for each lens design. Lower standard deviations are better because they indicate greater similarity among the 12 lenses of each design. The standard deviation of measurement could be used as a measure of the manufacturing consistency; however, the sample selection used in this study is probably inadequately sized for this purpose. Although lenses were obtained from different laboratories or over different time periods to avoid batch affects, our sample size is relatively small compared with the entire population of lenses in the marketplace.

Another area of improvement of the current study over the previous one is in the calculation of zone areas. In the previous study,[3] the areas were integrated in 1-mm vertical steps. This was accomplished by manually recording the width at each 1-mm vertical step as allowed by the Rotlex software, and the widths were summed to calculate the area—effectively integrating in 1-mm units. This was very time consuming and precluded measuring multiple lenses. In the current study, the ASCII data file from the measurement was exported to a newly designed software program that more accurately integrated area with 1/32-mm steps. This results in a more accurate assessment of the viewing zones.

Using the lens ratings

Deciding on an appropriate PAL design for a patient is the most common clinical decision concerning PALs. All patients and their visual needs are not the same. Therefore, it is also unlikely that the same PAL design is optimal for all patients. Greater patient satisfaction will likely result if the lens design is selected based on the patient's visual needs.

We propose that the ratings presented in this study can be used in 2 ways:

- to evaluate patient performance and experiences with their current PAL design or a recently dispensed pair to which they are having difficulty adapting
- to select a PAL design that will meet the particular viewing needs of the patient

Of course, adaptation difficulties can be caused by factors other than the PAL design. When a patient is having difficulty adapting to a PAL, it is important to verify the prescription, fitting height, interpupillary distance, vertex distance, and pantoscopic tilt. However, if difficulties persist after verifying the prescription and fit, then it is possible that the lens design is causing the problems. For example, if the patient complains that the near viewing zone is too limiting, then it is useful to check Table 3 to determine how the PAL is rated for the near zone. If the PAL is poorly rated for the near zone, then a design change is indicated. In selecting a new PAL design for the patient, the patient should be questioned about visual needs during the day. For example, if the patient spends considerable time in front of a computer, then the combined intermediate and near ratings presented in Table 5 should be consulted and a PAL design selected that is rated highly in that category.

Some patients have adapted to, and are wearing, a PAL design that is acceptable but not optimal for their

Table 2 Ratings for distance and intermediate viewing zones

Single Attribute Ratings

Distance Rating

PAL Design	Mean	SD	Ranges of Nonsignificant Differences									
Shamir Genesis	77.8	13.1	●									
Vis Ease Outlk	70.7	13.8	●	●								
Rdnstk Life AT poly	67.5	17.7	●	●								
Younger Image	57.5	15.5		●	●							
Zei Gradal Top	57.2	11.8		●	●							
Sig Kodak	45.9	14.1			●	●						
Sig Kod Precise	42.1	13.3			●	●	●					
Varlx Comfort	39.0	14.9				●	●	●				
Varlx Liberty	34.8	10.5				●	●	●	●			
Vis Ease Illumina	34.2	18.3				●	●	●	●			
Varlx Panamic	32.5	7.7				●	●	●	●	●		
Zei Gradal Brevity	30.2	13.7				●	●	●	●	●	●	
AO Easy	27.1	6.6					●	●	●	●	●	
Rdnstk Life XS	26.9	11.7					●	●	●	●	●	
Varlx Ellipse	25.2	6.2					●	●	●	●	●	
AO Compact	21.0	12.7						●	●	●	●	
Sig Kod Concise	20.5	11.3						●	●	●	●	
SolaMax	19.0	11.0							●	●	●	
SOLA One	18.2	5.9							●	●	●	
Sig Nav Short	15.5	15.5								●	●	
Shamir Piccolo	13.5	7.4									●	
Pentx AF	−4.2	19.7										●
Pentx AF Mini	−4.6	17.7										●
Mean	33.8	25.7										

Intermediate Rating

PAL Design	Mean	SD	Ranges of Nonsignificant Differences											
Pentx AF	100.4	35.9	●											
Pentx AF Mini	79.1	7.4		●										
Zei Gradal Brevity	70.3	12.9		●	●									
Zei Gradal Top	66.6	8.5		●	●	●								
Sig Kodak	61.1	7.0			●	●	●							
SolaMax	60.6	3.6			●	●	●							
Varlx Liberty	59.9	13.0			●	●	●							
Varlx Panamic	56.1	6.0			●	●	●	●						
Rdnstk Life AT poly	56.0	13.8			●	●	●	●						
Younger Image	55.7	12.4			●	●	●	●						
SOLA One	53.8	6.2				●	●	●	●					
AO Easy	49.1	5.5					●	●	●	●				
Varlx Comfort	47.3	8.1					●	●	●	●	●			
Shamir Genesis	45.9	2.9					●	●	●	●	●			
Sig Kod Precise	42.5	7.6						●	●	●	●	●		
Vis Ease Outlk	42.2	4.2						●	●	●	●	●		
Shamir Piccolo	38.7	3.2							●	●	●	●	●	
Vis Ease Illumina	34.6	12.5								●	●	●	●	●
Sig Nav Short	32.3	19.7									●	●	●	●
AO Compact	27.0	5.4										●	●	●
Sig Kod Concise	26.9	3.7										●	●	●
Rdnstk Life XS	26.4	7.5											●	●
Varlx Ellipse	22.8	4.3												●
Mean	50.3	21.4												

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 3 Ratings for near viewing zones—fitting heights of 16 and 18 Single Attribute Ratings

Near Zone Rating

Fitting Height 16

PAL Design	Mean	SD	Ranges of Nonsignificant Differences							
Shamir Piccolo	33.7	2.1	●							
Sig Kod Concise	31.6	2.7	●							
Rdnstk Life XS	30.0	1.5	●	●						
Varilux Ellipse	29.1	1.8	●	●						
AO Compact	29.0	3.4	●	●						
Sig Nav Short	28.7	12.7	●	●						
Vis Ease Illumina	22.8	4.7		●	●					
SolaMax	19.3	4.5			●	●				
AO Easy	18.4	4.4			●	●	●			
Pentax AF Mini	18.1	7.2			●	●	●			
SOLA One	17.7	4.1			●	●	●			
Vis Ease Outlk	17.3	3.2			●	●	●			
Sig Kod Precise	16.7	4.0			●	●	●	●		
Younger Image	16.1	6.9			●	●	●	●		
Pentax AF	11.3	10.5				●	●	●	●	
Varilux Comfort	10.1	6.9					●	●	●	
Varilux Liberty	10.0	7.2					●	●	●	
Rdnstk Life AT poly	8.8	6.1						●	●	
Shamir Genesis	8.6	5.1						●	●	
Varilux Panamic	8.3	6.0						●	●	
Sig Kodak	7.5	8.1							●	●
Zei Gradal Brevity	6.5	9.5							●	●
Zei Gradal Top	0.0	0.0								●
Mean	17.4	11.0								

Fitting Height 18

PAL Design	Mean	SD	Ranges of Nonsignificant Differences									
Shamir Piccolo	50.1	2.5	●									
Sig Kod Concise	48.5	4.0	●	●								
Sig Nav Short	48.2	10.0	●	●								
AO Compact	45.1	4.5	●	●	●							
Rdnstk Life XS	43.7	1.7	●	●	●	●						
Varlx Ellipse	40.0	2.3		●	●	●	●					
Vis Ease Illumina	38.3	3.6			●	●	●					
SolaMax	38.2	4.0			●	●	●	●				
SOLA One	34.8	3.8				●	●	●	●			
Younger Image	32.7	4.9					●	●	●	●		
AO Easy	32.5	3.2					●	●	●	●		
Vis Ease Outlk	32.3	3.1					●	●	●	●		
Pentx AF Mini	31.9	4.1					●	●	●	●		
Sig Kod Precise	31.5	2.8					●	●	●	●		
Sig Kodak	28.6	7.5						●	●	●		
Shamir Genesis	27.8	6.6							●	●		
Varlx Comfort	27.4	5.7							●	●		
Rdnstk Life AT poly	27.2	6.5							●	●		
Varlx Panamic	27.1	3.3							●	●	●	
Varlx Liberty	26.2	9.3							●	●	●	
Pentx AF	23.5	15.2								●	●	●
Zei Gradal Brevity	17.3	15.9									●	●
Zei Gradal Top	15.3	8.5										●
Mean	33.3	11.5										

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 4 Ratings for unwanted astigmatism and for near zone—fitting height of 22

Single Attribute Ratings

Astigmatism Rating

PAL Design	Mean	SD	Ranges of Nonsignificant Differences								
Varlx Panamic	73.9	2.3	●								
AO Easy	67.9	2.5	●	●							
Zei Gradal Brevity	67.7	4.0	●	●							
AO Compact	67.4	4.0	●	●							
SOLA One	66.6	3.1	●	●							
Pentx AF Mini	64.2	4.4		●	●						
Vis Ease Illumina	64.0	7.6		●	●						
Shamir Piccolo	57.9	2.1			●	●					
Sig Kod Precise	56.3	4.8				●					
SolaMax	56.1	2.8				●					
Pentx AF	55.3	20.0				●	●				
Shamir Genesis	55.3	3.2				●	●				
Varlx Ellipse	54.6	4.5				●	●	●			
Younger Image	52.3	3.1				●	●	●			
Varlx Liberty	51.1	3.3				●	●	●	●		
Sig Kod Concise	51.0	3.5				●	●	●	●		
Zei Gradal Top	47.5	2.7					●	●	●	●	
Sig Kodak	46.9	3.1						●	●	●	
Rdnstk Life XS	46.6	3.2						●	●	●	
Sig Nav Short	46.3	10.9						●	●	●	
Vis Ease Outlk	43.5	2.4							●	●	
Varlx Comfort	42.7	6.3								●	
Rdnstk Life AT poly	19.4	4.5									●
Mean	54.5	12.8									

Rating Fit Height 22

PAL Design	Mean	SD	Ranges of Nonsignificant Differences								
Shamir Piccolo	79.9	2.1	●								
AO Compact	72.7	6.5	●	●							
Sig Nav Short	70.7	6.6	●	●	●						
SolaMax	70.4	3.9	●	●	●						
Rdnstk Life XS	70.1	2.5	●	●	●	●					
Sig Kod Concise	68.0	6.8	●	●	●	●	●				
Vis Ease Illumina	67.1	2.9	●	●	●	●	●				
SOLA One	61.7	5.6		●	●	●	●	●			
Younger Image	61.3	7.3		●	●	●	●	●			
Rdnstk Life AT poly	60.7	4.2		●	●	●	●	●			
Sig Kod Precise	59.2	3.4		●	●	●	●	●			
Varilux Ellipse	58.1	3.7			●	●	●	●			
AO Easy	57.8	6.0			●	●	●	●			
Varilux Comfort	56.7	8.5				●	●	●	●		
Vis Ease Outlk	55.8	5.7					●	●	●	●	
Sig Kodak	55.7	8.6					●	●	●	●	
Pentax AF Mini	55.7	4.7					●	●	●	●	
Shamir Genesis	55.4	4.8					●	●	●	●	
Varilux Liberty	53.1	12.0						●	●	●	
Varilux Panamic	52.0	5.6						●	●	●	
Zei Gradal Top	43.8	8.5							●	●	●
Pentax AF	42.7	23.3								●	●
Zei Gradal Brevity	32.7	28.8									●
Mean	59.2	14.0									

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 5 Distance-oriented visual usage, based on combined ratings for distance and intermediate zones

Distance and Intermediate Combined

Without Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences							
Rdnstk Life AT poly	62.8	9.6	●							
Shamir Genesis	61.9	6.3	●							
Zei Gradal Top	61.9	6.8	●							
Younger Image	56.6	8.7	●	●						
Vis Ease Outlk	56.4	6.3	●	●						
Sig Kodak	53.5	8.1	●	●	●					
Zei Gradal Brevity	52.7	17.4	●	●	●	●				
Pentax AF	50.3	24.8	●	●	●	●	●			
Varilux Liberty	47.4	5.9		●	●	●	●	●		
Varilux Panamic	44.3	5.9		●	●	●	●	●		
Varilux Comfort	43.2	9.9		●	●	●	●	●		
Sig Kod Precise	42.3	6.2			●	●	●	●		
SolaMax	39.8	5.1				●	●	●		
AO Easy	38.1	3.3					●	●	●	
Pentax AF Mini	37.3	8.5					●	●	●	●
SOLA One	36.0	4.2						●	●	●
Vis Ease Illumina	34.4	13.8						●	●	●
Rdnstk Life XS	26.6	8.7							●	●
Shamir Piccolo	26.1	3.6							●	●
AO Compact	24.0	7.5								●
Varilux Ellipse	24.0	3.5								●
Sig Nav Short	23.9	15.5								●
Sig Kod Concise	23.7	6.3								●
Mean	42.0	16.1								

With Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences							
Shamir Genesis	60.2	4.5	●							
Zei Gradal Top	58.3	5.5	●							
Zei Gradal Brevity	56.4	13.5	●	●						
Younger Image	55.5	6.9	●	●						
Vis Ease Outlk	53.2	4.8	●	●	●					
Rdnstk Life AT poly	52.0	7.1	●	●	●	●				
Sig Kodak	51.9	6.2	●	●	●	●				
Varilux Panamic	51.7	4.3	●	●	●	●				
Pentax AF	51.6	15.3	●	●	●	●				
Varilux Liberty	48.3	4.5		●	●	●	●			
Sig Kod Precise	45.8	5.0			●	●	●			
AO Easy	45.5	2.7			●	●	●			
Pentax AF Mini	44.0	6.9			●	●	●	●		
SolaMax	43.8	3.6			●	●	●	●		
SOLA One	43.6	3.5			●	●	●	●		
Varilux Comfort	43.0	7.9				●	●	●		
Vis Ease Illumina	41.8	8.7					●	●	●	
AO Compact	34.8	6.3						●	●	●
Shamir Piccolo	34.1	2.8							●	●
Varilux Ellipse	31.7	3.3								●
Rdnstk Life XS	31.6	6.5								●
Sig Kod Concise	30.5	5.2								●
Sig Nav Short	29.5	9.4								●
Mean	45.2	11.4								

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 6 Near oriented visual usage based on combined ratings for intermediate and near (FH 22) zones

Near (FH 22) and Intermediate Combined

Without Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences							
Pentax AF	71.4	14.6	●							
Pentax AF Mini	67.4	3.1	●							
SolaMax	65.5	2.9	●	●						
Shamir Piccolo	59.3	1.5		●	●					
Younger Image	58.5	4.3		●	●	●				
Rdnstk Life AT poly	58.4	6.4		●	●	●	●			
Sig Kodak	58.4	3.8		●	●	●	●			
SOLA One	57.7	2.7			●	●	●			
Varilux Liberty	56.5	4.2			●	●	●	●		
Zei Gradal Top	55.2	3.9			●	●	●	●	●	
Varilux Panamic	54.0	3.7			●	●	●	●	●	
Zei Gradal Brevity	53.9	12.1			●	●	●	●	●	
AO Easy	53.4	2.6			●	●	●	●	●	
Varilux Comfort	52.0	3.3			●	●	●	●	●	
Sig Nav Short	51.5	7.6				●	●	●	●	
Sig Kod Precise	50.9	4.3				●	●	●	●	
Vis Ease Illumina	50.9	6.0				●	●	●	●	
Shamir Genesis	50.6	2.3					●	●	●	
AO Compact	49.8	2.1						●	●	
Vis Ease Outlk	49.0	2.3						●	●	
Rdnstk Life XS	48.2	3.3							●	
Sig Kod Concise	47.5	3.6							●	
Varilux Ellipse	40.4	2.9								●
Mean	54.8	8.6								

With Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences										
Pentax AF	67.4	8.8	●										
Pentax AF Mini	66.6	2.7	●										
SolaMax	63.1	2.1	●	●									
SOLA One	60.0	2.4		●	●								
Shamir Piccolo	59.0	1.4		●	●	●							
Varilux Panamic	59.0	2.7		●	●	●							
Zei Gradal Brevity	57.4	9.5			●	●	●						
AO Easy	57.1	2.0			●	●	●						
Younger Image	57.0	3.8			●	●	●	●					
Sig Kodak	55.5	3.0			●	●	●	●					
Varilux Liberty	55.2	3.1			●	●	●	●	●				
Vis Ease Illumina	54.2	3.2				●	●	●	●	●			
AO Compact	54.2	1.4				●	●	●	●	●			
Zei Gradal Top	53.3	3.2					●	●	●	●	●		
Sig Kod Precise	52.2	3.3					●	●	●	●	●	●	
Shamir Genesis	51.8	1.5						●	●	●	●	●	
Sig Nav Short	50.2	3.5							●	●	●	●	
Varilux Comfort	49.7	2.5								●	●	●	
Rdnstk Life AT poly	48.6	4.1									●	●	●
Sig Kod Concise	48.3	2.6									●	●	●
Rdnstk Life XS	47.8	2.8										●	●
Vis Ease Outlk	47.6	1.7										●	●
Varilux Ellipse	44.0	2.9											●
Mean	54.7	7.0											

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 7 General vision usage category using combined ratings for distance, intermediate, and near (FH 18) zones

Distance, Intermediate, and Near (FH 18) Combined

Without Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences						
Rdnstk Life AT poly	50.9	5.7	●						
Shamir Genesis	50.5	5.0	●						
Younger Image	48.6	5.0	●						
Vis Ease Outlk	48.4	4.2	●						
Zei Gradal Top	46.4	3.3	●	●					
Sig Kodak	45.2	4.1	●	●	●				
Pentax AF	41.4	11.9		●	●	●			
Zei Gradal Brevity	40.9	8.0		●	●	●			
Varilux Liberty	40.3	3.5		●	●	●			
SolaMax	39.2	3.0			●	●	●		
Sig Kod Precise	38.7	4.0			●	●	●		
Varilux Panamic	38.6	3.5			●	●	●		
Varilux Comfort	37.9	6.2				●	●	●	
AO Easy	36.2	2.0				●	●	●	●
Vis Ease Illumina	35.7	8.2				●	●	●	●
SOLA One	35.6	2.2				●	●	●	●
Pentax AF Mini	35.5	4.7				●	●	●	●
Shamir Piccolo	34.1	2.0				●	●	●	●
Rdnstk Life XS	32.3	5.6					●	●	●
Sig Kod Concise	32.0	3.3					●	●	●
Sig Nav Short	32.0	7.2					●	●	●
AO Compact	31.0	4.0						●	●
Varilux Ellipse	29.3	2.5							●
Mean	39.2	8.1							

With Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences					
Shamir Genesis	51.7	3.5	●					
Younger Image	49.6	4.1	●	●				
Zei Gradal Brevity	47.6	6.5	●	●	●			
Varilux Panamic	47.4	2.5	●	●	●			
Vis Ease Outlk	47.2	3.2	●	●	●			
Zei Gradal Top	46.6	2.7		●	●			
Sig Kodak	45.6	3.0		●	●			
Pentax AF	44.9	6.1		●	●	●		
AO Easy	44.2	1.7			●	●	●	
SolaMax	43.4	2.0			●	●	●	
SOLA One	43.3	2.0			●	●	●	
Rdnstk Life AT poly	43.1	4.4			●	●	●	
Sig Kod Precise	43.1	3.3			●	●	●	
Varilux Liberty	43.0	2.3			●	●	●	
Vis Ease Illumina	42.8	4.5			●	●	●	
Pentax AF Mini	42.6	4.0			●	●	●	
Shamir Piccolo	40.1	1.6				●	●	●
AO Compact	40.1	3.6				●	●	●
Varilux Comfort	39.1	5.0					●	●
Sig Kod Concise	36.7	2.8						●
Rdnstk Life XS	35.9	4.2						●
Sig Nav Short	35.6	3.6						●
Varilux Ellipse	35.6	2.6						●
Mean	43.0	5.6						

Highest and lowest rated designs, determined as explained in the text, are in bold.

Table 8 General vision usage category using combined ratings for distance and near (FH 18) zones

Distance and Near (FH18) Combined

Without Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences				
Shamir Genesis	52.8	8.1	●				
Vis Ease Outlk	51.5	7.1	●				
Rdnstk Life AT poly	48.4	11.4	●				
Younger Image	45.1	8.3	●				
Sig Kodak	37.2	6.4		●			
Sig Kod Precise	36.8	6.5		●			
Zei Gradal Top	36.3	6.6		●			
Vis Ease Illumina	36.3	8.0		●			
Rdnstk Life XS	35.3	5.5		●	●		
Sig Kod Concise	34.5	4.4		●	●		
Varilux Comfort	33.2	7.9		●	●		
AO Compact	33.1	5.3		●	●		
Varilux Ellipse	32.6	3.3		●	●	●	
Shamir Piccolo	31.8	3.4		●	●	●	
Sig Nav Short	31.8	5.2		●	●	●	
Varilux Liberty	30.5	8.7		●	●	●	
Varilux Panamic	29.8	3.5		●	●	●	
AO Easy	29.8	3.4		●	●	●	
SolaMax	28.6	4.8		●	●	●	
SOLA One	26.5	2.9			●	●	
Zei Gradal Brevity	23.8	4.5				●	
Pentax AF Mini	13.6	7.9					●
Pentax AF	12.0	9.0					●
Mean	33.5	11.6					

With Astigmatism

PAL Design	Mean	SD	Ranges of Nonsignificant Differences					
Shamir Genesis	53.4	5.7	●					
Vis Ease Outlk	49.5	5.2	●	●				
Younger Image	46.9	6.0		●	●			
Vis Ease Illumina	43.2	4.6			●	●		
Sig Kod Precise	41.7	4.9			●	●	●	
AO Compact	41.6	4.3			●	●	●	
Rdnstk Life AT poly	41.1	9.1			●	●	●	
Varilux Panamic	40.8	2.7			●	●	●	
Sig Kodak	39.7	4.3				●	●	
AO Easy	39.3	2.2				●	●	
Zei Gradal Top	39.1	4.7				●	●	
Sig Kod Concise	38.6	3.5				●	●	
Shamir Piccolo	38.3	2.6				●	●	
Varilux Ellipse	38.1	3.1				●	●	
Rdnstk Life XS	38.1	4.0				●	●	
SOLA One	36.5	1.9				●	●	
Varilux Liberty	35.7	5.9					●	
Sig Nav Short	35.5	4.8					●	
Varilux Comfort	35.5	5.7					●	
SolaMax	35.4	3.3					●	
Zei Gradal Brevity	34.7	3.1					●	
Pentax AF Mini	26.3	6.1						●
Pentax AF	22.9	9.0						●
Mean	38.8	7.9						

Highest and lowest rated designs, determined as explained in the text, are in bold.

viewing needs. Upon questioning, these patients will indicate that they have noticed limitations of their vision with their current PALs, even though the problems are not large enough for them to complain. In these cases, the ratings can be used to select a new PAL that will provide better correction than their previous lenses. For example, a patient may report noticing field limitations when driving. In this case, Table 2 should be consulted to determine the distance rating. If the distance rating is low, then the distance vision of the patient can be improved by prescribing a new PAL with a higher distance rating.

Many patients are more oriented toward either distance or near tasks. Commercial drivers, physical laborers, or those involved with mostly outdoor or driving activities are primarily oriented toward using distance and intermediate vision, and near vision is not as important for these patients. For such patients, the distance lens ratings in Table 2 or the combined distance and intermediate ratings in Table 5 apply. Many other patients largely work indoors and otherwise live in indoor environments. Distance vision is not as important for these patients. For such patients, the lens ratings in Tables 3 or 6 apply.

An identical approach can be used to troubleshoot adaptation difficulties to newly dispensed PALs. For patients reporting distortions as an adaptation difficulty, the astigmatism ratings in Table 2 or the vision usage ratings in Tables 5 through 8 that include the astigmatism weighting can be used to identify whether the design contains more astigmatism compared with others.

Many other patients do not seem to have greater needs for either distance or near vision—their daily visual needs seem to require a balance of the two. For such patients, the general visual usage ratings in Tables 7 and 8 apply. The ratings in Table 7 are based on all 3 viewing zones (distance, intermediate, and near) and apply to patients with viewing needs at all 3 distances. The ratings in Table 8 are based on only the distance and near ratings and optimize the combination of the two without considering the intermediate rating. These ratings would apply to people with few intermediate visual needs. Computer work is a common example of the need for intermediate vision.

Minimum fitting heights

When a patient desires a small frame and the fitting height is 18 mm or less, consideration should be given to a PAL design in which the near addition occurs higher in the lens. Lenses designed for short fitting heights are usually referred to as “short corridor” PALs. The minimum fitting heights for the PALs measured in this study, along with the recommendation suggested by the manufacturer, are shown in Figure 8. These data can be used to select lenses when the frame selection dictates a short fitting height. Some caution should be exercised, however, because the data in Figure 8 are based on the sole attribute of the height of the near add—other design attributes are not considered. Short corridor lenses should be selected on the basis of the minimum measured fitting height in Figure 8 along with consideration of the vision usage ratings in Tables 2 through 8.

Conclusions

The optical characteristics of the different PAL designs are significantly different from one another. The differences are significant in terms of the sizes and widths of the viewing zones, the amount of unwanted astigmatism, and the minimum fitting height. Reasoning and task analyses[3] suggest that these differences can be used to select a PAL design that matches the particular visual needs of the patient; clinical trials studies are required to test this hypothesis.

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