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Research Paper

Design and Construction of Chart Evaluating Quantity of Vision in Those Wearing Progressive Addition Lenses

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ABSTRACT

Background and Objectives: Currently, there is no standard way to check the optimal fitting of Progressive Addition Lenses (PAL) and visual acuity variations when looking at different objects according to PAL's production mechanism. We need a standard method to control PAL subjectively according to research on its monitoring. These topics are checked in this study.

Methods: Two charts was designed for far and near distances using Persian letters and sentences with a logarithmic scale. Twelve subjects wearing PAL sat at 3 m and 30 cm distances, respectively, from far and near charts, and their visual acuity at Primary Position (Pp) and 15° up and down gazes, and 30° right and left gazes with single and progressive lenses were measured. To evaluate the stability of sharpness, measurements were repeated 5 minutes later. Also, to check the accuracy of vision, the measurements were compared to measurements recorded with a portable Rosenbaum pocket vision screener and E chart.

Results: The correlations between Persian and E charts with PAL were confirmed in all gazes except pp. Mean visual acuity in all gazes except pp and 15° up gaze showed the difference in these charts. There are also mean differences in all gazes except 15° down gaze in near vision.

Conclusion: Persian and Electronic charts are helpful to evaluate the visual acuity of those wearing PAL and fix the above-mentioned problems.

Keywords: Visual acuity, Charts, Progressive

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What is "already known" in this topic:

In 1862 Snellen far chart was designed which Baily and Lovie did not confirm it as standard chart so in 1982 ETDRS chart was designed. Maleki and Riazi designed logarithmic E chart for far distance. In 2013 Abdollahinia designed Persian chart for near distance. In 2020 jafarzadehpur designed Persian MNREAD chart.

What this article adds:

Chart Evaluating Quantity of Vision in Whom Wearing PAL constitute 2 portable logarithmic charts for far and near distances in Persian which there is just one line of optotypes or sentence at every pages of charts because of not moving head or eye. In addition to near chart is designed based on statement by the International Ophthalmic View Committee with the ability to run on Android.

Introduction

The Progressive Addition Lens (PAL) is used to correct presbyopia and other accommodative dysfunctions. PAL has a power slope starting on the top of he lens with a minimum value and increasing to a maximum at the bottom [1, 2]. These lenses are associated with some challenges which should be solved:

• PAL has no distinct part to separate the far, middle, and near parts of the lens.

• The positions of the eyes are not obvious at far, middle, and near distances vision according to each part of the lens.

• There is a visual change in looking at different objects. The unwanted astigmatism effect in wavefront-optimized PAL is ignored by the human sight system to have a more natural vision by reducing the amplitude and changing its axis direction to a vertical position. Defocus is reduced to 10% in these lenses by controlling power distribution [2].

There are PAL dynamic ranges. Point diffraction interferometry is used to measure PAL by calibrating the device and to have dynamic range and accuracy; a set lens of -10 to +10 diopter in near vision power with 0.25 steps was used in 2012. Dynamic range increased in 2 directions by replacing a pinhole like optical vergence compensation lens [3].

• There is optimal lens fitting based on optical and geometrical conditions. PAL fitting needs exact displacement according to the pupil center to determine the far vision center. Selecting an incorrect fitting place causes problems such as decreasing visual field, obvious vision just in a specific position, blur at the visual axis, and adjustment with an unappropriated head position [2]. Freeform PAL design improves the far, middle, and near vision region, decreasing blur [4].

• There are objective and subjective methods of monitoring PAL. Ronchi upgraded test technique showed exactly PAL's power distribution in 2003. This non-contact technique with a full field could measure significant changes in power slope [5] due to the particular non-symmetrical, aspherical form of their convex surface. However, the testing of the surfaces is not usually performed using whole-field methods because of the high dynamic range and resolution required for the slope changes in the convex surface. Applying some simple enhancements, a robust Ronchi test technique can be used to obtain accurate power distribution maps of commercial progressive lenses. In this technique, a CCD detector is used as a high resolution slope map, which combined with multiple acquisition techniques, allow for high resolution measurements of both lateral displacement (10-4 m. In 2012, PAL was tested with point diffraction interferometry [4]. In 2019, it was proved that wavefront technology could have a more philosophical view of how optical parameters, such as PAL work when light crosses it and about retina image quality [2].

• There is the subjective method predominance. In 2011, by comparing objective and subjective consequences of using PAL, it was proved that there are no significant objective differences between types of PAL checked, although in subjective tests adjusting with PAL improved [4].

• Therefore, to solve the first three problems, there is no solution. There is no standard to check PAL's optimal fitting. We need a standard method to control this lens subjectively according to research about monitoring

PAL and subjective methods predominance. These items are considered in this study.

For this purpose, appropriate charts for far and near distances are needed. Different charts have been designed; for instance, the Snellen far chart was used, but it is not ideal as there are irregular distances between lines and letters and various letters and numbers at each line. Bailey-Lovie chart is a logarithmic standard chart that does not have problems with previous ones, but it is large and does not have clinical use [6] due to a lack of awareness and accessibility to affordable treatment, and is even as high as 34% in developed countries. Definitions of presbyopia are inconsistent and varied, so we propose a redefinition that states "presbyopia occurs when the physiologically normal age-related reduction in the eye's focusing range reaches a point, when optimally corrected for distance vision, that the clarity of vision at near is insufficient to satisfy an individual's requirements". Strategies for correcting presbyopia include separate optical devices located in front of the visual system (reading glasses. International Ophthalmic Society of Visual Function Committee for near vision notified a statement [7] , based on which, Roghiyeh and Jafarzadehpour (2020) designed a Persian MNREAD chart. However, the chart is unsuitable for evaluating PAL's user vision because of no separation part in this lens and visual variations in different directions [8] the sentences with inappropriate reading time and repeated errors were excluded. Thirty-eight sentences were approved to create charts. To check the charts' validity and repeatability, 20 adults read both charts and a paragraph of a daily newspaper. Reading acuity, critical print size, and maximum reading speed were calculated. The measured reading speeds were compared to the readers' reading speeds for a paragraph of a daily newspaper. Bland-Altman plots were used to evaluate the agreement between the two charts. Results: Thirty-eight selected sentences were used in the final printed charts. There were significant correlations between maximum reading speed for Charts 1 and 2 ($r=0.87$, $P<0.0001$).

So in the present study, we design suitable charts to evaluate the quantity of vision in PAL users. Actually, regarding the PAL fitting, the users suffer problems such as blurred far or near vision, a little far or near range of vision, moving the head to read correctly, and so on after a few days of using PAL. These fitting problems can be noticed with the new charts (Persian and Electronic) instantly after fitting in the clinic, and the optometrist can be sure about proper construction by solving problems and rechecking them. So using these charts saves time by adjusting to lens and optimizing its fitting.

2. Materials and Methods

Standard charts like ETDRS are designed by standard principles (distance between two optotypes in a row is equal to the width of an optotype, the number of optotypes is equal in all rows, using a logarithmic system, optotypes size reduction in consecutive rows is linear and based on logarithmic (MAR) steps. In other words, the difference between each row is equal to 0.1 logMAR. However, English letters are not common in Iran they do not have the standards [9]. They are in different format, fixed for 6 meter test, with or without lighting, with unequal number of letters in each line and different contrasts. As a result, there is an essential need for a standard E chart representing all the standard criteria's. Methods: The new design E chart has been developed with CorelDraw® Software. Progression of the letter size is changed geometrically (0.1 Log Unit, so we designed two charts for far (3 m) and near (30 cm) distances based on standard principles with Persian letters.

To design proper optotypes for a far chart, 5 factors should be considered [10-16]:

- Modification into a 5*5 grid: Based on the Snellen standard chart design, each letter is modified into a 5*5 grid which subtended 5 minutes of arcs. ث ,پ, چ, خ, ذ, س, ش, ص, ض, ف, ق, گ and ژ letters are out of 5*5 grid. ا, د, ر, ز and ہ letters are very simple. ﻫ letter is complicated. آ, ب, ت, ج, ح, ع, غ, ط, ظ, ک, م, ل, ن, و and ی letters are proper.

- Letter legibility: For this purpose, 50 students from Mottahary high school in Shiraz City, Iran, were randomly selected. Then, 5*5 grids of black letters in 8.7 mm size were printed on white cards. Next, one of the +1.00 sphere, +2*90, or +2*180 lens, and one eye were selected randomly, and the lens was placed in a trail frame, and the other eye was covered. The subjects were asked to move slowly from a distance beyond their threshold letter identification toward cards until they could identify letters correctly; then, the recorded distance for each letter was converted to relative letter legibility by dividing it over the mean distance recorded for all tested letters. The relative letter legibility by cylinder defocus to spherical defocus ratio should not be more than 10%. Based on this procedure, آ, ب, ت, ج, ح, ع, غ, ط, ظ, ک, م, ن, و and ی letters are acceptable (Table 1).

- Optotype complexity depends on 4 factors: strokes, the orientation of strokes, angle, and points. For example, the ی letter has 5 angles, 2 horizontal and vertical orientations, 0 point, and 6 strokes, so its total complexity is 13. Persian optotype percentage difference to mean

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Letter	+1-00DS	+2.00x90	%(Cx90-S)	+2.00x180	%(Cx180-S)
آ	1,034	1,037	0,29	1,076	4,06
ب	1,032	1,040	0,78	1,075	4,17
ت	1,028	1,038	0,97	1,036	0,78
ج	1,025	1,026	0,10	1,035	0,98
ح	1,023	1,027	0,39	1,027	0,39
ط	1,012	1,023	1,09	1,089	7,61
ظ	0,964	0,974	1,04	1,035	7,37
ع	0.901	0.913	1,34	0.957	6,23
غ	0,895	0,911	1,79	0,969	8,27
ک	0,982	0,993	1,12	1,053	7,23
ل	1,045	1,048	0,29	1,101	5,36
م	1,011	1,017	0,59	1,014	0,30
ن	1,039	1,045	0,58	1,045	0,58
و	1,007	1,010	0,30	1,010	0,30
ی	0,951	0,955	0,42	1,035	8,83
Mean	0,997	1,004	0,74	1,037	4,16

Figure 1. Relative letter legibility by cylinder defocus to spherical ratio

complexity is -33.56 to 38.36, which is less than English optotypes (-56 to 40). Therefore, the Persian chart is more reliable.

- Letter similarity: For this purpose, 0 (for white squares) and 1 (for black squares) codes for each row of 5*5 grids of letters were recorded. Recorded codes were put next to each other, respectively, and compared with each 2 letter code. Similarity, the code numbers, which were divided into total codes, showed similarity. Between ح and ج, ط and ظ, ع and غ, one letter should be selected due to their high similarity (Figure 1).

- Letters confusion: Letters that were mistaken more than 10% of the time or identified correctly less than 70% of the time were omitted because of mistaking letters for each other. So آ, ب, ج, ط, ظ, ل, م, ن and ی letters are acceptable (Figure 2).

Percepted \ Presented																
	%	آ	ب	ت	ج	ح	ط	ظ	ع	غ	ک	ل	م	ن	و	ی
	آ	95										1				
	ب		93													
	ت	5		62		3								5		
	ج				93					20						
	ح					73										
	ط				2		87		3						3	
	ظ						5	95		5	4				2	
	ع								65	20						
	غ									48						
	ک								10	6	86				5	
	ل											89				
	م					6	4						93		12	
	ن		2	35		3								90		
	و							5			10		7		78	
	ی			3					22	19						90

Figure 2. Letter confusion index for letters

Presented letters should not be mistaken more than 10% of time or percept correctly less than 70% of time

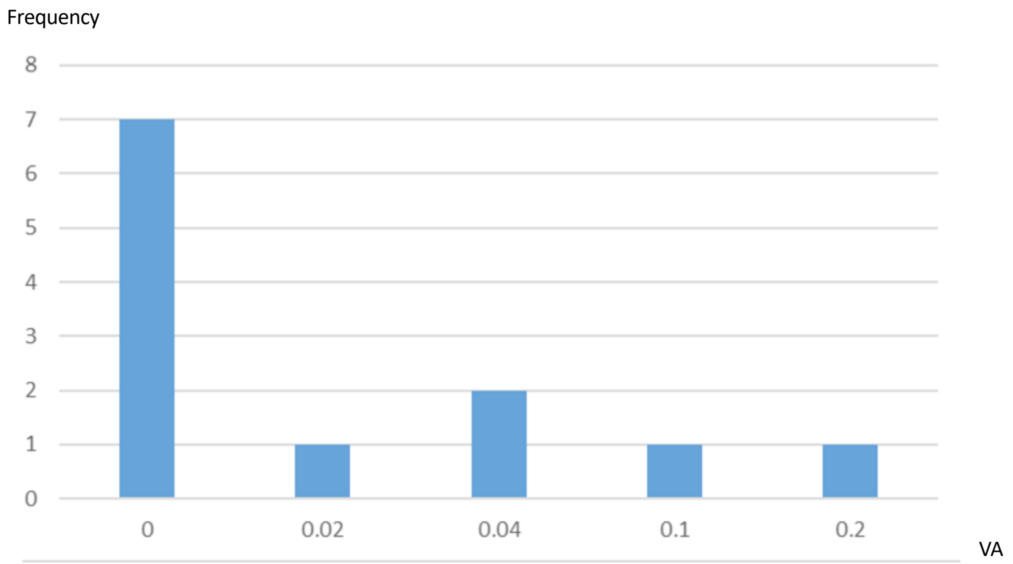

Figure 3. Far vision frequency based on logarithm with single lens and Persian chart at pp.

Finally, آ, ب, ج, ظ, ل, م, ن, and ی letters were selected for the far chart. The far chart has 11 rows and 5 letters (as it must be portable) that were randomly selected for each row (except the first one, which has 3 letters because of the large letter size). They printed black separately on white A4 cards to maximum contrast, and the subjects did not need to move their head and eye in each gaze direction (Figure 3).

Roghiey and Jafarzadehpour's study and Abdollahinia's results [8, 17] (sentences, B Nazanin font, and print size) were used to build the near chart. Each chart row was designed separately on a page (do not need to move the head) based on a logarithmic system in the form of software that is applicable to run on Android phones and tablets due to their easy use at clinics (Figure 4). Photopic light condition is usually 40-600 cd/m² [9] they do not have the standards. They are in different format, fixed for 6 meter test, with or without lighting, with unequal number of letters in each line and different contrasts. As a result, there is an essential need for a standard E chart representing all the standard criteria's. Methods: The new design E chart has been developed with CorelDraw® Software. Progression of the letter size is changed geometrically (0.1 Log Unit; therefore, room light is enough to use these charts.

Twelve subjects (Mean±SD age: 56.17±8.52 years) without pathological problems or deviation preventing the eye from rotating who was using E custom PAL were placed 3 m and 30 cm far away from respectively far and near charts in pp. 15° up and down gaze (80 cm far away from pp. in far vision and 9 cm from near vision) and 30° right and left gaze (1.5 m far away from pp. in far vision

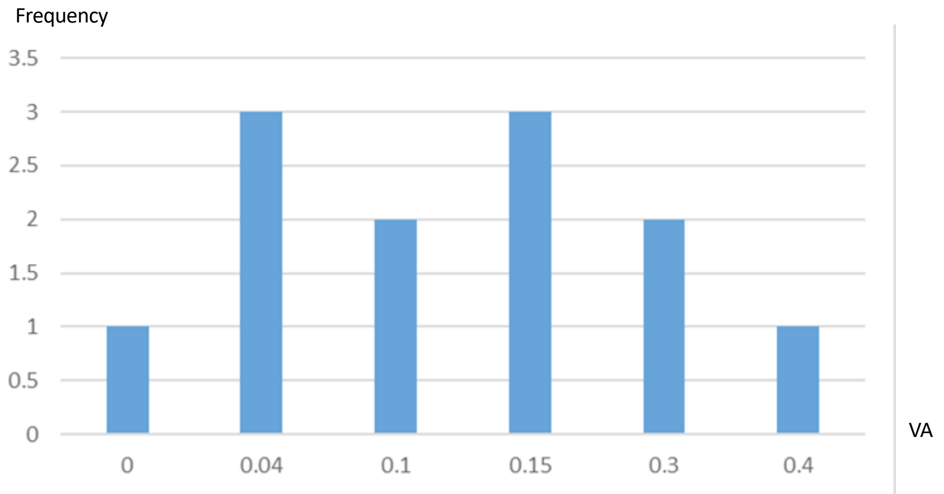

Figure 4. Far Vision Frequency Based on Logarithm With PALs and E Chart at 30° Right Gaze

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Figure 5. Row with 0.4 LogMar value of far Persian chart

and 20 cm from near vision) with single and progressive lenses were measured.

Far vision for 0-0.9 logMAR was calculated with this formula [9] they do not have the standards. They are in different format, fixed for 6 meter test, with or without lighting, with unequal number of letters in each line and different contrasts. As a result, there is an essential need for a standard E chart representing all the standard criteria's. Methods: The new design E chart has been developed with CorelDraw® Software. Progression of the letter size is changed geometrically (0.1 Log Unit:

VA=0.1+related row logarithm value -(0.02 numbers of read letters)*

Far vision for row with 1 logMAR:

VA=0.1+related row logarithm value - (0.034 numbers of read letters)*

Near vision [18]:

*VA=min print size read correctly+(errors*0.1/the rows words numbers)*

To evaluate the stability of sharpness, the measurements were repeated 5 minutes later. Also, to check the repeatability and accuracy of VA, the measurements were compared to measurements recorded with a portable Rosenbaum pocket vision screener and E chart [19, 20].

This study was conducted in Shiraz Imam Ali optometry clinic, Shiraz City, Iran.

3. Results

Mean far VA with E chart and PAL was not equal in different gazes. At 30° right and left gazes and 15° down gaze, VA reduction was seen. Also, there was a significant difference between them in the GLM test (P<0.0001) which was confirmed with the Persian chart too (Figure 5).

The comparison did not show significant differences (P=0.910). The correlation between visual acuities was confirmed except for visual acuity with PAL and Persian and E chart (P=0.064, r=0.549). There was a correlation between far vision with PAL at 30° right gaze with Persian and E chart (P=0.001, r=0.830) But their mean showed a significant difference (P=0.034) which were confirmed for 30° left gaze far vision (P=0.009, r=0.717), (P=0.001).

There was a correlation between far vision with PAL at 15° up gaze with Persian and E chart (P=0.003, r=0.769) and no proof to reject the equal mean hypothesis (P= 0.080). The correlation between far vision with PAL at 15° down gaze with Persian and E charts was confirmed (P=0.001, r=0.823), but their mean showed significant differences (P<0.0001) (Figure 6).

Average of visual acuity was the same for single vision and progressive lenses in the Persian chart and E chart

Figure 6. Row with 0.4 LogMAR value of near Persian chart

application. Mean near VA with PAL and Pocket chart at different gazes were not equal (P<0.0001), which was confirmed for the Electronic chart.

Mean near VA with a single and progressive lens with Electronic and Pocket chart at pp. in Wilkins Lambda (P=0.001), and the paired t test showed significant difference except for near vision with single glass and Pocket and Electronic charts comparison (P=0.250). However, the near vision with PAL with these charts had a significant difference (P=0.005).

The correlation between near vision with PAL at 30° right gaze with Electronic and Pocket charts was not confirmed (P=0.109, r=0.486) but at 30° left gaze, the correlation was confirmed (P=0.015, r=0.678). There was a correlation between near vision with PAL at 15° down gaze with Electronic and E charts (P=0.011, r=0.073), but at 15° up gaze, there were opposite results (P=0.146, r=0.446).

To evaluate the stability of sharpness in far and near, VA correlation with PAL at two different times (5 minutes later) at pp. was confirmed (r near=0.909 ,r far=0.795) and there was no proof of rejecting equal mean (P far=0297, P near=0.286).

4. Discussion

Far vision mean significant differences with E chart and PAL and with Persian chart and PAL at different gazes, as well as near vision mean significant difference with Pocket chart and PAL and with E chart and PAL at different gazes are due to unwanted astigmatism and power slope from top to bottom of PAL [1, 3, 5, 21, 22] and prove the first 3 PAL problems.

The correlation between Persian and E charts with a single lens at pp. was confirmed. So the Persian chart is valid because of using Bailey-Lovie principles in designing the chart, and equal legibility letters were selected as the correlation confirmed between the Snellen E chart and the Chinese chart in 2007 [15]. However, in 1996 Arabic chart did not correlate with the E chart [11] because of the more complex nature of Arabic letters. It seems that no correlation between Persian and E chart in far vision with PAL is because Persian letters are more sensitive due to different chart designs as the existence of just one line in each card.

VA reduction at 30° right and left gaze with Persian chart indicates more chart sensitivity due to different chart design as the existence of just one line in each card because of not moving head during measuring VA. VA reduction at 30° left gaze is less than the right due to the E Custom design lens.

There is a correlation between Electronic and Pocket charts in near vision at 15° down gaze with PAL. However, there is no correlation in 15° up gaze due to more Electronic chart sensitivity, as in 2013, there was a correlation between Persian near chart and Richman Card [17]. Because of using this study result to design an Electronic chart, the correlation with a Pocket chart is reasonable, so the E chart is valid.

Based on Figure 1, most subjects' far vision frequency with a single lens and Persian chart at pp. were 0 logMAR, while most subjects' far vision frequency with a single lens and E chart at pp. were 0.04 logMAR which is equal to two optotypes value less.

Based on Figure 2, most subjects' far vision frequency with PAL and E chart at 30° right gaze were 0.04 and 0.15, while most subjects' far vision frequency with PAL and E chart at 30° left gaze were 0.22. It seems that reducing the maximum VA at 30° left gaze is due to the E Custom lens design confirmed in far vision with the Persian chart and near vision with Electronic and Pocket charts.

Conclusion

Persian and Electronic charts for evaluating the vision of PAL users and solving told problems are helpful.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Conceptualization, Supervision, Investigation, and Writing – review & editing: All authors. Writing – original draft, and Funding acquisition, Resources Sahar Bache Sagha and Ebrahim Jafarzadehpour.

Conflict of interest

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مقاله پژوهشی

طراحی و ساخت چارت ارزیابی کمیت بینایی در افراد استفاده کننده از عدسی های پروگرسیو

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چکیده

مقدمه جهت بررسی فیت بهینه عدسی های پروگرسیو و بررسی تغییرات دید افراد در نگاه به اجسام مختلف با توجه به مکانیزم ساخت عدسی های پروگرسیو، استانداردی وجود ندارد. با توجه به تحقیقات صورت گرفته حول پایش این عدسی ها و برتری روش های سابجکتیو، نیاز به یک روش استاندارد برای کنترل سابجکتیو این عدسی ها ضرورت میابد. در مطالعه حاضر این موارد بررسی میشود.

مواد و روش ها بدین منظور دو چارت برای فواصل دور و نزدیک طراحی گشت که از حروف و جملات فارسی و مقیاس لگاریتم استفاده شد. سپس ۱۲ آزمودنی که از عدسی های پروگرسیو استفاده می کردند، در فواصل ۳ متری و ۳۰ سانتی متری به ترتیب نسبت به چارت دور و نزدیک قرار گرفتند و دید آنها در پرایمری پوزیشن و جهت نگاه ۱۵ درجه به بالا و پایین و ۳۰ درجه چپ و راست با عدسی های تک دید و پروگرسیو اندازه گیری شد. به منظور ارزیابی پایداری تیزبینی اندازه گیری ها پس از ۵ دقیقه تکرار شد. و به جهت بررسی تکرار پذیری و صحت و دقت آن اندازه گیری حدت بینایی با چارت استاندارد دیگری(چارت portable rosenbaum pocket vision screener در نزدیک و Eچارت در دور) ارزیابی گشت.

یافته‌ها مقایسه دو چارت فارسی و E چارت با عینک پروگرسیو همبستگی در تمام جهات به جز پرایمری پوزیشن تایید گشت. میانگین حدت در این حالات در تمامی جهات به جز پرایمری پوزیشن و ۱۵ درجه به بالا حاکی از تفاوت دو چارت می باشد.در دید نزدیک هم تفاوت میانگین در تمام جهات به جز ۱۵ درجه به پایین وجود دارد.

نتیجه‌گیری چارت فارسی و الکترونیک طراحی شده برای ارزیابی دید افرادی که از عدسی های پروگرسیو استفاده می کنند و رفع مشکلات گفته شده، مفید واقع شده است.

کلیدواژه‌ها:
چارت، حدت بینایی، پروگرسیو

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