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Individually Designed PALs vs. Power Optimized PALs Adaptation Comparison

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ABSTRACT

The practice shows that in everyday life we encounter ever-growing demand for better visual acuity at all viewing distances. The presbyopic population needs correction to far, near and intermediate distance with different dioptric powers. PAL lenses seem to be a comfortable solution. The object of the present study is the analysis of the factors determining adaptation to progressive addition lenses (PAL) of the first-time users. Only novice test persons were chosen in order to avoid the bias of previously worn particular lens design. For optimal results with this type of lens, several individual parameters must be considered: correct refraction, precise ocular and facial measures, and proper mounting of lenses into the frame. Nevertheless, first time wearers encounter various difficulties in the process of adapting to this type of glasses and adaptation time differs greatly between individual users. The question that arises is how much the individual parameters really affect the ease of adaptation and comfort when wearing progressive glasses. To clarify this, in the present study, the individual PAL lenses- Rodenstock's Impression FreeSign (with inclusion of all parameters related to the user's eye and spectacle frame: prescription, pupillary distance, fitting height, back vertex distance, pantoscopic angle and curvature of the frame) were compared to power optimized PAL – Rodenstock's Multigressiv MyView (respecting only prescription power and pupillary distance). Adaptation process was monitored over a period of four weeks. The collected results represent scores of user's subjective impressions, where the users themselves rated their adaptation to new progressive glasses and the degree of subjective visual impression. The results show that adaptation time to fully individually fit PAL is easier and quickly. The information obtained from users is valuable in everyday optometry practice because along with the manufacturer's specifications, the user's experience can give us a better insight in design and characteristics of progressive lenses.

Key words: *progressive lenses, individual parameters, individual progressive lenses, geometry, adaptation time*

Introduction

According to previous studies which compared types of presbyopic correction, progressive additional lenses were the most acceptable solution[1–3].

In this study two types of lenses were used, both lens types are freeform manufactured using spherical front surface and back surface modified for power prescription data combined with progression for addition. The perceived width of the field of good vision is a consequence of the combined action of the surface astigmatism of the progressive surface, the other surface and the oblique astigmatism induced by both surfaces. In particular the oblique astigmatism cancels the advantage which one might expect from back-surface progression. Rodenstock has shown in a study that due to this combined effect all unwanted astigmatism is merely the same, regardless if the progressive surface is front or back. Moreover, the study has shown similar results regarding magnification: although using approximation formulas associating some contribution to magnification to the base curve, a rigorous computation including all oblique bundles shows that the magnification distribution of a front-surface progression can be reproduced by a back-surface progression also. Lens aberrations can also cause the viewing zones of a progressive lens to become distorted from their ideal location as certain regions of unwanted astigmatism become more blurred while other regions actually become clearer.

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With sufficiently advanced software and a free-form delivery system, it becomes possible to customize the progressive lens design based upon the unique prescription requirements of each wearer. By fine-tuning both individual PALs and power optimized PALs the optical design of the progressive lens for the exact prescription using a sophisticated optical optimization process, residual lens aberrations are virtually eliminated within the limits of Minkwitz's Theorem. Wearers can therefore enjoy the widest fields of clear vision possible, regardless of prescription. Furthermore, the binocular utility of the lenses is maintained with more symmetrical fields of view[4]. This technology makes possible the application of various forms of lens design customization for the individual PAL's for the wearer[5]. When ordering individual PALs the correctness of several parameters must be assumed: correct refraction, precise ocular and facial measures, and proper mounting of lenses into the frame.

When ordering power optimized PALs the each progression is power optimized taking into account individual prescription power, the addition and the individual pupillary distance, which means that progression is made by using the new freeform technology of surface processing point by point, it is positioned on the back surface of the lens and is computer optimized for each prescription.

For manufacturing individual lenses, the manufacturer has to take customization a step further. Individual PALs are made individually for each face and frame. The physiognomy and the chosen frame determine the position of the lens in front of the eye. These individual factors are taken into account when producing the individual PALs.

The individual parameters are:

– Pantoscopic Angle (PT) represents the inclination of the lens in the vertical plane
– Face Form Angle (FFA) represents the angle between the lenses
– Corneal Vertex Distance (CVD) represents the distance between the eye and the lens
– Pupillary Distance (PD) is the distance between the pupils[5–8].

When ordering individual PALs a variety of additional parameters are considered, such as:

- power optimized corridor (frame style)
- power optimized distance zone
- power optimized addition power
- power optimized 3D position
- power optimized sphero-cylindrical power
- power optimized front base curve
- power optimized inset by order or by prescription and PD (pupillary distance)
- corrected wave front and optical aberration[9].

The question that arises is how much the above-mentioned individual parameters really affect the ease of adaptation and comfort when wearing progressive glasses. To clarify this, in the present study, the individual PAL lenses Rodenstock's Impression FreeSign (with inclusion of all mentioned options of individual design) were compared to power optimized ones Rodenstock's Multigressiv MyView.

A number of studies analyse preferences between different types of progressive additional lenses. For example, the aim of Han's study[6] »Clinical Assessment of a Power optimized Free-form Progressive Add Lens Spectacle« was »to compare objective clinical outcomes and subjective wearing experience with power optimized, freeform PALs to traditional, non-freeform PALs in an experienced wearing population and determine whether there are significant differences«[6]. The study compared power optimized, freeform to standard, non-freeform PAL spectacles through standard objective clinical vision assessments with computerized vision testing system for visual acuity under both high and low contrast such as would be performed in a doctor's office or clinic, and through novel objective assessments with specifically designed apparatus to detect more subtle differences in visual utility between various types of PAL spectacles. Finally, the study compared the two types of PAL spectacles in terms of subjective preferences, adaptation times and overall satisfaction; and they were evaluated through a battery of questions that have been specially adapted to study. That study is similar to this study in the part where they compared adaptation time and wearers satisfaction. The Han's results show that subjects adapted significantly more quickly to the power optimized freeform spectacles. The actual difference in adaptation time between the two was on the order of a few days at most, and nearly all subjects adapted to both pairs of spectacles within 2 to 4 days. It should be pointed out that all subjects were experienced PAL wearers. Subjects from this study preferred the test lenses for distance vision, active vision, transitional, and midrange vision, as well as overall[6,7]. Another study, of Boutron10, »The VEPRO trial: a cross-over randomised controlled trial comparing 2 progressive lenses for patients with presbyopia«, has »compared older and newer generation of progressive additional lenses but both were of nonfreeform technology«[10]. In this study subjects were randomly assigned to 2 treatment sequences: 1) use of the older-generation progressive lens for 4 weeks followed by the new-generation lens for 4 weeks or 2) use of the new-generation lens for 4 weeks followed by the older-generation lens for 4 weeks. To assess outcomes, opticians clinically evaluated subjects during visits at baseline and at weeks 4 and 8. The primary outcome was evaluated at the final visit (i.e., week 8), and secondary outcomes were assessed during the follow-up period (i.e., weeks 4 and 8). The primary outcome was patient preference for a progressive lens based on period of wear. Patients had to indicate the period they preferred on a scale of –5 to 5. Secondary outcomes were subjective measures of various areas of binocular visual performance. These were measured on a scale of 0–10 and included assessment of near visual acuity, distance visual acuity, intermediate visual acuity, global visual acuity, distance visual field, near visual field, kinetic visual skills when the person is moving but the environment is still, kinetic visual skills when the person

is still but the environment is moving, visual adaptability and comfort. Adaptation time to progressive lenses was measured on an 8-point Likert scale. The results showed faster adaptation with new PALs generation and subject's tendency to prefer the new generation of progressive lens[11]. The study is very similar to this study in way how evaluates wearer's answered. To our knowledge, there is no or not readily available published study which compared power optimized and individual free form PALs.

Materials and Methods

The sample of present research consisted of 40 participants aged between 40 and 70 (56±6; $\overline{X}$±SD). All participants had an addition, ranging from 1.50 to 2.75 dpt (2.2±0.3 dpt $\overline{X}$±SD). The participants have at least 1.0 visual acuity (0 logMAR) in both eyes and did not have any eye condition that could potentially affect their ability to use PALs as their refractive correction. The test spectacles were fitted using the 3D measurement tool »Impression Integrated Service Terminal« and manually with manual tools, all measurements were taken three times to ensure that fitting parameters were repeatable and reproducible. The Impression Integrated Service Terminal is a video centration device that automatically measures various fitting characteristics for individual subject and chosen frame. The 3D video centring system is the only system on the market, which provides a real three-dimensional measurement of all individual parameters and centring data precisely according to their position in space. This allows all the individual parameters and centring data to be determined as per DIN EN ISO 13666, DIN EN ISO 8624 and DIN EN ISO 58208[12].

Participants were given their new glasses with individual PALs (20 participants) or power optimized PALs (20 participants). They were observed over a period of 28 days or until they reported they were totally adapted to their new glasses and gave an estimate of final adaptation. The outcomes were assessed during the follow-up period. The follow-up period was not limited; participants were monitored every 7 days until they had achieved full adaptation to the new spectacle. It was considered that the longest period was four weeks. Participants were surveyed with questionnaire sets. The primary goal was to assess the rate of visual adaptation time to progressive additional lenses on a scale of immediately, 7 days, 14 days, 21 day, 28 days, more than 28 days or no adaptation. Participants were assessed for the visual comfort in different life situation, (e.g. reading, computer work, driving) and visual feeling when the person is moving, immediately after dispensing new spectacles and during adaptation time, which was scored on a grade scale of 1 to 5 (1-bad; 5-very well). In addition, they were assessed for subjective adaptation speed, which was graded with a scale from 1 to 3 (1-slowly; 2-moderate; 3-quickly). During the follow-up, they were asked if they have a particularly problem with looking at some of the particular distances. Same question was asked after adaptation time to assess if subjects were adapted to the new type of lenses. Finally, participants were asked whether they need additional lenses for reading, middle distances, or driving after adaptation time. In the end, they were asked the very important question, whether their next spectacles will be PALs?

During the test period participants were wearing exclusively their new PALs. The collected results represent the scores of user's subjective impressions, where the users themselves rated their adaptation to new progressive glasses and the degree of subjective visual impression.

Results

Descriptive statistics were calculated for each variable and a summary of the results can be seen in Table 1.

Variance of a single variable represents the average amount that the data vary from the mean and if two variables are associated they covary. Standard deviation is typically used as a unit of measurement into which any scale of measurement can be converted and is used for calculating covariance. Standardized covariance is known as a correlation coefficient and Pearson's correlation coefficient is regularly used to show the extent of bivariate correlation or correlation between two variables. Standardized covariance has to lie between –1 and +1[13]. The sign (+ or –) indicates only a direction of the correlation, not its degree[14]. A positive correlation indicates that if one variable increases the other increases by a proportionate amount. Conversely, a negative correlation suggests that if one variable increases the other will decrease by a proportionate amount.

Analysis showed that there is a statistically significant difference between people with individual PALs and power optimized PALs in the estimated speed of the initial adaptation ($t=2.4$; $df=38$; $p<0.05$). Participants with individual PALs have a higher initial estimate of speed of adaptation (2.8±0.4) than those with power optimized PALs (2.4±0.8). Also, there is a significant difference ($t=3$; $df=38$; $p<0.01$) in days that were needed for final adaptation. People with power optimized PALs needed more days to adapt to their new glasses (13.7±6.8) than those with individual PALs (8.9±2.2) (Figure 2).

Visual feeling when the person is moving, immediately after dispensing new spectacles, average grade of group power optimized PALs wearers was lower (3.5±0.6) than average grade of group individually PALs wearers (3.7±0.6), during adaptation time average grades were started to be significantly higher and similar for both group (power optimized PALs group, 4.2±0.5; group individually PALs wearers 4.4±0.4) (Table 1).

When putting on their glasses (with both individual and power optimized lenses) for the first time, average adaptation grade for that moment was 4.4±0.6, (Adaptation 1), vision comfort for the group was 4.5±0.6 and average time for final adaptation was 11.3±5.5 days and grade for the final adaptation to new glasses was 4.8±0.5, (Adaptation 2), and their estimation for speed of adaptation was 2.6±0.6. Correlations were conducted for all variables

TABLE 1
DESCRIPTIVE STATISTICS FOR THE GROUP, FOR INDIVIDUAL AND POWER OPTIMIZED PROGRESSIVE ADDITIONAL LENS WEARERS, NUMBER OF PARTICIPANTS=40

	All group $\overline{X}$±SD deviation	Individually PALs wearers $\overline{X}$±SD deviation	Power optimized PALs Wearers $\overline{X}$±SD deviation
Number of participants	40	20	20
Age [years]	56±6	56±6	56±6
Add [D]	2.2±3	2.2±3	2.2±3
Vision Comfort after adaptation time [Grade 1–5]	4.5±0.6	4.8±0.4	4.2±0.7
Days need for adaptation [days]	11.3±5.5	8.9±2.2	13.7±6.8
First assessment immediately after dispensing Adaptation 1 [Grade 1–5]	4.4±0.6	4.6±0.6	4.1±0.7
Assessment after adaptation time Adaptation 2 [Grade 1–5]	4.8±0.5	4.9±0.4	4.6±0.7
Visual feeling when person is moving immediately after dispensing [Grade 1–5]		3.7±0.6	3.5±0.6
Visual feeling when person is moving after adaptation time [Grade 1–5]		4.4±0.4	4.2±0.5
Speed of adaptation [Grade 1–3]	2.6±0.6	2.8±0.4	2.4±0.8

and the Pearson's correlation coefficients are shown in Table 2.

The correlation analysis showed that the addition was significantly correlated with all of the other variables, negatively with adaptation estimates and with speed of initial adaptation but, expectedly, and positively with age and days that were needed for final adaptation.

On the other side, positive correlation between variables of initial and final adaptation and vision comfort and speed of adaptation estimates show us that people with higher initial adaptation have reported higher comfort of vision and higher final adaptation. Also, there is a negative correlation between amount of days needed for final adaptation with comfort of vision in the beginning of wearing new glasses and also with initial and final adaptation. This shows that for the people estimating a lower comfort and adaptation initially will take longer to adjust to new glasses.

Dependent samples t-test is used when we want to compare means of two experimental conditions and the same participants took part in both conditions of the experiment. If the samples came from the same population then we expect their means to be roughly equal. The t-statistic is used to test whether the differences between two means collected from the same sample or related observations are significantly different from zero[13]. Student's t-test produces test statistics, which can be interpreted using p-values. The p-value is the probability of obtaining the observed sample results or any stronger deviation if the null hypothesis is actually true[15]. If this p-value is very small, usually less than or equal to a threshold value previously chosen called the significance level, traditionally

TABLE 2
CORRELATION BETWEEN AGE, ADD, GRADE OF VISION COMFORT, GRADE OF ADAPTATION IN THE BEGINNING, GRADE OF ADAPTATION SPEED, DAYS NEEDED FOR FINAL ADAPTATION

	Age	Add	Comfort	Adaptation 1	Speed of adaptation	Adaptation days	Adaptation 2
Age [year]	1	0.765**	−0.317*	−0.175	−0.292	0.15	−0.05
Add [dpt]	0.765**	1	−0.499**	−0.419**	−0.582**	0.468**	−0.334*
Comfort [grade]	−0.317*	−0.499**	1	0.684**	0.632**	−0.590**	0.575**
Adaptation 1 [grade]	−0.175	−0.419**	0.684**	1	0.709**	−0.745**	0.569**
Speed of adaptation [day]	−0.292	−0.582**	0.632**	0.709**	1	−0.902**	0.724**
Adaptation days [day]	0.15	0.468**	−0.590**	−0.745**	−0.902**	1	−0.708**
Adaptation 2 [grade]	−0.05	−0.334*	0.575**	0.569**	0.724**	−0.708**	1

*Correlation is significant at the 0.05 level; **Correlation is significant at the 0.01 level.

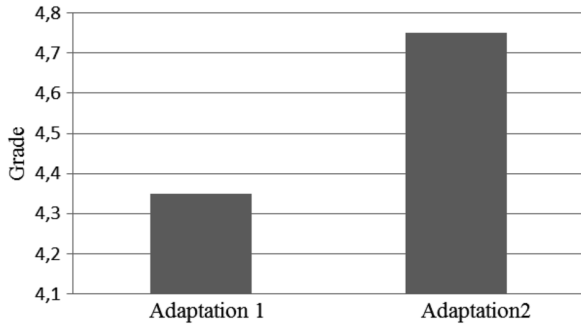

Fig.1. Initial (Adaptation 1-immediately after dispensing) and final (Adaptation 2-Adaptation was achieved) estimate for adaptation to progressive additional lenses.

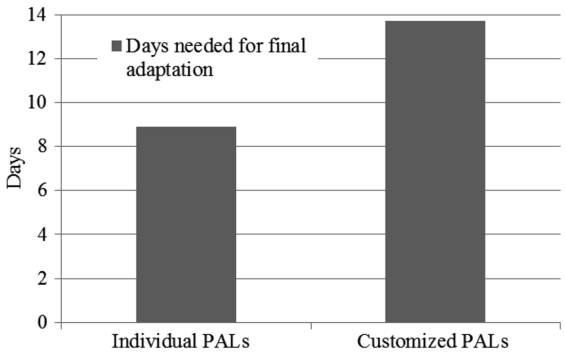

Fig.2. Days needed for final adaptation to individually and power optimized progressive additional lenses.

5% or 1%, it suggests that the observed data is inconsistent with the assumption that the null hypothesis is true, and thus that hypothesis must be rejected and a suitable chosen alternative hypothesis accepted as true[14]. If p is lower than 0.01 then probability that the null hypothesis is true is 1% (or 5% when $p<0.05$).

An analysis was carried out in order to better determine whether there was a difference between initial and final adaptation. Dependent samples t-test was carried out and a significant difference was found between adaptation to new glasses in the beginning and after days needed for final adaptation ($t=4.6$; $df=39$; $p<0.01$). As expected, final adaptation was estimated as higher (4.8 ± 0.5) than the one immediately after dispensing (4.4 ± 0.6), meaning that people should take some time to adjust to new glasses (Figure 1).

A series of t-tests for independent samples were conducted to see if people wearing different PAL-types also achieved different adaptation estimates, comfort of vision and speed of adaptation (initial estimate and days needed for final adaptation).

Figure 3 shows that approximately 20% of the complaints by individual PALs wearers were insufficient midrange (PC monitor) segment, on the other hand 40% of power optimized PALs wearers complained about insufficient both midrange, and near viewing segment. After the adaptation period passed, 10% of the complaints by individual PALs wearers remained compared to 25% of power optimized PALs wearers. Only one wearer of individual PALs and four of power optimized PALs wearers needed additional lenses for reading and middle distances, after adaptation time. Only one wearer of individually PALs and four of power optimized PALs wearers were asked, after adaptation time, additional lenses for reading and middle distances.

As it was already mentioned, the last question of the questioner sets was, whether the participant's next spectacles will be PALs. At the end of adaptation time, only

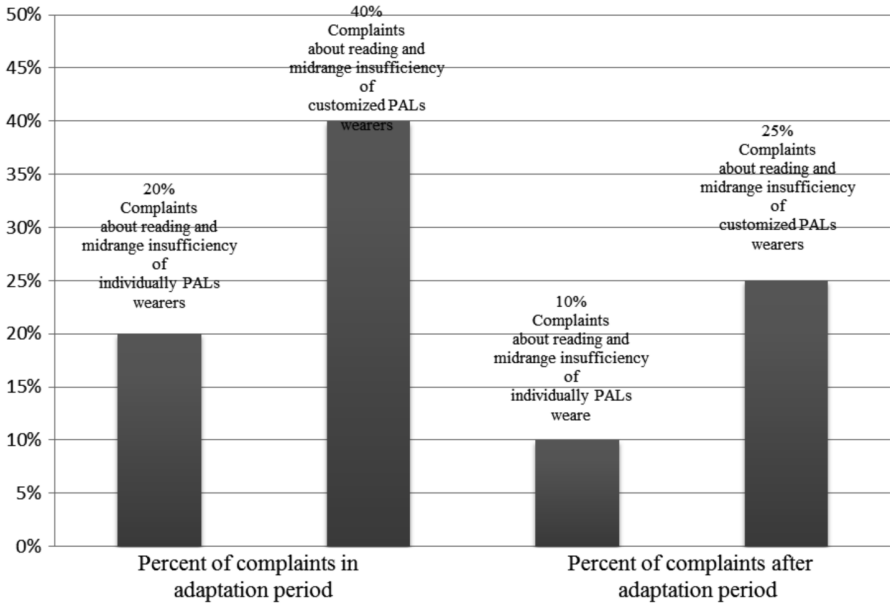

Fig.3. Complaints about particular distance range in period of adaptation and after adaptation time on progressive additional lenses.

one participant, who wore power optimized PALs answered negatively to that question.

Discussion

Power optimized PALs wearers adaptation time was a 54% longer, probably due to the optical compromise caused by use of only prescription and PD for customization versus the full set of parameters used in individual lens.

The parameters used in individual lenses in this study were[4,5,7,9]:

- power optimized length of the corridor 0.1 mm step from 10 mm up to 19 mm
- power optimized distance zone 0.1 mm step
- power optimized addition power 0.01 D step
- power optimized 3D position of wear (Face Form Angle up to 15 degrees)
- power optimized sphere 0.12 D step by order and 0.01D step by vertex distance
- power optimized front base curve
- power optimized inset by order or by prescription and pupillary distance
- corrected optical aberration
- wearer's specific visual demand resulting from lifestyle or work habits can be met by customizing progressive corridor

The complex interrelationship among the optics of the lenses, the fit of the frame, and position of wear, movement of the eyes and head for visual tasks at different viewing distance as well as individual characteristics of the user, seem to result in more successful visual performance[8].

The complaints by individual PALs wearers with insufficient midrange (PC monitor) segment and complaints of power optimized PALs wearers about insufficient both midrange, and near viewing segment after using their PALs for everyday activities for some time, most of the complaints were dropped; the users got use to the viewing conditions. The information obtained from users is valuable in everyday optometry practice because along with the manufacturer's specifications, the user's experience can give us a better insight in design and characteristics of progressive lenses.

A couple of wearers (7.5% of total) needed four weeks of time to adapt to their new viewing conditions with their power optimized PALs. Double-checking one wearer's parameters such as pantoscopic tilt and pupillary distance showed significant difference from standard values which are pantoscopic tilt 7 degrees, vertex distance 13 millimeters, face form angle 5 degrees and pupillary distance 63 millimeters[8,16]. Pantoscopic tilt is in minus range, which have significant effect on subjective outcomes on vision and it is fundamental parameter in the optical customization of the individual lenses[5–8,17]. Figure 4 shows how much these values differ from standard ones.

Figure 5 shows the case study of both power optimized (ordered ones) and individual (if ordered could improve

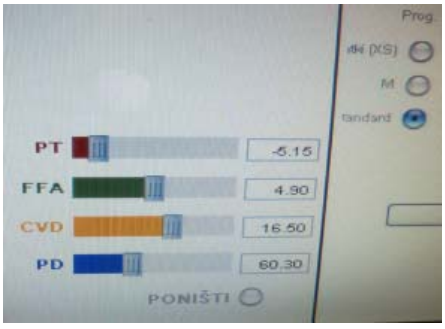

Fig.4. Case study parameters – pantoscopic tilt is in the minus range (measured with »Impression Integrated Service Terminal«).

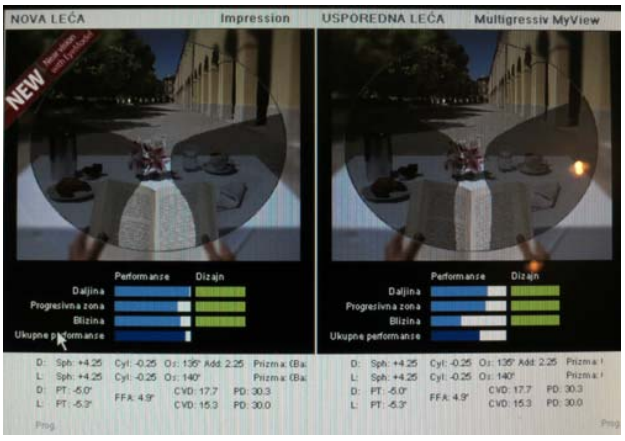

Fig.5. The case study – picture of comparison between individual (left) and if ordered how much could improve vision and power optimized (right), ordered ones progressive additional lens.

vision significantly) PALs, with pantoscopic tilt value and how much can viewing zones can differ if wearer's individual parameters were calculated when PALs were ordered.

The customization process for individual PALs is not an easy task, but with enough knowledge and patience one can achieve excellent results, providing top end optical solution for their customers.

Conclusion

The results shows that adaptation time to fully individual fit progressive additional lenses is shorter and less correlated to the addition, the perceived subjective quality of visual comfort are greater approximately by 12% for this type of lenses. It was observed that visual demand in everyday activities (movements, driving, work, computer usage, reading) are met with more ease (in terms of less swimming sensations that may occur when wearing progressive lenses) and more accuracy in individually designed PAL's. It is shown that adaptation time can be shortened if individual parameters related to the user's eye and position of spectacle frame on the face are used

when ordering progressive additional lenses. The adaptation can be further facilitated by choosing between designs of individual viewing zones in the progressive corridor, accordingly to user's daily activities (e.g. expanded middle zone for computer work), offered by the manufacturer.

It is very important to be very careful with frame parameters regardless the type of PALs that we are going to mount. The result shows that if power optimized progressive additional lenses are ordered the frame parameters should be as near as possible to standard ones.

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INDIVIDUALNO DIZAJNIRANE PROGRESIVNE ADICIJSKE LEĆE VS. PROGRESIVNE ADICIJSKE LEĆE OPTIMIZIRANE SNAGE USPOREDBA PRILAGODBE

SAŽETAK

Praksa pokazuje da se u svakodnevnom životu susrećemo s rastućom potrebom za boljom vidnom oštrinom na svim udaljenostima gledanja. Populacija s prezbiopijom treba korekciju za daljinu, blizinu i srednje udaljenosti s različitim dioptrijskim snagama. Progresivne adicijske leće (PAL) se pokazuju ugodnim rješenjem. Cilj ove studije je analiza čimbenika koji određuju prilagodbu na PAL korisnika koji ih po prvi put koriste. Samo novi korisnici su uključeni u studiju kako bi se izbjegle predrasude vezane uz prethodno nošene leće određenog dijazna. Za optimalan rezultat s ovim tipom leća nekoliko individualnih parametara je moralo biti uzeto u obzir: korektna refrakcija, precizne očne mjere i mjere lica, kao i pravilno postavljanje leća u okvir. Ipak, novi korisnici se susreću s raznim poteškoćama u postupku prilagodbe na ovaj tip naočala, a vrijeme prilagodbe značajno varira među pojedinačnim korisnicima. Nameće se pitanje koliko individualni parametri stvarno utječu na lakoću prilagodbe i udobnost pri nošenju progresivnih naočala. Kako bi se to razjasnilo, u ovoj studiji učinjena je usporedba individualnih PAL – Rodenstock's Impression FreeSign (s uključenim svim parametrima vezanim za korisnikovo oko i okvir naočala: recept, razmak zjenica, visina fitanja, udaljenost stražnjeg verteksa, pantoskopski kut i zakrivljenost okvira) s PAL optimizirane snage – Rodenstock's Multigressiv MyView (uzimajući u obzir samo prepisanu snagu i razmak zjenica). Proces prilagodbe je praćen tijekom razdoblja od četiri tjedna. Prikupljeni rezultati predstavljaju bodovanje korisnikovih subjektivnih dojmova, gdje su korisnici sami ocjenjivali svoju prilagodbu na nove progresivne naočale i stupanj subjektivnog vizualnog dojma. Rezultati pokazuju da je prilagodba na potpuno individualno prilagođene PAL lakša i brža. Informacije dobivene od korisnika su vrijedne u svakodnevnoj optometrijskoj praksi, stoga što nam, uz specifikacije proizvođača, iskustvo korisnika daje bolji uvid u dizajn i značajke progresivnih leća.