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VISUAL SYSTEM OPTICAL ANALYSES AND ITS CORRECTION BY PROGRESSIVE LENSES

Mihaela Baritz[1] **Diana Cotoros**[1], **Viorica Climov**[1], **Luciana Cristea**[1],
[1] University TRANSILVANIA from Brasov, Romania,
mbaritz@unitbv.ro, dcotoros@unitbv.ro, climov_vio@yahoo.com, lcristea@unitbv.ro,

Abstract : *In this paper we present certain aspects concerning the modeling and simulation of some Seiko type lenses used to correct different refraction defects. In the first two parts of the paper we presented the theoretical and mathematical aspects of the research upon the modeling procedures of the Seiko type lenses. In the third part we presented the results of the refractive defects correction modeling using Seiko type lenses and we analyze the aspects we got after modeling.*

Keywords: *visual system, progressive lenses, modeling,*

1. INTRODUCTION

In order to correct the unique refraction defects, air monofocal lenses are used, but for combined refraction defects this is only possible by using complex lenses (bifocal or trifocal) or progressive lenses. The monofocal air lenses consist of a simple sphere, assuring the correction for the close vision. The intermediate and far vision is unclear and distorted. The design of the bifocal, trifocal and progressive lenses combines the correction surfaces for intermediate and far vision with the correction surface for close vision in a single lens, obtaining this way a performing combined lens.

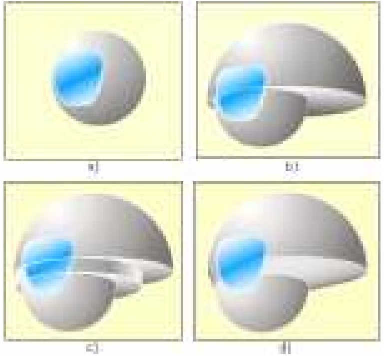


Figure 1 Basic differences between the Seiko progressive lenses (d) and monofocal (a), bifocal (b) and trifocal (c) lenses [6]

For the suitable, optical correction of a human subject, it is necessary to use an air lens in order to avoid the disadvantage of passing from the far-intermediate-close vision limits and allow a flexible, continuous vision process with no distortions of the image area. By comparing the characteristics of the trifocal lenses with those of the progressive lenses we can draw the following conclusions:

- *In case of* ***trifocal lenses****, a „third sphere" added between the spheres for close vision and far vision, has the role of producing an area for the intermediate vision. This way two distinct separation segments will be formed among the three areas. The trifocal lenses assure a clear close, intermediate and far vision for the human subject but due to raising of the diopter power suddenly from one area to the other, introduces a substantial visual discomfort;*
- *In case of* ***progressive lenses, especially the Seiko type****, a series of curvilinear continuous lines makes the connection between the areas, which assure the three vision types without visible separations. The progressive lenses have three distinctive areas, one used for far vision (the upper part of the lens), an area used for the close vision (lower part of the lens) and one for the intermediate vision (central part of the lens). The diopter power of the progressive lens is gradually increasing from the area corresponding to the far vision through the middle area for the intremediate vision to the area for close vision located at the lens lower part, so that the frontal area of the lens is a progressive surface assuring the visual correction and aberations control. By comparison to the bifocal and trifocal lenses, the progressive*

ones have an important benefit, namely the normal adaptability of the pacient, without fluctuations when the vision transfers fron an area to another.

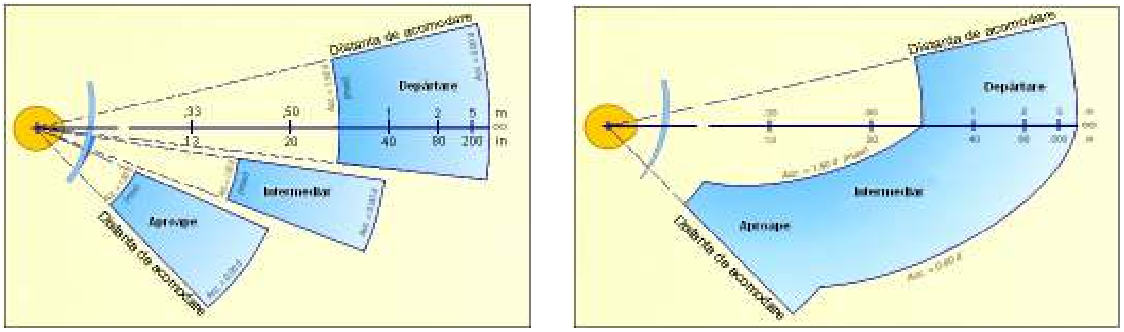


Figure 2. Concept scheme of the trifocal (a) and Seiko progressive lenses (b) [6]

Besides, the addition Seiko type progressive lenses assure a clear and continuous visual field from far to near, while the monofocal and bifocal lenses offer a clear visual field just limited to near or far. Also, the progressive lenses are the only lenses which assures a clear and comfortable intermediate vision, regardless of the diopter prescription.

2. LOCAL DESCRIPTION OF THE PROGRESSIVE LENSES SURFACES

In order to assure an optimal performance as far as the foveal vision is concerned, the image aberrations should be maintained at the lowest parts of the lens surface, mainly along the meridian axis and within its vicinity. In the edge areas of the lens, used for extra-foveal vision, the aberrations can not be totally eliminated. In these areas, the image quality is not absolutely necessary as long as the prismatic effects control is not very important. On the contrary, a very important factor connected to the lens edge is the motion perception, where the variation gradient of the residual aberrations is more important than their absolute value.

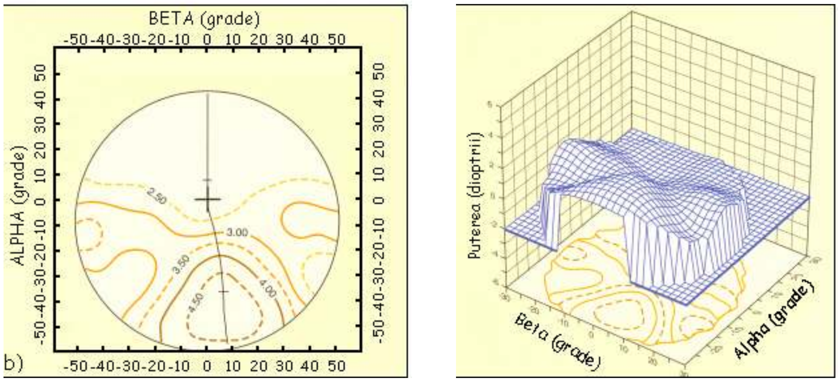


Figure 3 Description of the optic characteristics (contour diagram in 2D and 3D) for Seiko progressive lenses [6]

Any surface defined by the equation $z = f(x,y)$ can be mathematically expressed in a 3D system of coordinates *Oxyz – xOy*, which is tangent to a surface at the point O, by a quadric equation and this quadric surface being oscillatory with the surface at O, will be described by the following equation [4]:

$$z = rx^2 + 2sxy + ty^2 \tag{1}$$

where *r,s,t* are the local surface derivatives:

$$r = \frac{d^2z}{dx^2};\ s = \frac{d^2z}{dxdy};\ t = \frac{d^2z}{dy^2} \tag{2}$$

The quadric surface defines the local axes and the main curves of the surface at point O. Besides, any surface can be locally assimilated to a toric surface. This toric surface is characterized by its own main curves C_1 and C_2 and by the derived axes described in equation (6) [4].

$$C_1 \cdot C_2 = \frac{r \cdot t - s^2}{(1 + p^2 + q^2)^2} \quad \text{(total curvature),} \tag{3}$$

$$\frac{C_1 + C_2}{2} = \frac{t \cdot (1 + p^2) + r \cdot (1 + q^1) - 2 \cdot p \cdot q \cdot s}{2 \cdot (1 + p^2 + q^2)^{3/2}} \quad \text{(main curvature),} \tag{4}$$

where:

$$p = \frac{dz}{dx} \text{ si } q = \frac{dz}{dy}. \tag{5}$$

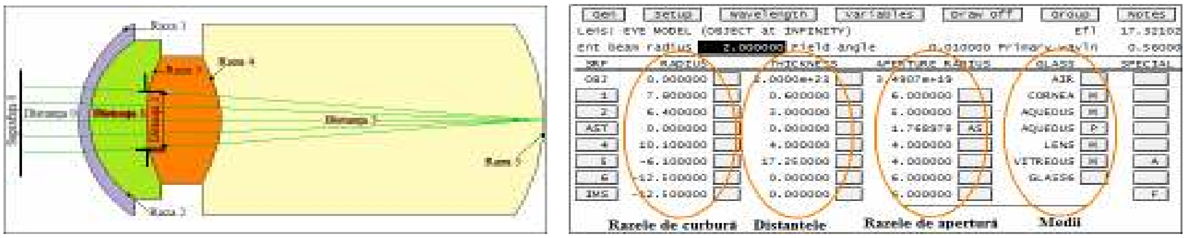
$$[tpq - s(1 + q^2)m^2 + [t(1 + p^2) - r(1 + q^2)]m + s(1 + p^2) - rpq = 0 \tag{6}$$

3. CORRECTIONS MODELING WITH SEIKO TYPE PROGRESSIVE LENSES

In order to model the corrections by help of Seiko progressive lenses we used the OSLO (*Optics Software for Layout and Optimization*) program. The"OSLO" software is used for the simulation and analysis of the optical systems offering a software development technique, including an interactive graphical and mathematical system, libraries and databases.
For the optical simulation of the normal visual function and the progressive lenses corrections it is necessary to obtain a mathematical model of the phenomena involving these functions, namely:

- analysis of the image generation on the retina for an emmetrop, farsighted and nearsighted eye, for all the three areas of presbyopia (close, intermediate and far), as well as the calculus of the optical transfer function.

This study begins by presenting a modeling of the normal visual function (emmetrop eye) analyzing: image generation on the retina by identifying the focal length, optical aberrations, as well as the wave front. Also, by means of this modeling we accomplish the calculus of the optical visual transfer of the visual system and its optical simulation, presenting the eye optical model and determining the image quality obtained by this.
In fig.4 we represented the geometric parameters of the optic system, required for the emmetrop eye modeling, where: *surface 0* – is represented by the object located at an infinite distance; *distance 1* – thickness of the watery humor; *distance 2* – pupil diameter; *distance 3* – distance between the interior curvature of the crystalline and retina surface (thickness of the vitreous humor); *radius 1* – radius of curvature of the cornea external surface; *radius 2* – radius of curvature of the cornea internal surface; *radius 3* – radius of curvature of the crystalline external surface; *radius 4* – radius of curvature of the crystalline internal surface; *radius 5* – retina radius of curvature.



Lens: EYE MODEL (OBJECT AT INFINITY) Efl 17.32102

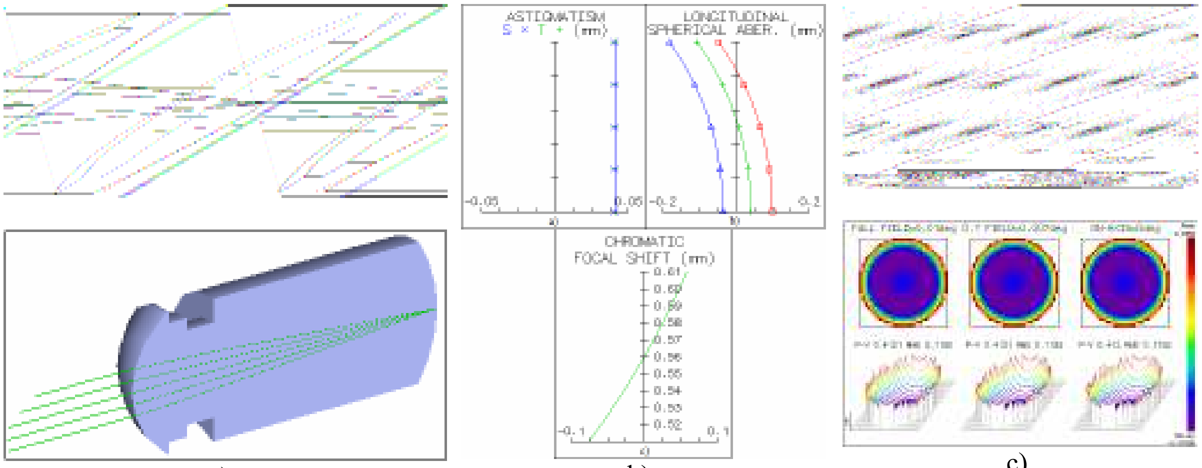
Ent beam radius 2.000000 Field angle 0.010000 Primary wavln 0.56000

SRF	RADIUS	THICKNESS	APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000	2.0000e+22	3.4907e+18		AIR		
1	7.800000	0.600000	6.000000		CORNEA	M	
2	6.400000	3.000000	5.000000		AQUEOUS	M	
AST	0.000000	0.000000	1.768978	AS	AQUEOUS	P	
4	10.100000	4.000000	4.000000		LENS	M	
5	-6.100000	17.260000	4.000000		VITREOUS	M	A
6	-12.500000	0.000000	6.000000		GLASS6		
IMS	-12.500000	0.000000	6.000000				F

Razele de curbură Distanțele Razele de apertură Medii

Figure 4 Representation (graphical and tabulated) of the geometric parameters for an emmetrop eye.

Following the introduction of the geometric parameters for the emmetrop eye (according to table in fig.4) we got its 2D/3D optical system, as one can notice in fig.5, also the graphical representations of the geometric and chromatic aberrations and the size of the light spot and wave front.



a) b) c)

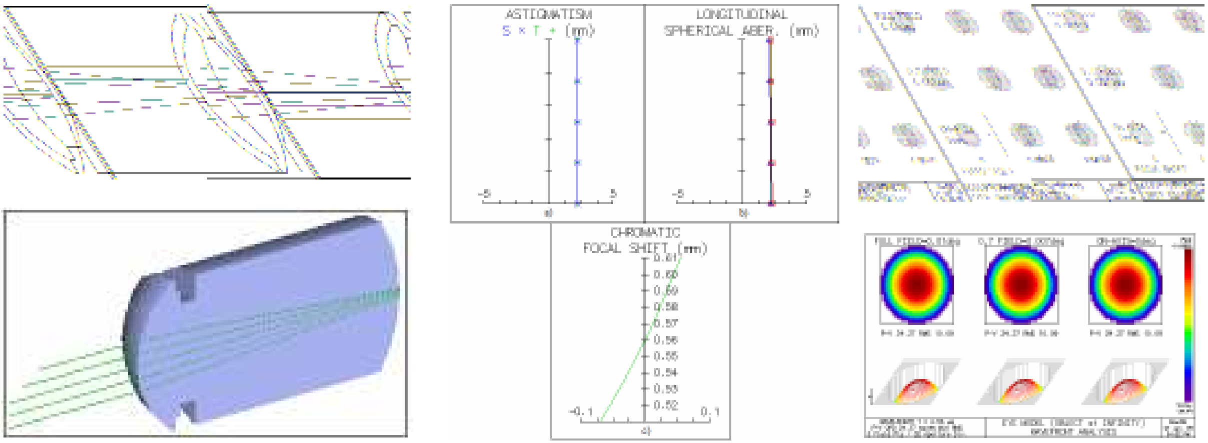
Figure 5. Representation of the 2D and 3D model for the emmetrop eye eyeball obtained by software modeling (a) and respectively the aberrations values(b), light spot and wave front(c)

After the visual function analysis of the emmetrop eye we analyzed and modeled both, the farsighted eyeball and the nearsighted one, as well as the optical correction of these refraction defects using progressive lenses in the following alternatives:

- ☐ correction of the hyperopic eye for close vision with progressive lenses with refraction index *1,5*;

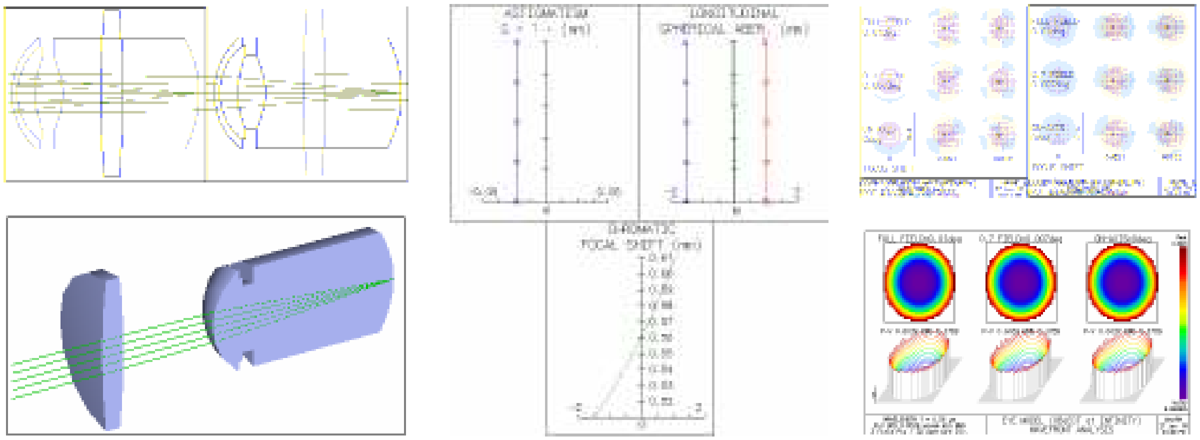
- correction of the hyperopic eye for intermediate vision with progressive lenses with refraction index *1,5*;
- correction of the hyperopic eye for far vision with progressive lenses with refraction index *1,5*;
- correction of the myopic eye for close vision with progressive lenses with refraction index *1,5*;
- correction of the myopic eye for close vision with progressive lenses with refraction index *1,67*;
- correction of the myopic eye for intermediate vision with progressive lenses with refraction index *1,67*;
- correction of the myopic eye for far vision with progressive lenses with refraction index *1,67*.

Following these models by OSLO software we obtained a series of graphical represented results shown in the next figures, as for example for the hyperopic eye, both as shape and construction of the eyeball structure affected by the refraction defect and as analyses of the image quality and not least of the correction with Seiko type air lenses.



a) b) c)

Figure 6. 2D and 3D representation of the optical system from the hyperopic eyeball with a focal distance of 16,21 mm (a), non-corrected system aberrations graph (b), analysis of light spot and wave front (c)



a) b) c)

Figure 7. 2D and 3D representation of the optical system from the hyperopic eyeball with a focal distance of 16,21 mm corrected with a positive lens with n= 1,5 (a), corrected system aberrations graph (b), analysis of light spot and wave front (c)

In the same way we performed the optical models by OSLO software according to the presented variants. The OSLO software allows the obtaining of other data out of the adopted model, like the graphical representation of the PSF function for the analysis of the intensity distribution on the image surface, an extremely important parameter especially for the progressive lens, because the image quality should not be deteriorated at the lens edge.

4. CONCLUSION

Each time we accomplished the modeling of the defect correction by this modeling program kit OSLO we analyzed all the variants possible to be met in the current practice, allowing thus the construction of a database for corrections comparison. The correction by Seiko type progressive lenses proved to be more laborious as the design of the surface shape requires more dimensioning and optimizing calculus operations due to the ”freeform” procedure and to the different values of the progression channel. Thus, we could observe along the simulations that the non-spherical Seiko type progressive lens manufactured by freeform technology and having a progression channel of 10,4 to 14 is the variant that might cover a very large range of corrections of the refraction defects, especially when they are accompanied by a pronounced astigmatism.

5. ACKNOWLEDGMENTS

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