SIMULTANEOUS VISION OPTICAL LENS FOR CORRECTING PRESBYOPIA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention concerns an optical lens for correcting presbyopia, that is to say a lens for compensating defective accommodation of the crystalline lens, the accommodation capability of which decreases with age.

2. Description of the Prior Art

An optical lens of this kind must enable the wearer to see clearly an object at any distance (far away, intermediate distance or near).

The present lens is of the progressive simultaneous vision kind in which the non-optical central part, which has a diameter substantially equal (at low light levels) to that of the pupil, comprises respective annular areas for far vision, intermediate vision and near vision, with the near vision area inside the far vision area or vice-versa.

It may be a contact lens or an intra-ocular implant or an intra-corneal lens.

A unifocal optical lens is usually characterized by its power in diopters which is the reciprocal of its focal length, all incident light rays parallel to its optical axis passing through its focus irrespective of their initial distance from this axis.

A bifocal optical lens with two well-defined concentric areas has two corresponding separate powers, one for correcting ametropia in far vision and the other for compensating presbyopia in near vision. The difference between these two powers is referred to as the "addition".

Strictly speaking, however, in the case of a progressive simultaneous vision lens these power characteristics (which from the wearer's point of view represent the ophthalmic requirements for satisfactory sight) are more or less wanting, the useful optical area of a progressive lens of this kind having no stable power characteristics, strictly speaking.

For this reason the term "proximity" is used hereinafter rather than the term "power" to refer to the reciprocal of the distance at which a light ray parallel to the optical axis of the lens crosses the axis after passing though the lens.

In practise the proximity of an optical lens for a person with presbyopia must have at least two distinct ranges of values appropriate to the changing visual requirements of the wearer, namely a range of values specifically intended for far vision and a range of values specifically intended for near vision, the latter being deduced from the former by adding a specific "addition" with continuous intermediate joining values between these values, the whole representing a particular law of evolution determined in each case.

The problem is that, given the theoretically ideal solution of a rapid change between the proximity value for far vision and its value for near vision, there is no law of evolution universally applicable to obtain good results for all persons, the best law of evolution for each person depending in particular on the addition needed by that person.

A linear or quasi-linear addition law, for example, or a single law whatever the addition, does not give good results in practise, the wearer not seeing particularly well either far away or near.

The present invention is based on the new discovery that it is possible to achieve good results systematically by making the curve representing the proximity as a function of the distance from the axis fit within specific limits characteristic of the addition needed by the wearer.

SUMMARY OF THE INVENTION

The invention consists in a progressive simultaneous vision optical lens for correcting presbyopia in which the curve representing its proximity P defined as the reciprocal in diopters of the distance D at which a light ray parallel to and at a distance h from its axis crosses the axis after passing through the lens lies within an area between a lower envelope curve P_{inf} and an upper envelope curve P_{sup} defined by nth and hth degree polynomials and satisfying the following equations:

$$P_{inf}=f(h)=(\Sigma A'_i h^i)+P_{VL}$$

$$P_{sup}=f(h)=(\Sigma A''_i h^i)+P_{VL} \quad (I)$$

in which P_{VL} is the proximity needed for far vision and A'_i, A''_i are the coefficients of the various polynomials depending on the value of the proximity addition $\delta_1=A_{DD}$ corresponding to the degree of presbyopia of the wearer, the values of these coefficients being substantially as follows:

for A_{DD} = 1.5 D:	
A'0 = 12.532267	A''0 = 16.9452
A'1 = −92.695892	A''1 = −106.8394
A'2 = 305.16919	A''2 = 302.62347
A'3 = −513.44922	A''3 = −443.97601
A'4 = 476.63852	A''4 = 362.53815
A'5 = −247.99097	A''5 = −166.29979
A'6 = 67.868942	A''6 = 40.015385
A'7 = −7.6131396	A''7 = −3.9203446
for A_{DD} = 2 D:	
A'0 = 23.56555	A''0 = 14.368889
A'1 = −182.77804	A''1 = −87.219223
A'2 = 605.05684	A''2 = 244.35987
A'3 = −1 024.1053	A''3 = −337.92626
A'4 = 962.99613	A''4 = 241.37509
A'5 = −511.24120	A''5 = −85.757212
A'6 = 143.7355	A''6 = 12.008102
A'7 = −16.663562	
for A_{DD} = 2.5 D:	
A'0 = −28.307575	A''0 = 2.874459
A'1 = 190.37743	A''1 = 11.541159
A'2 = −445.545294	A''2 = −35.715782
A'3 = 512.44763	A''3 = 37.849808
A'4 = −315.3125	A''4 = −19.0199096
A'5 = 99.678413	A''5 = 4.2867818
A'6 = −12.731333	A''6 = −0.28934118
for A_{DD} = 3 D:	
A'0 = 22.19555	A''0 = 57.071102
A'1 = −157.74065	A''1 = −357.09277
A'2 = 529.74104	A''2 = 1 000.8899
A'3 = −918.56382	A''3 = −1 509.5112
A'4 = 881.73279	A''4 = 1 311.576
A'5 = −475.73774	A''5 = −657.94254
A'6 = 135.48897	A''6 = 177.01095
A'7 = −15.888513	A''7 = −19.763759

and, for possible intermediate additions whose value δ is between two above-mentioned addition values δ_1 and $\delta_1+0.5$, the envelope curves of these intermediate additions are deduced from the envelope curves corresponding to δ_1 and $\delta_1+0.5$ by the equations: