PROGRESSIVE POWER OPHTHALMIC LENSES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 246,139, filed Apr. 2, 1981, now abandoned, which is a continuation-in-part of application Ser. No. 232,755, filed Feb. 9, 1981, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to ophthalmic lenses in general and is more particularly concerned with improvements in progressive power lenses for the correction of presbyopia.

2. Description of the Prior Art

The use of progressive power lenses for the correction of presbyopia has become increasingly popular in recent years. In addition to their obvious cosmetic appeal, progressive lenses provide significant functional benefits to the patient, namely a continuous range of focal powers and an unobstructed visual field. Such advantages are, however, partially offset by peripheral astigmatism and distortion aberrations that are unavoidably present in all progressive lenses. The design of progressive lenses thus naturally centers on reducing the unwanted aberrations to minimum effect.

It is generally recognized that the aberrations can be minimized permitting them to extend over broad areas of the lens including, for example, the peripheral portions of the near vision level. This, of course, implies a sacrifice of acuity in those peripheral areas. However, virtually all modern commercial progressive lenses make use of the principle of extended-area aberration control. U.S. Pat. Nos. 3,687,528 and 4,056,311 are exemplary.

It is not enough merely to state that the aberrations shall occupy extended areas of the lens. The manner of their distribution within those areas is critically important. Badly distributed aberrations can undo the potential advantage gained by sacrificing acuity within the peripheral areas. For example, if a high value is placed on the requirement of orthoscopy (i.e. the maintence of horizontals and verticals in visual field), the designer shapes the peripheral aberrated zones in such a way that the component of vertical prism along horizontal lines remains constant. The corrected peripheral areas, however, must be joined to the central portion of the intermediate area, and the latter cannot be corrected to preserve orthoscopy. Therefore, a blend zone must be interposed between the inner and outer areas. The blend must not be made too abruptly or the visually annoying condensation of aberration within the blend zone will overpower and may effectively negate the advantage of orthoscopy gained at the lens periphery.

Progressive lenses heretofore designed for preservation of orthoscopy do not directly address the requirement of uniform distribution of aberrations and it is a principal object of this invention to fully exploit a technique of extended-area aberration control to achieve smooth and natural optical effect.

More particularly, there is the objective of providing a progressive power ophthalmic lens with progressive surface designed to insure a uniform distribution of aberrations and a smooth optical effect with orthoscopy at least approximately preserved in lateral peripheral areas of the lens and without accrual of strong aberrations elsewhere in the lens.

Still another object is to provide a natural flow of optical lens power which will be readily accepted by emerging and advanced presbyopes alike.

SUMMARY OF THE INVENTION

The only known method for reducing the strength of progressive power lens aberrations is to allow a spread over a larger than usual area which entails redefinition of boundaries of the spherical distance portion (DP) and reading portion (RP) zones.

With many variations possible, including circular and parabolic RP's beneath a straight or upwardly concave arc defining the DP boundary, a progressive intermediate portion (IP) is generated by the line of intersection of an ordered sequence of intersecting spheres and cylinder surfaces with cylinder chosen to produce a gently curving surface insuring smooth optical effect.

Details of the invention will become apparent from the following description when taken in conjunction with accompanying drawings:

IN THE DRAWINGS

FIGS. **1A** and **1B** illustrate, in vertical elevation and cross-section respectively, a progressive power ophthalmic lens of a type dealt with according to the present invention;

FIG. **2** illustrates the evolute of the meridional line of the lens of FIGS. **1A**, **1B**;

FIG. **3** is a schematic illustration of construction of a progressive surface of the lens of FIGS. **1A**, **1B**;

FIG. **4** is a vertical elevational view of a prior art progressive power ophthalmic lens showing various viewing zones thereof and the associated power law;

FIGS. **5A**, **5B**, **5C** and **5D** diagrammatically illustrate some of various definitions of DP and RP boundaries possible to achieve a reduction of strength of aberrations according to the invention;

FIGS. **6A** and **6B** demonstrate a geometrical transformation from a prior art IP of lens progressive power to one representative of the present invention;

FIG. **7** schematically illustrates a development of cylindrical surfaces chosen to satisfy aims of the present invention;

FIG. **8** depicts viewing zones of a lens constructed according to principles of the invention;

FIG. **9** is an electronic computer evaluation of one half of a symmetrical lens of the general design depicted in FIG. **8**; and

FIG. **10** illustrates a grid pattern produced by a lens of the FIGS. **7–9** design.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Lenses under consideration by the present invention are assumed to be made of glass or a plastic material having a uniform refractive index. The changing curvatures required for progressive power are confined to the convex side of the lens with the concave side being reserved for prescription grinding in the usual way. The convex side of the lens will hereafter be referred to as a "progressive surface". However, there is no intention to limit the invention to lenses having convex progressive surfaces since the present principles apply equally well to convex or concave progressive surfaces.

The lens design which comprises the present invention is considered an improvement over earlier design