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FURTHER DEVELOPMENT OF A BADAL TYPE PHOTORETINOSCOPE

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Author Biography

Jeffrey Scott Fleming was born in Lancaster, California. His family moved to Torrance, California when he was age four. He began working in his father's practice during his last two years in high school. He received his Associate in Arts degree from El Camino Junior College, and then his Bachelors in Biology from California State University, at Long Beach. He has held employment throughout his education, including working in several practices, supervising the finishing department of a large ophthalmic laboratory, and being sole proprietor of his own ophthalmic finishing laboratory. He has also been very active in local and national optometric student politics, holding positions such as the American Optometric Student Association (AOSA) Trustee, Chairman of the AOSA Membership Development Committee, Chairman of the AOSA Benefits Committee, AOSA National Liaison to the Optical Laboratories Association (OLA), and AOSA Treasurer. He is listed in the 1990-91 Who's Who Among Students in American Universities and Colleges, and was given the AOSA Service Award for his devoted service to AOSA in 1991-92. His goals are to enjoy his own private professional optometric practice providing quality care in all facets of the ophthalmic field.

Abstract

Several design changes have been made to improve the sensitivity of the existing experimental Badal type photoretinoscope apparatus to make the instrumentation more practical as a screening device. The design changes include the use of: aspheric lenses; a narrow pass light filter; a decreased exit pupil diameter; and a single luminous object used with a coincidence (vernier) Scheiner system implemented with a pair of vertically oriented pinhole apertures to test the vertical meridian of the test eye.

The resolution of the apparatus (using an emmetropic human eye analogue) was well under 1.0 D. Further modifications contemplated for the future include: a second pair of pinholes, horizontally oriented, to test the horizontal meridian, and the ability to axially rotate the pinholes along with the doubling prisms so as to sample oblique meridians, if necessary. Finally, the entire apparatus will need to be miniaturized and lightened to make it portable for field use (screening).

Key Words

Refraction, infant/children refraction, Badal optometer

Introduction

The most common preschool vision problems at the present time are strabismus and amblyopia. The estimate for their occurrence is near 5% [1]. The work of Ingram *et al* [2] shows that infants with errors of 2.50 diopters of hyperopia or more at age one, are 20 times more likely to develop strabismus and amblyopia than children with a refractive status closer to emmetropia. This raises the possibility that refractive screening of the population in infancy could identify children at risk of these disorders [3]. Another factor in screening infants is the ability to record accurate objective findings in a short amount of time. Given these points, and the ever escalating costs of today's health care, a portable, easily used, refractive screening device which can be used by paramedical personnel after a short training period would be useful.

Photoretinoscopy is an objective method of determining the refractive state from a photograph of a luminous fundus image. There are many types of photoretinoscopic devices, but the principles involved are similar. Typically, the subject is in a cycloplegic state when a form of photography records an image from the fundus on film for subsequent evaluation of the refractive status.

Urness *et al* [4] designed the original prototype of the system discussed in this paper, and also included a summary of several other types of photoretinoscopic devices. The design of Urness *et al* [4] was incorporated into a working laboratory prototype apparatus reported by Lim *et al* [5]. Several modifications have been made to this prototype and these are the subject of this paper.

Materials & Method

Modifications

The previous Badal type photoretinoscope system constructed by Lim *et al* [5] was modified as follows:

1) First quality aspheric lenses where used for **L1** and **L2** (formerly **P1** and **P2**) to improve the optics of the system (Figure 1).

2) The exit pupil of the system was more accurately positioned at the entrance pupil of the test eye, and was reduced in diameter to 3.5 mm. The foregoing necessitated replacing **L3** with a +3.00 D spherical lens (formerly +2.00 D), reducing the working distance from 50 to 37 cm.

3) A sharp cutoff yellow filter was introduced to improve the image quality by reducing the effects of chromatic aberration.

4) Several attempts were made to use opaque objects with the idea that they would provide easier fabrication and a less critical need for flux uniformity in the fundus images. However, the opaque objects presented an inadequate resolution of the image which led to the readoption of the original luminous type [6] object.

5) The object was further modified to a single luminous source used with a coincidence (vernier) Scheiner system (**CSS**).

6) Image retrieval is achieved via a beamsplitter less than one focal length from **L1**. This allows a fundoscopic view of the vernier images.

Explanation of the Apparatus (Figure 1)

Light originates from a coiled tungsten filament (**S**), and is collected by lens **L** to form the image of **S** at **S'**. **O** is a 0.8 mm diameter aperture located at the focal point of **L1** and transilluminated by **S'**. Thus, **O** acts as a luminous object with its image at infinity. **AS**, a circular stop close to **L**, limits the light reaching **S'** and acts as the entrance pupil for the entire system. **PR** is a prism placed halfway in the cone of light leaving **O**, its ultimate purpose is to produce horizontal doubling of the image(s) of **O** formed on the fundus of the test eye. The horizontal doubling is what makes this a *coincidence* (vernier) system. The *Scheiner* feature results from the placement of a vertically oriented double pinhole (**DA**, 1 mm diameter apertures) to the right of **L1**. Thus, only the vertical meridian of the eye is tested.

YF is a sharp cutoff yellow filter (t = 50% of max. at about 555 nm) intended to improve image sharpness by reducing the effects of chromatic aberration. **BS**, a beam splitter with about 50:50 t:r ratio, allows collimated light to pass to **L2** which forms a double image of **S'** at **F2**, and **F3**, a common focal point between **L2** and **L3**. **M1** and **M2**, front surfaced mirrors, fold the optical path for more efficient use of space. **L3** provides collimated light to the eye's entrance pupil, 37 cm away, in the form of two narrow beams (due to **DA**). The end result is the formation of two horizontally oriented images of **O** on the fundus of the test eye. If the latter is emmetropic, the images are vertically aligned; if ametropic, the images are misaligned by an amount proportional to the degree of ametropia. The direction of the misalignment corresponds to the sign of the ametropia.

Up to this point the description pertains only to *input* light. The *output* consists of light emerging from the eye and retracing its path through all the optical elements until reaching **BS**. About half the light hitting **BS** is reflected into a detector (eye or camera); the rest is transmitted through **BS** and lost.

Schematic eye (human eye analogue)(Figure 2)

The schematic eye consists of a single methyl methacrylate biconvex lens in air with a diffusing screen acting as a fundus. The latter is fine grained lint-free paper attached to a piece of thin cardboard. The fundus is mounted on a screw-operated translator (Ealing-Beck, England).

Calibration of the schematic eye was done using a TOPCON 3 Coincidence Refractionometer (Ser. No. 110030), patterned after the Hartinger Refractionometer (Carl Zeiss, Jena).

Procedure

Video recordings of the fundus images were made for subsequent evaluation. The effects of three kinds of procedures were recorded:

A) Lenses of various powers were placed in front of the schematic eye, which was set at emmetropia, to simulate refractive ametropia. The following lenses were used (in diopters): plano; +1.00; -1.00; +2.00; -2.00; +3.00; -3.00.

B) A plano lens was used while the fundus of the schematic eye was moved to various positions to simulate axial ametropia. The following amounts of ametropia were represented (in diopters): plano; -2.00; -4.00; +2.00; +4.00.

C) Lenses of relatively low power were placed in front of the schematic eye to test the sensitivity of the system. The powers used were as follows (in diopters): plano; +0.50; -0.50; plano.

Results

The present system produces vernier images on the fundus. The field of view, although small (7 deg.), is more than adequate for present purposes. The image offset data is given below (Table 1), followed by a graphical representation (figure 3). Visual inspection of offsets due to changing lens power by as little as 0.50 D shows sensitivity to this amount of change. The telescopic system used (cathetometer) was not as sensitive, but could measure changes well under 1.0 D.

Discussion & Conclusions

There have been significant improvements made in the apparatus as described in this paper. However, further improvements are recommended before human trials are preformed. These improvements include:

1) A second pair of pinholes, horizontally oriented, to test the horizontal meridian.

2) The ability to axially rotate the pinholes along with doubling prisms so as to sample oblique meridians, if necessary.

3) The use of infrared (IR) light, and an IR camera (either video or photographic) in order to avoid the obtrusive effects of visible light.

4) An optoelectronic scanner to improve the sensitivity of image offset evaluation.

5) A second object at a different optical distance for internal calibration purposes. This would enable a more accurate calibration (the amount of vernier offset per unit diopter of refractive error varies with posterior nodal distance of the test eye).

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DIAGRAM OF PHOTOTRETINOSCOPE APPARATUS
AS OF 03 MAY 1991

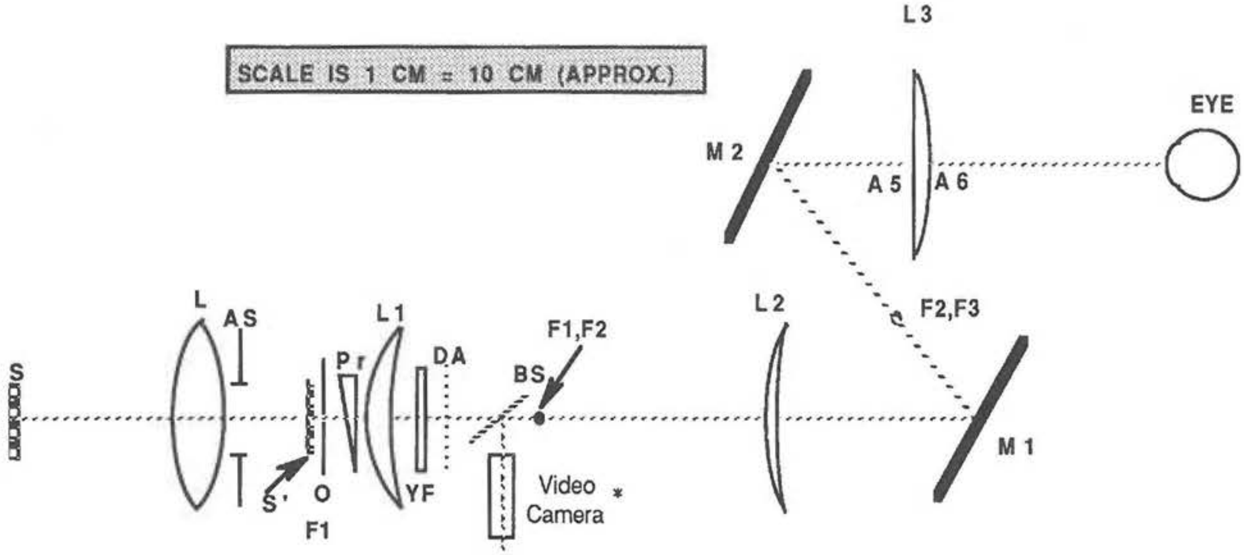

FIG. 1

* In order to inspect the images visually, the video camera can be replaced by an observer's eye.

L_1 SPECIFICATIONS: P_1=+14.12 D; P_2=-1.00 D; t=0.008 m; Pv=+14.25; P_N=+13.12
n=1.523 (assumed) fv=7.34 cm;f_N=7.60 cm

L_2 SPECIFICATIONS: P_1=+5.12 D; P_2=-3.25; t=0.002; Pv=+1.90; P_N=+2.01
n=1.523 (assumed) fv=52.60 cm;f_N=49.7 cm

SYMBOLS

P_1= convex surface power
P_2= concave surface power
t= center thickness
Pv=back vertex power = 1/fv
P_N=front vertex power = 1/f_N
Ai and Ai+1 are front and back vertices, respectively.
O=0.8 mm diameter aperture
YF=yellow filter
BS=beam splitter; DA= double aperture (1 mm Diam.)
AS=aperture stop; Pr=prism
S=coiled tungsten filament
S'=image of tungsten filament (S)

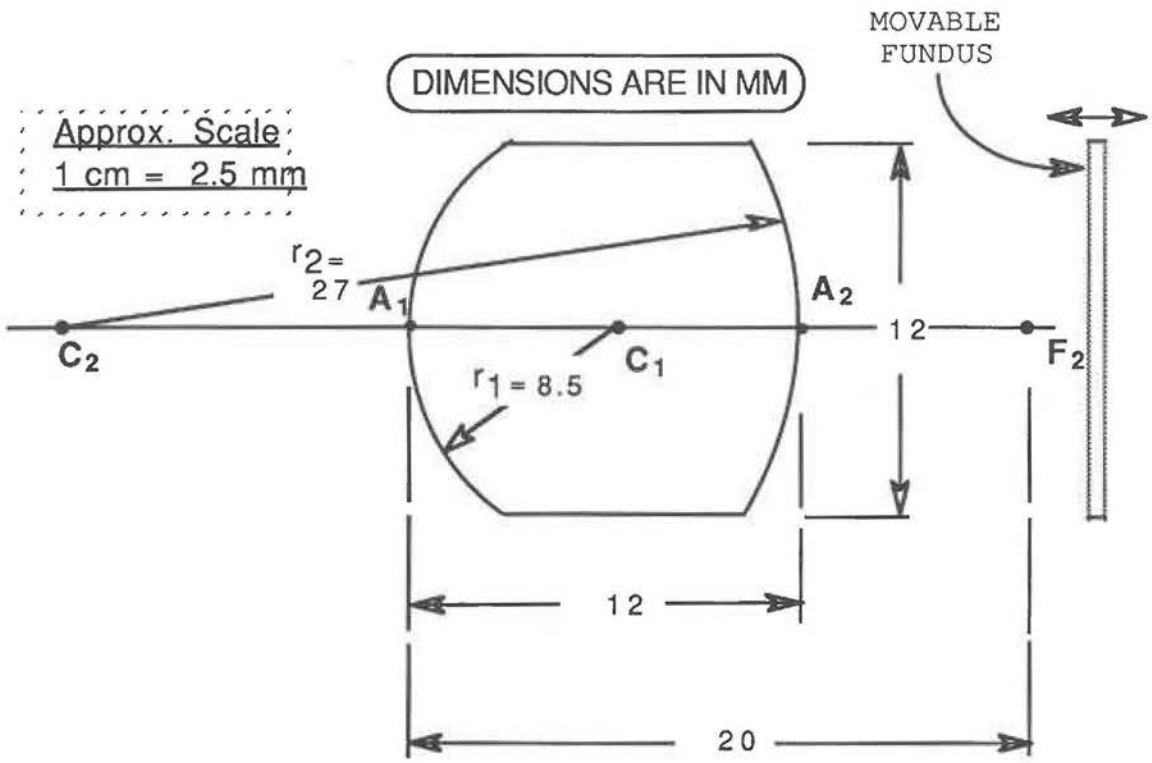

FIG. 2

P_1 = +57.65 D; P_2 = +18.15 D; P_v = +125.76 D; f_v = 8.0 mm (approx.)
A_1F_2 = 20 mm

REFR. ERROR	SCALE RDG.
+5.0	1.1
+4.0	1.2
+3.0	1.45
+2.0	1.6
+1.0	1.75
+0.5	1.85
↖MYOPIA	
PLANO	1.9

REFR. ERROR	SCALE RDG.
-0.5	2.05
-1.0	2.15
-2.0	2.35
-3.0	2.45
-4.0	2.65
-5.0	2.8
↖HYPEROPIA	

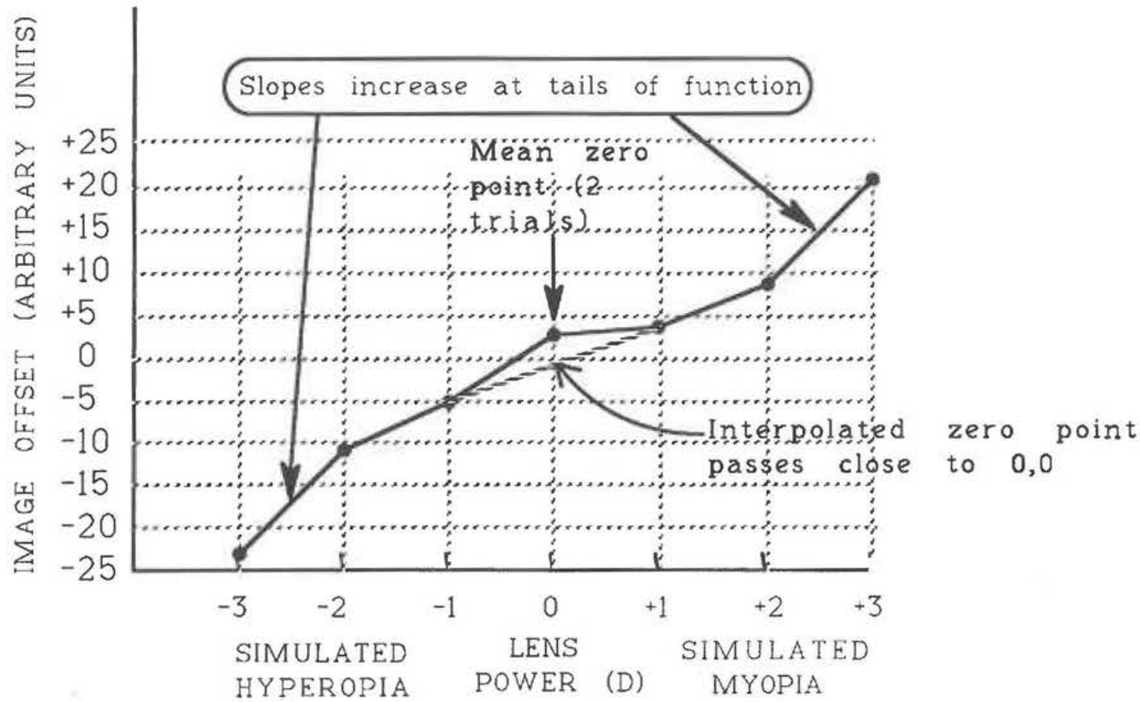

FIG. 3. VERNIER IMAGE OFFSETS VERSUS LENS POWER PLACED IN FRONT OF SCHEMATIC EYE.

LENS	RT RDG	LT RDG	DIFF (VERNIER OFFSET)
+3	2911	2890	+21
+2	2905	2896	+9
+1	2900	2896	+4
PLANO	2898	2895	+3 ??*
-1	2895	2900	-5
-2	2891	2902	-11
-3	2886	2910	-24

POSITIVE DIFFERENCES MEAN THAT THE RIGHT IMAGE IS HIGHER THAN THE LEFT IMAGE.

TABLE 1

THE READINGS IN COLUMNS 2 AND 3 ARE ARBITRARY, TAKEN FROM THE VERNIER SCALE OF THE CATHETOMETER (1/10 MM RESOLUTION).

* *THIS READING SHOULD BE CLOSE TO ZERO (SEE THE GRAPH).*