An Overview on the Use of a Low Magnification Telescope in Low Vision

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1. Introduction

A Galilean telescope in its simplest form is a two element system consisting of a positive lens as an objective and a negative lens as an eyepiece. The system is restricted to lower magnifications and smaller fields of view in comparison with a Keplerian telescope. The image through the system, however, is always erect permitting its use for distance viewing for partially sighted patients. Other optical factors besides magnification and field of view that need to be considered include exit pupil size, focus adjustability, vertex distance, and image quality in terms of color and brightness. Such non optical factors as weight, portability, ease of use, appearance and cost are also influencing variables[1]. In this overview on the clinical use of low power telescopes in the examination room, only a few properties will be examined. The use of a low power full-field telescope in subjective and objective refractions will be discussed. Magnification through a telescope will also be elaborated upon.

1.1 Low Power Telescopes

Bier[2] states there are two basic types of Galilean telescopes used in low vision. They are available either in fixed focus form for insertion in ordinary spectacle frames or in variable focus form available commercially. These full field telescopes are relatively inexpensive and are commonly prescribed as distance aids for low vision patients. Although no prescription may be incorporated into the eyepiece of these 2.5X or 2.8X low power telescopes, the refractive error of the patient can be compensated, in the form of equivalent spheres, by altering the telescope from an afocal to a focal system. This is achieved by altering the distance between the eyepiece and the objective. According to Emsley[3] this method was first proposed by von Graefe in 1863. When these telescopes are used by emmetropes, the amount of accommodation required through the telescope can be obtained by increasing the lens separation. Uncorrected ametropes can also use these devices by increasing or decreasing the distance between the eyepiece and the objective lenses depending upon the error of refraction. There are, however, some limitations. The separation between the objective and the eyepiece is limited in length and the field of view is generally restricted to 15 degrees or less. The proximity of the object as viewed by the patient will alter the image vergence at the ocular to require a large amount of accommodation[4]. On the other hand, instrument myopia or instrument accommodation through the telescope may induce accommodation which partially counteracts the demand for accommodation through a telescope.

2. Magnification of Low Power Focal Telescopes

Afocal telescopes are used focally by emmetropic users looking at objects other than at infinity or ametropic users without any correction. The question is whether or not the actual magnification of the telescope will be changed significantly from the nominal magnification.

If the position of the object is relatively fixed in relationship to the focusable low power telescope, an appropriate definition of magnification would be the relative size of the retinal image after the telescope is introduced to the eye without the telescope (Figs. 1 and 2). The value of that ratio depends on whether or not the user changes the relative position of his eye and the object when he uses the telescope. There are two extreme cases. In the first the user merely places the telescope into the space between himself and the object of regard, adjusting the telescope length until the object is in focus. In this case the distance from the

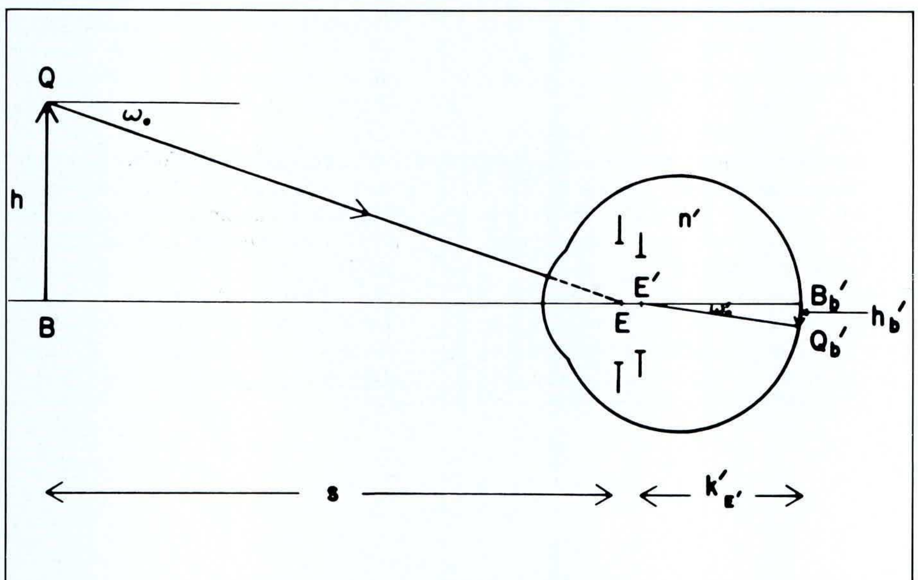

Figure 1. Geometry of retinal image formation by an unaided eye (from Long and Woo[5]).

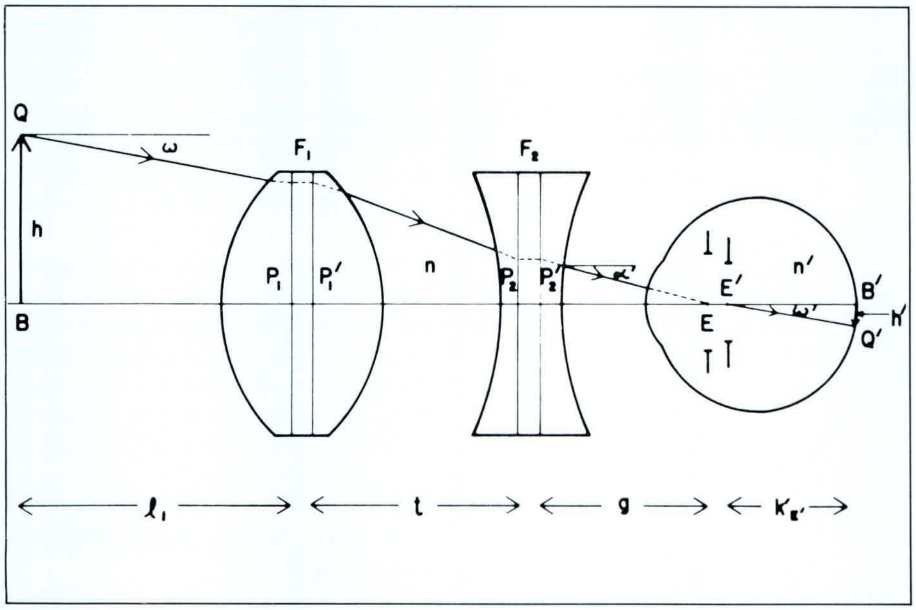

Figure 2. Geometry of retinal image formation by an eye-telescope system (from Long and Woo[5]).

eye to the object is the same with and without the telescope. Spectacle magnification in this case will be designated M_1 [5].

In the second case the user places the objective lens of the telescope in his spectacle plane and focuses while holding the position of the objective lens constant, moving his head back and forth as the position of the eyepiece is adjusted. Magnification will be designated M_2. For practical interest $M_1 > M_2$.

In practice a user may move both ocular and objective while focusing a telescope so that his actual retinal magnification will lie between M_1 and M_2. These values should be interpreted as the limiting value of retinal magnification. In most cases of interest, the numerical value of the two kinds of magnification do not differ very much from each other.

Long and Woo[5] derived a general expression for spectacle magnification. It is used to determine the magnification of focal telescopes for correcting ametropia and/or for viewing objects at finite distances. The results of careful calculations of retinal image magnification show that changes in telescope magnification large enough to alter acuity by a line on a LogMAR chart occur only when the viewing distance is less than 60 cm or when a Galilean telescope used at distance is adjusted to compensate for a very large ametropia. In practice, the expression reveals a clinically negligible difference between spectacle and nominal magnification.[5]

$$M_s = s/[\,1 - \bar{t}\,F_1)\,(1\ gF_g'\ v)\ 1_1 - \bar{t} - (1 - \bar{t}\,F_2)g]$$

3. Refraction

3.1 Subjective Refraction with the Use of a Low Power Telescope

In a low vision assessment, the use of a low power telescope will often enable the practitioner to evaluate the refractive status of a patient. Refraction in equivalent spheres can be determined by asking the patient to move the knurled knob (Fig. 3) slowly either clockwise or counter clockwise until the visual acuity chart is in best focus at 6 m. The practitioner can of

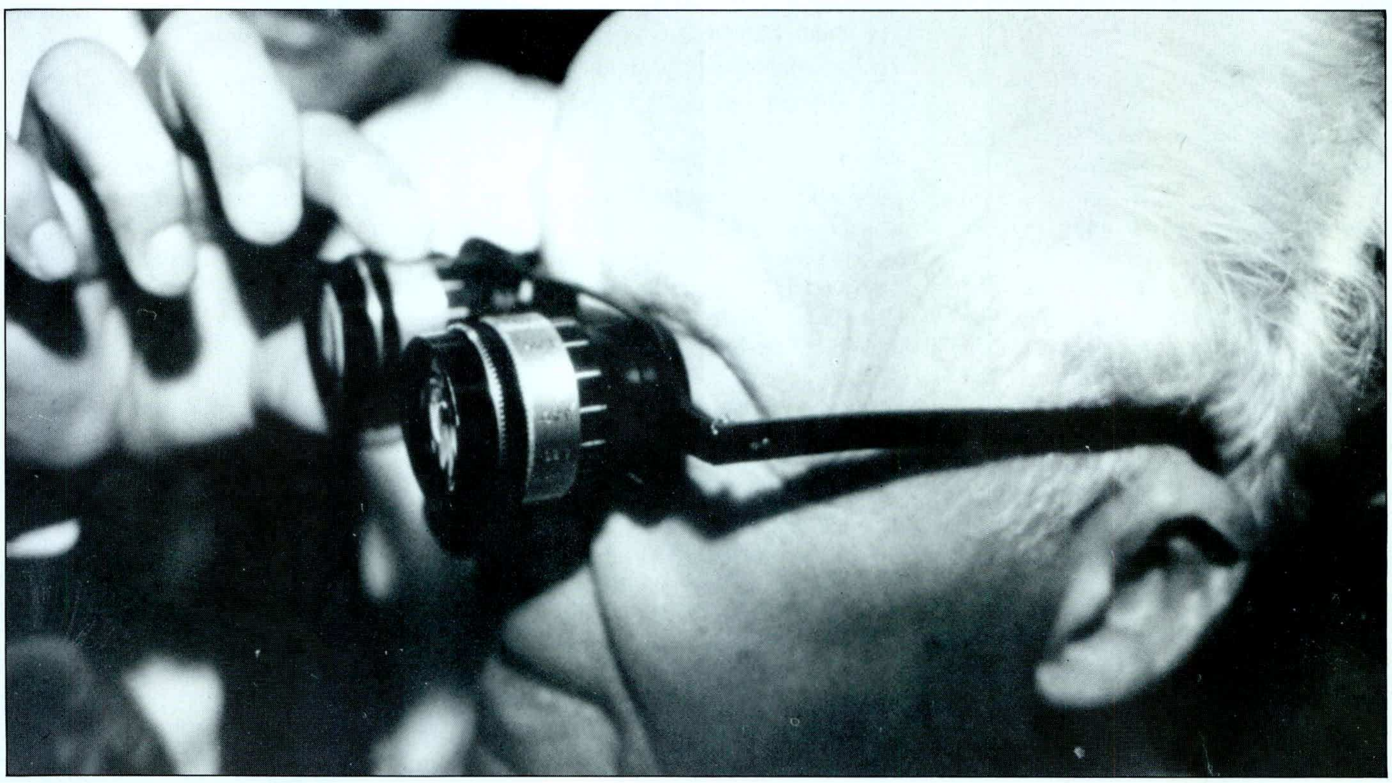

Figure 3. Use of a calibrated telescope in subjective refraction

course choose to turn the knob instead. Provided the patient does not accommodate at a distance considerably closer than the location of the visual acuity chart, the indication is that the patient is hyperopic when the knob is turned clockwise. Turning the knurled knob clockwise is equivalent to lengthening the distance between the eyepiece and the objective. When the knob is turned counterclockwise thus shortening the separation between the eyepiece and the objective, the patient is shown to be myopic.

The amount of ametropia can be quantified by noting the setting relative to the zero position. On most of these devices, there is a zero position marked in red. On either side of this red mark are inscribed white marks at equal intervals. Table 1 gives measurements of back vertex powers of a typical 2.5X monocular achromatic telescope taken from a *Sportscope* when it is placed in the lensometer and adjusted to different positions away from the zero position. The minus sign indicates shortening of the separation and that the vergence leaving the eyepiece is divergent: the plus sign indicates lengthening the separation and that the vergence leaving the eyepiece is convergent. Table 1 shows that although positions of white marks are separated linearly at equal intervals, they are not linearly related dioptrically.

Repeated measurements on a number of 2.5X monocular achromatic telescopes of the same type yield similar findings. Occasionally, there is a difference of +/− 0.25 D which can be attributed to a misalignment of the individual white mark from the zero position when the reading is taken through the lensometer.

Another consideration is that the demand on accommodation through the telescope is substantially greater than indicated by the object distance. The demand is due to the image vergence at the ocular when an object is imaged through the telescope. An approximate formula used to calculate the vergence is $L_2^1 = M^2L_1{}^4$, where M is the magnification of the telescope, L_1 is the object vergence at the plane of the objective, and L_2^1 is the image vergence at the plane of the eyepiece.

For low magnification telescopes of 1.7X and 2.5X, the respective discrepancy is 0.50 D and 1.00 D when the distance is 6 m. A 4X telescope on the other hand requires an accommodation of approximately 2.75 D for the same object distance. Thus a compensating lens should be incorporated in the calibration of a 4X telescope if it is to be used for subjective refraction.

Table 1

Calibrated back vertex powers of a 2.5X telescope at specific intervals.

Counter-clockwise marks	BVP in diopters	Clockwise marks	BVP in diopters
-1	-0.75	+1	+0.75
-2	-1.50	+2	+1.25
-3	-2.00	+3	+1.75
-4	-2.50	+4	+2.50
-5	-3.00	+5	+3.00
-6	-3.50	+6	+3.50
-7	-3.75	+7	+4.25
-8	-4.25	+8	+5.25
-9	-4.50	+9	+6.25
-10	-5.00	+10	+7.25

Occasionally, however, it is impossible to determine refractive errors of some low vision patients using conventional refractive techniques including radical retinoscopy. It is in these cases that the technique becomes invaluable in estimating the refractive error subjectively.

The use of a calibrated telescope in determining the refractive error of low vision patients clinically has been reported by Woo[6]. The technique, however, is far from being precise as pointed out by Bailey[1]. It does not, for example, provide accurate astigmatic corrections. Although instrument accommodation would generally counter the effect of image vergence through a telescope, the net result is determined by the accommodative state of the patient, thus contributing to the inaccuracy of subjective refraction through a telescopic device. Information on the amplitude of accommodation of low vision patients is essential to obtain a more accurate refraction.

In order to obtain a more accurate reading, the examiner could "fog" the patient by lengthening the distance between the objective and the eyepiece of the telescope after the subjective refraction has been established either by the patient or the examiner. This procedure is similar to the fogging technique employed by some automated refraction systems and by conventional subjective refraction.

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3.2 Objective Refraction with the Use of a Low Power Telescope

Retinoscopy is an objective technique used to measure refractive errors. In retinoscopy there are two systems in operation[7]. The illumination system begins with the light source of the instrument and ends in the patient's retina and the observation system begins on the patient's fundus as a light patch and ends in the examiner's eye. The retinoscopic finding determines the amount and type of refractive error by bringing the far point of the patient's eye coincident with the plane of the retinoscope. When this occurs, the examiner has reached the "neutral" point or the "flashing" point in retinoscopy. With the use of a low power telescope, the same principle holds. The required emerging vergence from the objective can be obtained by having the illuminated retinal patch focused at the examiner's entrance pupil. A schematic diagram illustrates this principle in Fig. 4. As an example, a typical 2.5X telescope would have the following values:

F_1 = +15.00 D (objective)
F_2 = −37.50 D (eyepiece)

separation distance of F_1 and F_2 = 4 cm
working distance = 60 cm

Given the above values the required emerging vergence from the objective would be +1.67 D in order to have the illuminated retinal patch focused at the observer's entrance pupil when arriving at the neutral point in retinoscopy. The calculated neutralizing lens using the simplified vergence formula [4] $L_2^1 = M^2L_1$ is equal to +10.44 D for an emmetrope. Thus by calculation it is predicted a neutralizing lens of approximately +10.50 D is required for an

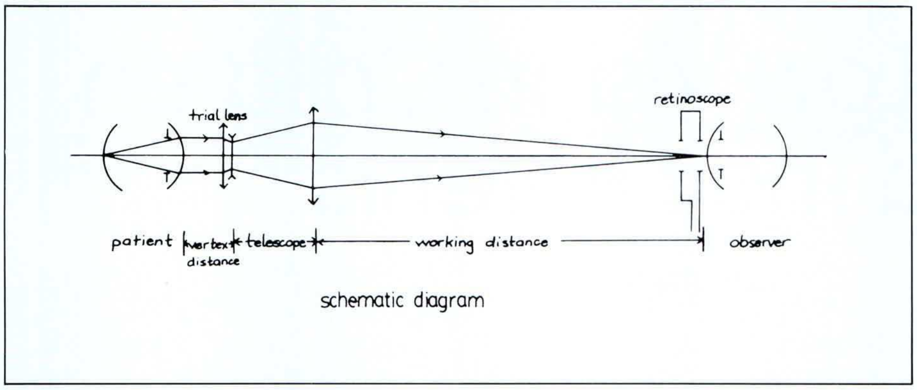

Figure 4. Schematic representation of telescopic retinoscopy.

emmetrope. The technique is similar to loose lens retinoscopy whereby lenses are inserted behind the eyepiece at the spectacle plane at regular intervals until the "with" movement of the reflex is neutralized. Insertion and removal of lenses in this manner are cumbersome and the vertex distance is not always maintained. Alternative methods such as increasing the separation between the objective and eyepiece by a specific amount and/or placing low power reading caps in front of the telescope can reduce the amount of positive lenspower required at the spectacle plane immediately adjacent to the eyepiece.

For practical purposes actual magnification of a lower power focal telescope and its nominal magnification may be viewed as being identical.

Thirty normal subjects were subjected to telescopic retinoscopy. Preliminary data indicate correspondence between the experimental results and the predicted values. Discrepancies however do occur. These can be attributed to sources of error usually attributed to retinoscopy including: 1. inexact working distance 2. scoping off the patient's visual axis 3. failure to obtain a reversal 4. failure to locate the principal meridians 5. failure to recognise scissors motion and 6. failure of the patient to fixate the distance target[8]. It is our observation that there appears to be a zone of neutrality once the "neutral" point is reached contributing perhaps to much of the discrepancy in most cases. To verify this, we are planning to refract two groups of subjects with and without cycloplegia. These results would then tell us whether accommodation could be another influencing factor in telescopic retinoscopy. In addition to conventional sources of error in retinoscopy, there are other factors to be considered in telescopic refraction. These include vertex distance, the tilt of the telescope, aberrations of the telescope, Modulation Transfer Function (MTF) of the telescope, alignment of the exit pupil of the telescope with the pupil of the eye and the brightness of the reflex. Clinically there is little or no advantage obtained by refracting low vision patients with a telescope. The employment of such a technique will not provide additional information in refraction. Observation of media opacities in some low vision patients could occasionally be made easier because of the larger reflex seen by the examiner.

4. Summary

For practical purposes actual magnification of a lower power focal telescope and its nominal magnification may be viewed as being identical. The use of a low power telescope in refraction has been described. This technique for subjective refraction can be useful in estimating the refractive error of some low vision patients. The use of the same device in objective refraction provides little clinical advantage.

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