

THE PINHOLE AND ITS USE IN VISION SCREENING

Donald H. Lakin, O.D.  
Sid Morse, O.D.  
Henry J. Spiro, M.D.

This paper reports on the use of the pinhole to determine the presence of an uncorrected refractive error. The procedures were developed by Dr. Lakin in conjunction with Dr. Spiro who sponsored the "Vision Days" screenings. Analyzing the material and preparing the paper was the works of Dr. Morse as part of his Senior Project at Ferris State College of Optometry. Dr. Lakin served as his faculty advisor.

## ABSTRACT

The purpose of this study was to determine if the use of a pinhole used in a large screening project of adults could identify the presence of an uncorrected refractive error. Visual acuity screening on a monocular basis was performed at a 20/40 level with the most recent distance correction. Qualitative improvement with a pinhole was solicited and recorded. A follow-up on referrals was made to assess false-positive and false-negatives. Results indicate that this is a viable procedure in this setting for determining if there is a refractive component to a visual impairment. With the proliferation of glaucoma and cataract screenings this simple technique could help in directing persons to the proper professional source for vision care.

## BACKGROUND

Before we examine the actual screening procedure and the results obtained, let us first explore the pinhole. How does the pinhole improve visual acuity? To answer this question we first must review some basic geometric optics principles. First consider the object. An object is composed of many different point sources. Each of these point sources has its own bundle of light rays associated with it. In turn, all of the bundles of light from all of the point sources on the object make up the beam of light from that object. Next consider the image. In the case of the eye, the image is formed on the retina by the converging properties of the cornea and lens upon the entering bundles of light. When each of the bundles from

each of the point sources on the object is converged by the eye to form single points on the retina, then the collection of all these points forms a clear image of the object. This represents the ideal case, the emmetropic eye. Such is not the case in the ametropic eye. In myopic, hyperopic, or astigmatic ametropias, light is not converged to form points on the retina. Instead of points, the cross-sectional shape of the bundles of light approximates circles on the retina. These circles are called blur circles because of the blurred image formed. The farther away that light bundles are to being focussed on the retina, the larger will be the blur circles. The larger the blur circles the more out of focus will be the image. (See Figure 1)

With this background we can now begin to understand how pinholes can improve visual acuity in ametropic eyes. A pinhole placed next to an eye acts as an aperture. This aperture is smaller than the pupil which normally controls light entering the eye. The smaller aperture formed by the pinhole acts to reduce the cross-sectional size of the bundles of light striking the retina. This results in smaller blur circles being formed on the retina. (See Figure 2). As the size of the blur circles is reduced the clearer the image becomes upon the retina. The smaller the aperture (pinhole) is made, the smaller the blur circles become. Theoretically, if an aperture were made small enough so that only a single ray from each point source passed through it, a point to point correspondence would exist between object and image and the

resulting image would be clear. This does not happen in practice however. As the pinhole is made smaller and smaller, two phenomenon occur that begin to negate the effects produced by blur circle minimization. These two phenomena are decreased retinal illumination and diffraction. The size of the pinhole serves to limit the amount of light that enters the eye. As with a round pupil, the amount of light entering the eye through a pinhole is proportional to the radius of the opening squared. As the retinal illumination decreases so does visual acuity. Diffraction is the tendency of light waves to propagate around corners. Diffraction causes an increase in image spread which decreases visual acuity. Diffraction increases as the size of the pinhole decreases. Clinically, Takahashi has determined that at pinhole diameters of less than 0.75mm diffraction effects overcome the benefits produced by blur circle minimization.

Pinholes may also increase visual acuity by reducing such aberrations as coma and spherical aberration. These aberrations are dependent on aperture size and decrease as the aperture size decreases. These are only minor effects on acuity because these aberrations are only significant in eyes with large pupils.

In summary, pinholes influence acuity by their net effects on the beneficial aspects of blur circle minimization and aberration reduction versus the detrimental aspects of decreased retinal illumination and diffraction.

The use of pinholes is not a recent innovation. Pinholes have been used for centuries. The pinhole effect was used by Aristotle,

Alhazen, Leonardo da Vinci, and Kepler. Early cameras used the pinhole effect to produce clear images on the film. These cameras required long exposure times to compensate for the little amount of light that could be passed by the pinhole. Nature also provides us with several examples of the pinhole effect. The eye of cuttlefish nautilus and the infrared pits of the rattlesnake are two examples. Several variations of the pinhole have also been devised. One is the use of multiple pinholes in a disk. Another variation of the pinhole is the stenopaic slit. A stenopaic slit is a line of overlapping pinholes. When a person squints he or she is using their eyelids to form a stenopaic slit and thus achieve an increase in visual acuity.

Now that we know all about pinholes and how they work, let's examine how they can be used for screening and referral purposes. During visual screenings, the visual acuity of each participant is taken. Suppose the visual acuity of some of the participants is reduced. Why is their acuity reduced and to whom should they be referred to correct this problem? The reduced acuity could mean that the patient has some uncorrected refractive error which may be corrected by a new prescription. In this case referral to an optometrist would be appropriate. The reduced acuity could also mean that some pathology was present. In this case referral to an ophthalmologist would be appropriate. How do we know what the reason for the reduced acuity is? Is it due to uncorrected refractive error or to some pathology? This is where the pinhole may help us. If a pinhole is used and the visual acuity of the patient is improved then

we can assume that the problem is an optical one which may be corrected with the appropriate lenses. If, on the other hand, a pinhole is used and the acuity is not improved then we must suspect a pathological condition exists. Failure of acuity to improve with the use of a pinhole is not proof positive that a pathological condition exists, but it alerts us to that possibility. When using a pinhole we must consider the problem of interpretation of results. Sometimes a pinhole may increase acuity but only slightly. What does this mean? Does it mean that some pathological condition exists? Does it mean that some uncorrected refractive error exists? Or could it be a combination of both? Takahashi has several suggestions to improve your pinhole test and to better interpret the results. One way to improve your pinhole test is to use high luminance charts which help improve retinal illumination and cut diffraction effects. Another way is to use pinhole disks with multiple holes which will make alignment easier for the patient. Also the pinhole disk should be thin or the holes should be countersunk into the disk. If the pinhole disk is too thick, even a slight tilting of the disk will result in a decreased diameter of the pinhole. To help interpret your results Takahashi suggests the following be done in your practice. On several subjects with normal acuity or fully corrected acuity, take their acuity when using a pinhole combined with several different lenses. Start with their acuity when using the pinhole and a +5D lens. Work down in 1D steps. Plot all the acuities on a graph and draw a best fit curve.

This curve will help with the average expected acuities for out of focus images in your office. Takahashi also suggests that if a pinhole does not increase acuity substantially, try retaking acuities with the pinhole in combination with several lenses. The lenses added should be plus and minus spheres added in 2D or even 4D steps. If vision does not improve any further then a non-optical cause for visual reduction should be considered.

#### ACTUAL SCREENING

The screening in which we participated was entitled Vision Days '85. It was a program of eye health education and free vision screening for glaucoma, cataracts, and visual acuity. The program included consultations with both optometrists and ophthalmologists. It was held October 7 and 8, 1985 at the Oakland Mall in Troy, Michigan.

The screening consisted of three parts and a consultation contingent upon the results of the different parts. The three parts of the screening dealt with glaucoma, cataracts, and visual acuity. The glaucoma portion of the screening used non-contact tonometers to measure intraocular pressures. Passing criterion for this portion of the screening was 23mm Hg or less. The cataract screening consisted of examination with a slit-lamp biomicroscope. The cataract portion of the screening was not performed on all patients. Its implementation depended on the visual acuity findings. Findings were reported as yes or no to the presence of significant lenticular opacities. The visual acuity portion of the screening will be

discussed in detail below.

The visual acuity portion of the screening was performed using vision charts with a testing distance of ten feet. The ten feet was measured and then marked with tape to ensure accuracy. The vision charts used had three levels of acuity, 20/40, 20/30, and 20/20. Each level of acuity was color coded for easy reference. At each acuity level there were three lines with six figures in each line. The first two lines at each acuity level consisted of letters while the third line at each level consisted of tumbling E's. The tumbling E's were identified by patient hand signals as pointing up, down, left, or right. The passing criterion for a visual acuity level was four or more letters correct at that level. Testing was done using the patient's most recent distance correction. The right eye was always tested first and a different row of letters was used if the patient was testing on the same acuity level for both eyes. A bookmark was used for an occluder as the testing was done monocularly. The pinholes used were 1.2 mm in diameter. Each patient was screened as follows. The patient was instructed to move to the tape marks on the floor. Then, using his or her most recent distance correction and with the left eye occluded, the patient was asked to read the smallest row of letters that he or she could. The patient was also instructed to identify by color the level at which he would attempt to read. The resulting acuity was recorded as the smallest level on which four letters were read correctly. Next a pinhole was placed before the right eye with the left eye still



occluded and the resulting acuity recorded. After this was done, the recording form was marked yes or no in reference to whether the vision was improved when the pinhole was used. Note that if all six letters on the 20/20 level were read correctly acuity using a pinhole was not taken. The criterion for vision improvement with use of pinhole was an objective improvement and not a subjective response. The right eye was next occluded and the procedure repeated for the left eye.

After the screening was completed, the next step was to direct the patient to the appropriate consultation area. Optometric consultations consisted of information on optometric exams, glasses and contact lenses. Literature on common ocular problems was also available. Also available were lists of all area optometrists. Ophthalmological consultations consisted of information on cataracts, glaucoma, diabetic retinopathy, tearing, and eyelid problems. Lists of all area ophthalmologists were also available. As stated before, whether the patient was directed to the optometry consultation or the ophthalmology consultation was contingent upon the results of the screening. Any patient failing the glaucoma portion of the screening was referred for ophthalmological consultation. Any patient failing to read 20/40 and whose vision was not improved with the pinhole was referred for cataract screening and ophthalmological consultation. If a patient failed to read 20/40 but his vision was improved with the use of a pinhole then that patient was referred for optometric consultation. Any patient who could not read 20/20,

regardless of whether or not his vision was improved by using a pinhole, was referred for optometric consultation unless he failed the glaucoma portion of the screening, in which case he was referred for ophthalmological consultation. Any patient requesting a cataract screening was given one, even if one was not indicated.

In order to study the effectiveness of the pinhole in identifying the presence of uncorrected refractive errors, stamped, self-addressed postcards were given to patients. These follow-up postcards were to be filled out by their optometrist or ophthalmologist at the time of examination and returned to us. An example of these postcards is shown in Figure 3. It was explained to each patient that these postcards were to be used in a research program involving visual acuity. It was further explained that all results were confidential and to be used for statistical purposes only. All patients who failed to read 20/20 and whose vision was improved with a pinhole and all patients who could not read 20/40 and whose vision was not improved with a pinhole were given the option to participate in the study.

#### RESULTS

As a result of the screening, some 500 cards were given out. Of those 500 approximately 230 were optometric referrals. At the time of this writing only 23 of those cards had been returned. Eight cards were returned with no full examination results and no signature by an eye care practitioner. Two of the cards returned showed an increase in uncorrected visual acuity with a pinhole and a subsequent

improvement of corrected acuity with a refractive change. Ten of the cards returned showed corrected acuity improvement with pinhole during the screening and a subsequent increase in corrected acuity with a refractive change. Two of the cards returned showed a visual acuity of 20/40 or less with no improvement using a pinhole during the screening and upon full examination showed an improved acuity with a refractive change. One card showed mixed results with one eye belonging in each of the last two categories mentioned. See Table 1 for a summary.

#### CONCLUSIONS

Before commenting on the results, it must be noted that this sample was too small to have great statistical significance. From this small sample, however, it appears that the pinhole can be very accurate in identifying those individuals who have some uncorrected refractive error. In fact, in every case in which the pinhole suggested that visual acuity could be improved, it was when a subsequent full examination was performed and a refractive change was made. In other studies using pinholes similar results have been found. In a study written by Lowenstein, Palmberg, Connett, and Wentworth the authors found a false-positive rate of 26% and a false-negative rate of 1.5%. The screening they chronicled included 135 patients screened in home and then later given a complete examination. In our study the false-positive rate was 0% while the false negative rate was 10.7%. The reported false-positive and true-negative rates were also 0% for our study. It should be noted

that in the case of the true-negatives, ophthalmological referral was a priority and increased visual acuity was not the prime concern. The encouraging results from our study, despite the small numbers, suggest that this screening should be repeated. Now that this study has been done once, a second study with some modifications should help to improve it. The aspect of this study that needs the most improvement is the one that deals with the follow-up examination after the screening. In our study follow-up examination was done on a voluntary basis. We had no control over it. As a result, of the 500 follow-up cards given out only 23 have been returned to date. Obviously, some change in protocol needs to be made to address this problem.

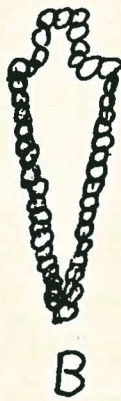
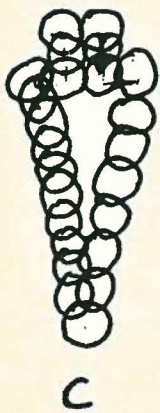
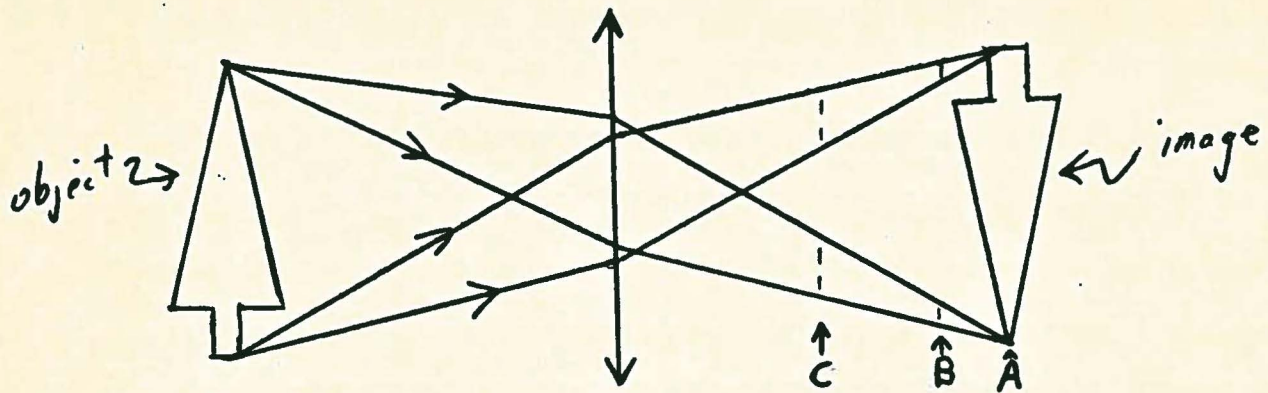


Figure 1

Effect of Blur Circle Size on an Extended Image

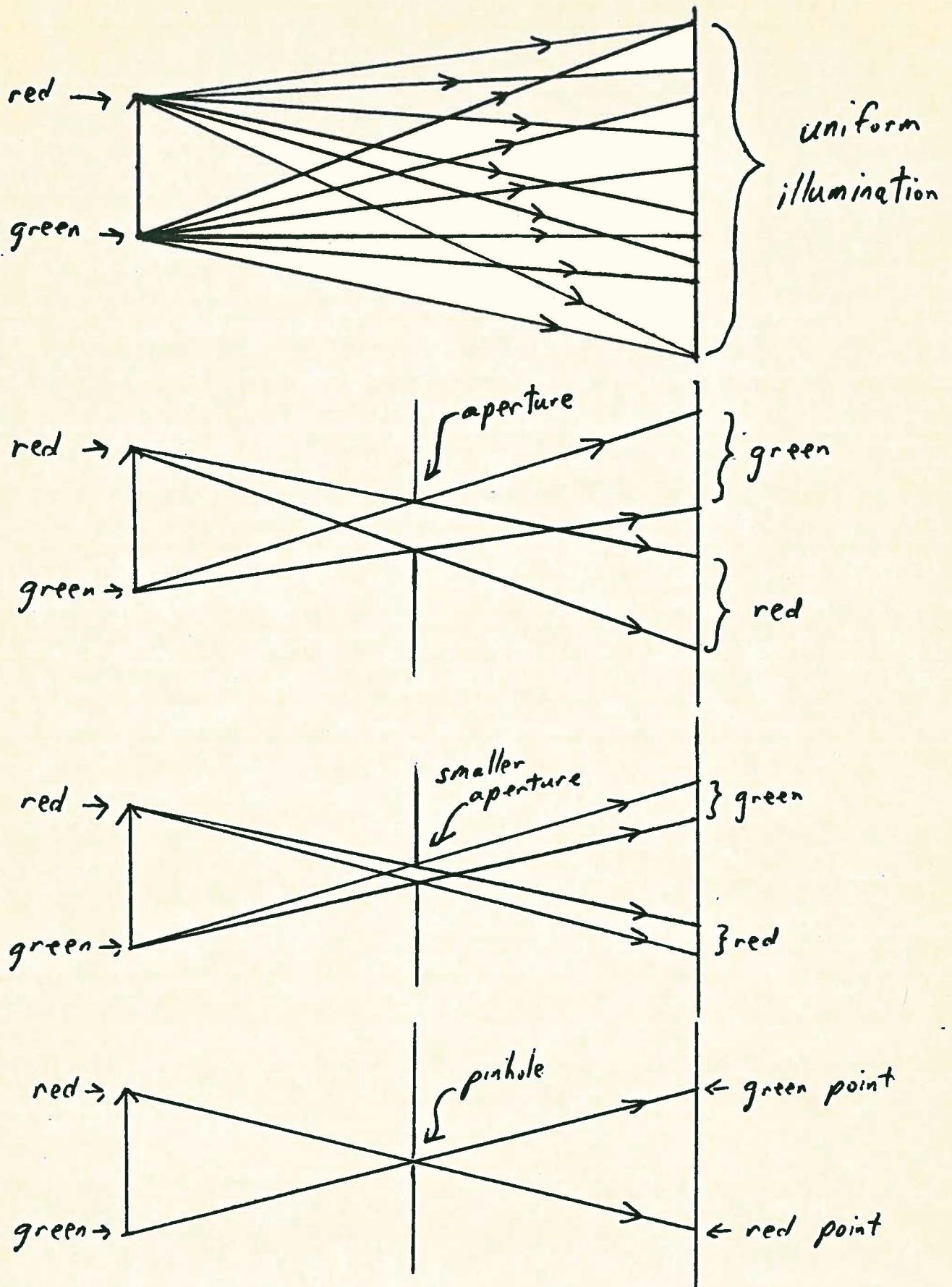


Figure 2

The Pinhole Effect and Blur Circle Minimization

Dear Doctor,

As part of the "Vision Days" screening we used a pin-hole to determine if a change in refractive correction would improve visual acuity. We want to collect data regarding the validity of this procedure. Please indicate under "Full Examination Results" your findings regarding this part of our screening.

Name \_\_\_\_\_

Screening Results

\_\_\_\_\_ V.A. Improved with pinhole

\_\_\_\_\_ V.A. Less than 20/40 with no improvement with pinhole

Full Examination Results

\_\_\_\_\_ Improved with Rx change

\_\_\_\_\_ No improvement with Rx change

Thank you for your cooperation.

Figure 3

Follow-Up Card

Table 1

|   | Visual Acuity improved with use of pinhole during screening | Visual Acuity Not improved with use of pinhole during screening |
|---|---|---|
| Visual Acuity Improved with change in prescription            | 12 1/2  | 2 1/2   |
| Visual Acuity <u>Not</u> improved with change in prescription | 0   | 0   |

Note: 1/2 means only one eye.

True-Positives - 12 1/2

False-Positives - 0

False-Negatives - 2 1/2

True-Negatives - 0



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