A Fundus Camera Dedicated to the Screening of Diabetic Retinopathy in the Primary-Care Physician’s Office

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PURPOSE. To increase the number of diabetic patients being screened for retinopathy, an instrument, the DigiScope, was specifically designed to operate in primary-care physicians’ offices. The DigiScope is described and its automated functions are evaluated.

METHODS. The DigiScope consists of a semiautomated optical head to acquire fundus images, evaluate visual acuity, and transmit the data to a remote reading center through telephone lines. Normal volunteers and 17 consecutive diabetic patients visiting their primary-care physician were recruited, and nonophthalmic staff performed the acquisition session.

RESULTS. The pupil center and working distance were set automatically. Centering was achieved within 750 μm in less than 500 ms. The fundus was successfully focused by an automated algorithm, and an imaging session covering 71° of the posterior pole of both eyes lasted 5.6 ± 2.4 minutes. It was found that a file-compression ratio of 12 did not degrade the clinical information and allowed data transfer in less than 6 minutes. A pilot study in normal eyes showed that the DigiScope images yielded the same amount of details as conventional color fundus photographs obtained by an expert photographer.

CONCLUSIONS. The DigiScope fulfills the instrumental requirements for a practical and cost-effective tool to acquire data needed to identify diabetic patients who must be referred to an eye-care specialist. Widespread screening with the DigiScope may help reduce the risk of vision loss in an estimated 4 million individuals in the United States alone, who currently do not undergo an annual eye examination. (Invest Ophthalmol Vis Sci. 2002;43:1581–1587)

Diabetic retinopathy is estimated to be the most frequent cause of new cases of blindness among adults 20 to 60 years of age.1 Prospective clinical trials have shown that pan-retinal laser photocoagulation for neovascular proliferation can reduce the risk of severe visual loss from proliferative retinopathy and that focal laser treatment for macular edema can reduce the risk of moderate visual loss.1 The effectiveness of treatment depends on accurate and timely detection of retinopathy. Thus, to quote the Center for Disease Control’s Guideline for Primary Care Practitioners: “Because mild, moderate and even severe retinopathy may be present without any symptoms, the responsibility to screen or examine the patient with diabetes for retinopathy is significant” (Ref. 2, p 45).

As stated by many experts, regular screening for diabetic retinopathy and education of patients are critical in limiting visual loss. Unfortunately, many diabetic patients do not receive an annual eye examination. A review of the literature by Mukamel et al.3 indicates that, in the United States, less than half of the diabetic population receives an annual eye examination. Lack of awareness by the primary-care physician used to be considered an important factor, but even in health plans owned by well-informed physicians, the screening rate is low. Patient education has had a marginal effect, as indicated by the poor results despite efforts by managed-care plans to provide informational brochures. Cost is not the culprit, because health plans with no copayment have screening rates in the 40% to 50% range.

It has been suggested repeatedly that one promising approach to increasing screening could be based on the acquisition of fundus photographs at locations frequently visited by patients, followed by expert evaluation of the photographs.4-12 Because diabetic patients visit their primary-care physicians often, screening in this setting would increase the screening rate significantly. However, the practical implementation of such a screening faces stringent demands:

1. A typical primary-care physician who cares for 2000 adults is likely to see, on average, 80 patients with diabetes (using a prevalence of 4%). A practice with four primary-care physicians would thus care for 320 diabetic patients and would screen, on average, approximately 1 patient a day. This low volume implies that the cost of the instrumentation used for screening must be low.
2. The procedure must be easy to administer by non-eye-care personnel, such as a physician’s assistant or a secretary.
3. The images must have enough resolution and contrast to allow the detection of small vascular abnormalities.
4. The imaged area must cover a significant portion of the posterior pole.
5. The data must be digital, to be compatible with transfer to a remote reading center.

None of the existing fundus cameras can meet all these demands. We have thus developed a fundus camera, referred to as the DigiScope, dedicated to detect, in the primary-care physician’s office, abnormalities that indicate the need for referral to an ophthalmologist familiar with the treatment of retinopathy. This article describes the DigiScope and the assessment of its automatic features. The application and perfor-
mance in diabetic patients is the subject of another study lead by an independent investigator. Preliminary findings presented in abstract form showed a sensitivity of 0.99 and a specificity of 0.96.13

METHODS

Principle and Design of the DigiScope

Principle. The DigiScope consists of an optical head located at the site of screening (typically the primary-care physician’s office) to acquire digital images and transmit them through phone lines to a remote reading center.

A panel of experts from the American College of Physicians, the American Diabetes Association, and the American Academy of Ophthalmology have stated in their screening guidelines for diabetes retinopathy: “Stereoscopic fundus photographs are the ‘gold standard’ for diagnosis. They provided the assessment for the Diabetic Retinopathy Study (DRS), the Early Treatment Diabetic Retinopathy Study (ETDRS) and the Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR), and they measure the accuracy of [the] diagnostic approaches.” A new imaging method for detecting diabetic retinopathy should provide the same diagnostic power as the current gold standard. Our pilot estimates, based on digitization of fundus photographs, indicated that a resolution of 50 pixels per degree would suffice. Although others have shown that good results can be obtained with less pixel density, it is preferable to fulfill higher requirements and lower them if it can be shown that they do not lower the specificity and sensitivity significantly. Because the cost of the instrument is an important factor in determining its practical use in screening, we have chosen to use a low-cost video camera as the electronic imaging device. Such cameras can be imaged. To provide coverage for the posterior pole, the instrument is designed to acquire multiple digital images at the required resolution in a manner that allows later generation of a mosaic image covering the posterior pole.

Another requirement for practical implementation is ease of operation by available staff in a primary-care environment. This implies that the instrument must operate quasiautomatically. To obtain a fundus image with refractive optics the operator must be able to align the center of the pupil with the optical axis of the camera, set the pupil at a well-defined working distance from the camera, focus the fundus image, and image the correct region of the fundus. These conditions must be met simultaneously in the short period during which a patient can comfortably fixate and keep the eyelids open. As will be described, the DigiScope has been designed to perform these functions without input from the operator.

The DigiScope uses monochromatic illumination. Treatable diabetic retinopathy is diagnosed by abnormalities associated with blood vessels. These are optimally visualized under illumination in red-free green light. Imaging in monochromatic light yields other important advantages. It permits use of a black-and-white video camera (thereby reducing the cost and increasing resolution in comparison to color video cameras) and alleviates the need for careful correction of chromatic aberrations.

Macular edema is a complication of diabetic retinopathy that must be identified in a screening program. In previous studies, macular edema was assessed by reviewing stereophotographs of the fundus. However, with the introduction of objective methods to assess retinal thickening such as the retinal thickness analyzer (RTA) and optical coherence tomography (OCT), it has been recognized that stereophotography provides limited sensitivity. The risk of missing macular edema will be limited by assessing visual acuity with the DigiScope and by referring any patients with early-stage retinopathy (a few microaneurysms or hemorrhages). In the WESDR cohort of 569 eyes of diabetic patients with disease classified as nonproliferative, none was found to have clinically significant macular edema (CSME). Thus, there is very little risk, if at all, that CSME can be present without the presence of retinopathy that would trigger a referral. This issue has been addressed by the independent investigator who assessed screening with the DigiScope.

General Description of the DigiScope. The layout of the DigiScope’s components is shown in Figure 1, and details are provided in schematic diagrams in Figure 2. The imaging head (Fig. 1; 1) is mounted on an XYZ motorized and computer-controlled stage (2, 3, and 4, respectively). The X, Y, Z components is shown in Figure 1, and details are provided in schematic diagrams in Figure 2. The imaging head (Fig. 1; 1) is mounted on an XYZ motorized and computer-controlled stage (2, 3, and 4, respectively). The X, Y, Z components are responsible for movements in the superior-inferior direction, to and from the eye, and in the nasal-temporal direction, respectively. During operation, the subject leans the head on a nape (6) and views one of the target diodes that are inside the imaging subsystem (Fig. 2) and are used for fixation. At the same time, a shutter occludes the fellow eye. The electronics and computer (7) that control the system are placed next to the imaging subassembly. The operator interfaces with the DigiScope by touch screen (5).

Fixation Procedure

To obtain images at different locations on the fundus, the eye to be imaged is directed toward different orientations by internal light-emitting diodes (Fig. 2; 19). These are turned on in a preset order under computer control. These diodes provide fixation for all the locations except the central one (foveal), which is provided by a diode in the light path (not shown in the figure). The diodes are arranged in an array of 10 targets. Fixation and imaging at each of these targets is used to generate a mosaic of 10 images covering the posterior pole, as illustrated in Figure 3.

Fundus Illumination

As shown in Figure 2, the illumination is generated by a halogen bulb (Fig. 2; 1). A computer-controlled shutter (2) turns the light beam on and off. The beam is focused by a condenser (3) on a doughnut-shaped aperture (4). Infrared light is eliminated by the first filter (5), and the visible spectrum is limited to green by the second filter (6), which
passes light between 510 and 570 nm. The doughnut aperture (4) is imaged on the pupil of the eye (13) after reflection by mirrors (8) and (12). From the pupil, the beam expands and illuminates the fundus.

**Fundus Imaging**

Lenses (Fig. 2; 14, 16, 17) image the fundus into the sensing area of a CCD camera (18). The lens (17) is moved under computer control to compensate for the spherical refractive error of the eye and to focus the image on the video camera (18). An aperture (15), conjugated to the pupil, is placed in the optical train to ensure that only rays passing through a well-defined aperture in the pupil generate the image. Similar to a conventional fundus camera, the separation in the pupil plane between the illuminating doughnut and the coaxial imaging aperture minimizes the light reflected and scattered by the cornea and the crystalline lens. The output of the camera (18) is fed into an image-acquisition board in the computer.

**Pupil Imaging**

A diode (Fig. 2; 20) illuminates the iris with infrared light. The light scattered by the iris and sclera is reflected by a mirror (12) and projected by lenses (9, 11) on a video camera (10). The infrared reflecting mirror transmits visible light and prevents infrared light from reaching the fundus imaging optics. The use of infrared light permits the optical head to image the pupil without constricting it and without being noticed by the subject. The output of the camera (10) is fed into an image-acquisition board located in the computer.

**Automatic Pupil Centering**

The image of the pupil captured by the video camera (10) appears as a disc darker than most of the surrounding iris, sclera, and lids. The image is processed by a software algorithm that first performs a dynamic threshold operation and converts the pupil into a black disc and the surrounding tissue into white. The image is inverted to generate a white disc for the pupil surrounded by black. The algorithm then locates the position of the pupil center along the horizontal and vertical axes.

The amount of deviation of the pupil center from the center of the image is used to command the X and Z stages and nullify this deviation. The procedure is repeated until the center of the pupil is close to the center of the image, thereby aligning the pupil with the optical axis of the imaging optics.

**Automatic Pupil Focusing**

Once the unfocused pupil has been brought to the center of the image, a series of eight images are digitized in 260 ms while the Y linear stage moves toward the eye from a default location. The reflection of the infrared diodes on the cornea is seen in the eight images. An algorithm identifies the image with the smallest reflection. The Y stage is brought to the location corresponding to the selected image, thereby yielding a focused image of the pupil. If necessary, the procedure can be repeated across a narrower range of motion centered on the previous location of rough focus, thereby refining the focus.

**Automatic Fundus Focusing**

Once the pupil is centered and in focus, the fundus image is automatically focused. The shutter is turned on for 260 ms and eight frames are digitized by camera (18) while the lens (17) moves across a large range. A region of interest that crosses some large and small vessels is selected for each of the eight frames. A frequency transform is performed on each of these regions to yield a two-dimensional array in the frequency domain. The components in a predetermined high-frequency region of this domain are summed, and eight values are obtained. The frame with the maximal sum is identified and the lens (Fig. 2; 17) is moved to the location that yields the best focus. If necessary, the procedure can be repeated across a narrower range of motion centered on the previous location of rough focus, thereby refining the focus.

**Automatic Light Adjustment**

The images acquired during the fundus-focusing procedure are also used to determine the illumination level. The average pixel density is calculated and compared to the desired range (for example, 80–120 for a 256-pixel, or 8-bit, gray-scale image). The deviation from the desired range is used to change the light output of the bulb by adjusting the duty cycle of the alternating voltage supplied to it.

**Fundus Image Acquisition**

Fundus image acquisition can be performed in a variety of modes. In each of the two modes described, the shutter is turned on for 130 ms, during which four frames are digitized. In the first mode, the four frames are acquired while the lens (Fig. 2; 17) is moved around the fine focus. This mode ensures that the most focused image is always acquired, even if the refractive error changes for the particular gaze corresponding to the fixation light. In the second mode, four frames are acquired while the optical head (Fig. 1; 1) is moved horizontally along the x-axis. This mode permits acquisition of images through four well-defined locations across the pupil. A pair of images obtained from two opposite horizontal locations in the pupil generates a stereo image. The pair with the larger separation yields a better stereo base and thus a better stereoscopic effect. The pair with the smaller separation ensures that a good fundus image and some stereoscopic views are obtained, even in the presence of poorly dilated pupils.

**Visual Acuity Measurement**

Once the eye has been imaged, we are assured that the DigiScope is focused on the retina. The imaging CCD camera (Fig. 2; 18) is replaced by a screen (22) with Snellen letters, illuminated by a lamp (21). The DigiScope is automatically centered on the pupil, and the subject is asked to read the chart. The same chart is provided to the operator on the touch screen, and the operator presses each of the letters correctly identified. The results are then converted into visual acuity units at the reading center.

**Operation of the DigiScope**

A first target is presented to the subject. Pupil tracking is initiated, and the optical head is aligned with the optical axis of the eye and positioned at the working distance. The fixation diode turns into a flickering mode to further attract the subject’s attention and, if the pupil is still centered, the fundus is imaged in the focusing mode. The best-focused image and the brightness of that image are determined. The imaging lens and the intensity of the bulb are set accordingly. The procedure is repeated for fine adjustment of focus and light intensity.

The imaging session then begins. The different targets corresponding to the different areas in the fundus are presented in sequence. For each desired location on the fundus, a single diode is turned on. For
each location, the pupil is tracked and centered on the monitor. The fundus is imaged in one of the two modes according to a preset choice for each target. The digitized images are presented to the operator on the touch screen. The operator accepts the fundus images or repeats the acquisition, and accepted images are saved.

The role of the operator is limited to instructing the patient about the procedure, encouraging the patient to fixate well when the target light flickers, and checking the general quality of the images before saving them. To minimize further the role of the operator, computerized voice messages are implemented (potentially in various languages) to provide feedback and instructions to the patient and the operator.

Subjects

A DigiScope was installed in an office with a number of primary-care physicians, and the staff was instructed in its use. The first 17 consecutive sessions were used for this study. Employees at the Wilmer Eye Institute volunteered to be imaged by the DigiScope and a conventional fundus camera. They were devoid of eye disease and signed an informed consent form. The recruitment was performed in accordance with the Declaration of Helsinki for research involving human subjects.

Before the imaging with the DigiScope, the eyes were dilated with 1% tropicamide ophthalmic solution and, if the pupil were less than 5 mm, 1% phenylephrine hydrochloride was instilled.

Conventional Fundus Photography

Color fundus photographs were obtained by experienced ophthalmic photographers. A high-quality fundus camera (model FF4; Carl Zeiss, Thornwood, NY) was used, and the images were recorded on film (Ektachrome 100; Eastman Kodak, Rochester, NY).

Imaging with the DigiScope

Pupil Alignment. The time required to detect the pupil’s center was derived from the computer clock reading before and after the routine. The time required to finish the alignment sequence was determined for each subject by recording the computer clock.

The precision of the alignment was assessed by saving the pupil image obtained after the alignment before fine fundus focusing. The deviation from the intended location of the pupil’s center was assessed by the SD of the distance between the computed center of the pupil and the nominal location. This location was not necessarily the center of the screen, due to the introduction of an offset programmed for each target, to minimize corneal reflections.

Fundus Focusing. All the focusing sequences were presented to a masked reader who selected the best-focused frame. Forty-two sequences were generated, including the repeated ones. Fifteen were of a quality too poor to allow the reader to identify the best focus. In no case (0%) was there a deviation of three or more frames, and in two (7%) cases there was a deviation of two to eight frames. After focusing, four frames were acquired from each target. An error of two frames would cause the best focus not to be the central frame but rather the first or last image.

Acquisition Time. The time for completing pupil and fundus adjustment and the acquisition time for the first target were measured for each eye.

Compression Ratio. The images obtained after fine focusing were compressed and decompressed by a ratio between the original and final file sizes up to 60. To assess the effect of compression, objective and subjective methods were used. The objective method was based on the subtraction of the compressed image from the original one. The deviation in gray intensity was calculated for each pixel. The mean of the absolute deviation was derived for each image. The low and high quartiles and the median were calculated for the whole sample. The subjective method consisted of presenting the images to a masked reader who was asked to identify the subtlest vascular features and determine where in the sequence of compression the features were first lost.

FIGURE 4. Example of fundus focusing. Eight images were acquired in 240 ms while the focusing lens was in motion. The algorithm detected the image with the highest features content determined from the discrete cosine transform.

Transfer Time. The images were sent through the Internet by telephone line with the use of a 56-K-baud modem and at the compression ratio determined. File transfer protocol (FTP) was used at different times of the day.

Comparison of the original files on the DigiScope with those received at the reading center was performed to check the integrity of the files. The comparison method was identical with the objective method used to assess the effect of compression.

RESULTS

Pupil Alignment

An example of an alignment sequence is given in Figure 5 (top sequence). The subject was given a new target to fixate, and thus the pupil had to be realigned. From the sequence, it can be noted that the centering was accomplished in less than eight video frames or in 265 ms. Experience showed that the time to bring the pupil into focus is determined by the speed of the motor, because the processing time is small, even in a rapid application development (RAD) tool (Visual Basic, Microsoft, Inc.). The slowest motion is the vertical one at a velocity of 2 mm/sec. Once the deviation due to the change in gaze between targets is corrected, the typical residual deviation of the pupil is less than 1 mm and can thus be corrected within 500 ms.

The SD of the computed geometric center from the nominal location of the pupil center was obtained from 140 pupil-centering sequences. The precision of the algorithm and the motorized motion was 710 and 550 μm for the horizontal and vertical axes, respectively. This precision is equivalent to 10% to 13% of the average pupil diameter of 5.5 mm.

An example of a rough pupil-focusing sequence is shown in Figure 5 (bottom sequence). The correct working distance was identified from the frame with the sharpest corneal reflection, and the XYZ table was moved to that location.

Fundus Focusing

An example of a sequence of eight frames acquired for focusing is shown in Figure 4. The motion of the lens during this sequence was enough to correct for +10 D to −10 D. The best-focused frame was selected by the algorithm in 660 ms. The algorithm selection deviated from the manual by three
frames in 0% of the cases and by two frames in 12% of the cases.

**Light Power Density**
The power typically delivered through the pupil is 2.5 mW, corresponding to a power density of 1.1 mW/cm². According to the calculations in Delori et al., based on national standards for safe exposure to light, the maximum permissible power density for a single 250-ms exposure is approximately 6 W/cm². Also, at this power density, the maximum permissible continuous exposure is approximately 800 seconds.

**Acquisition Time**
The time for completing pupil positioning and fundus focusing was 1.9 ± 1.3 minutes. The total time to image one eye was 5.6 ± 2.4 minutes.

**Compression Ratio**
The effect of compression is shown in Figure 5. Note that at the magnification under which the image is displayed, very little effect can be noted, up to a compression of 60. The mean absolute deviation of pixel densities and the maximum deviation were plotted as a function of the compression ratio (Fig. 6). There seemed to be an increase in the rate of degradation at a compression of 15. For compression limited to 12, the maximum deviation in pixel density was 10% of an 8-bit gray scale (0–255).

**Transfer Time**
Files were transferred at night at 23 different times. For a fundus file compressed 10 times from 330 K to 33 K, the transfer time was 18 seconds with a 56-K-baud modem and a regular telephone line. Fundus images acquired at the 10 locations in both eyes were thus transferred in 6 minutes.

**Pilot Evaluation of the Image Quality**
Figure 7 left is an example of a fundus image obtained with the DigiScope. A mosaic of the 10-frame sequence was formed to generate a fundus image. The composite of the 10 individual images covered a fundus region 71° diagonally without any gap.

The comparison of the DigiScope images with those obtained by an ophthalmic photographer with conventional fundus camera (Fig. 7, right) shows that the DigiScope image yielded the same clinical information as the gold standard. This is illustrated by the visibility of small blood vessels and small drusen. Because the low magnification may not show the high resolution of conventional photography, a small region of interest was enlarged for comparison. Even under this magnification, no meaningful difference was detectable between the two imaging modes.

**DISCUSSION**
Bresnick et al., in a recent article based on the ETDRS data, has shown that fundus photography can be used for screening of patients and has concluded that “if the protocols can be implemented effectively in a primary care setting, patients requiring referral for specialty care could be reliably identified.” Presently, the barrier to implementation in the primary-care setting is the cost of the equipment necessary to acquire

**FIGURE 5.** Effect of compression on image quality. Top frame: original uncompressed image. To permit better visualization of the effect of compression, only a region of interest is displayed in the lower frames. The number on the top left corner of each frame is the compression ratio used in that frame.

**FIGURE 6.** Mean ± SD of the change in pixel density as a function of compression ratio. Left: plot of the maximum absolute difference between the pixel density of an image before and after compression. Right: plot of the SD of the absolute difference between the pixel density of an image before and after compression.
and transfer digital images and the need for well-trained operators.

The DigiScope was developed to permit efficient and cost-effective implementation in the primary-care setting. As mentioned in the Methods section, the DigiScope had to satisfy a number of stringent demands to be of practical use.

The DigiScope was shown to have effective automated functions that alleviate the need for a trained photographer. The pupil alignment based on image processing of digital images was found to center the pupil within 700 μm in less than 270 ms. Because the mean pupil diameter was 5.5 mm, the precision is equivalent to 13% of the pupil diameter. This precision ensures that, when the image is taken, the optics of the eyes are well aligned with those of the DigiScope, thereby optimizing the optical quality and the illumination. On the rare occasions that the present algorithm fails because of partial eyelid closure or blink, the operator can proceed by pointing at the center of the pupil seen on the monitor. Based on reflections on the cornea, the DigiScope can automatically set the working distance. The procedure for focusing the fundus is efficient enough to ensure that the best-focused image is within the series of four images acquired at each location.

One of the requirements for the quality of the DigiScope image was that it must provide the same clinical information as the gold standard—namely, conventional fundus photography on film. To make this comparison, we chose a high-quality fundus camera operated by certified ophthalmic photographers. The pilot test in normal eyes indicated, as shown in Figure 7, that the smallest vascular features seen on the conventional photograph were also visible on the DigiScope image. The monochromatic imaging of the DigiScope seems to enhance the contrast and ease the visualization of white and red features. All diabetic retinopathy lesions fall into this category, particularly those that differentiate mild from more severe retinopathy: microaneurysms, exudates, and hemorrhages. The sensitivity and specificity of screening with the DigiScope needed evaluation, and an independent investigator has performed a validation study. The results, presented in part at the 2001 annual meeting of ARVO, showed a sensitivity of 0.99 and a specificity of 0.96. The upcoming publication of the complete study will also provide information on the prevalence of images that are ungradable due to such factors as media opacity, high myopia, and pseudophakia.

The imaging procedure was acceptable to the subjects. They all found that the light’s intensity was much more comfortable than the flash in conventional photography. The light-energy density of the DigiScope is 1.1 mW/cm², or more than three orders of magnitude less than the recommended permissible exposure. Conventional-flash fundus cameras are typically one to two orders of magnitude below the recommended permissible exposure. For the time being, the DigiScope will be used with drug-induced dilation to ensure good images in a large portion of the population. Dilation is not an added procedure, because the current preferred practice procedures call for a dilated eye examination, and photography with mydriasis has not been as successful as imaging without. Moreover, if dilation is performed with tropicamide, there is no risk of inducing angle closure, as demonstrated by the review of the literature between 1933 and 1999. The staff in charge of dilation will be instructed on the symptoms of angle closure and on the steps to be taken. The drawback of mydriasis is the time necessary to achieve dilation, even the required is to 5-mm diameter. Therefore, means to image without pharmacologic dilation will be investigated.

Once the images have been acquired, they must be transferred to a reading center. We have chosen to use FTP through the Internet rather than e-mail, which may transfer different parts of the data via separate routes. We found that by compressing the data by a factor of 12, a whole session can be transferred through regular telephone lines in less than 10 minutes. This time is totally acceptable, because the automatic transfer is performed outside office hours, and a typical office is expected to screen an average of one patient a day. Our pilot tests have shown that this compression does not affect the informative content of the images.

In summary, this evaluation of the DigiScope indicates that it fulfills the requirements for a practical and cost-effective instrument for the acquisition of clinical data that could be used to identify diabetic patients who must be referred to an eye care specialist. Should validation studies in diabetic patients indicate that this screening method is sensitive and
specific, its widespread use in the United States alone is likely to reduce the risk of vision loss in 8 million individuals, half of whom currently do not receive annual eye examinations.

References


