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Detecting Common Eye Diseases Using the First Teleophthalmology GlobeChek Kiosk in the United States: A Pilot Study

Rahul Kapoor, MD, Cansu Yuksel-Elgin, MD†, Vipul Patel†, Jennifer Alcantara-Castillo, COA†, Maya Ramachandran, BS*, Kamran Ali, BS*, Rahm Alshamah*, Deborah Popplewell, OD*, Emery Jamerson, MD*, Cecile Truong, BS*, Janet Sparrow, MD*, William J. Mallon, MD‡, Adam M. Katz, MD‡, and Lama A. Al-Aswad, MD, MPH†*

Purpose: The aim of this study was to assess the benefit and feasibility of the teleophthalmology GlobeChek kiosk in a community-based program.
Design: Single-site, nonrandomized, cross-sectional, teleophthalmologic study.
Methods: Participants underwent comprehensive evaluation that consists of a questionnaire form, brief systemic evaluation, screening visual field (VF), and GlobeChek kiosk screening, which included but not limited to intraocular pressure, pachymetry, anterior segment optical coherence tomography, posterior segment optical coherence tomography, and nonmydriatic fundus photography. The results were evaluated by a store-and-forward mechanism and follow-up questionnaires were obtained through phone calls.
Results: A total of 326 participatents were screened over 4 months. One hundred thirty-three (40.79%) participants had 1 condition in either eye, and 47 (14.41%) had >1 disease. Seventy (21.47%) had glaucoma, 37 (11.34%) narrow-angles, 6 (1.84%) diabetic retinopathy, 4 (1.22%) macular degeneration, and 43 (13.10%) had other eye disease findings. Age >65, history of high blood pressure, diabetes mellitus, not having a dental examination >5 years, hemoglobn A1c measurement of ≥5.6, predibates risk score of ≥9, stage 2 hypertension, and low blood pressure were found to be significant risk factors. As for the ocular parameters, all but central corneal thickness, including an intraocular pressure >21 mm Hg, vertical cup to disc ratio >0.7, visual field abnormalities, and retinal nerve fiber layer thinning were found to be significant.
Conclusions: GlobeChek kiosk is both workable and effective in increasing access to care and identifying the most common causes of blindness and their risk factors.

Key Words: leading causes of blindness and ophthalmic kiosk, teleophthalmology

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The leading causes of blindness are cataract, diabetic retinopathy (DR), glaucoma, and age-related macular degeneration (AMD).[1] Several demographic variables, such as race, ethnicity, socioeconomic status, and level of education may influence the prevalence of these common eye diseases, and the rate of eye examinations.[2] Therefore, telemedicine, which is defined as the electronic exchange and communication of medical information between 2 locations, is now being routinely used to improve screening and to monitor chronic eye diseases in at-risk populations around the world.[3] Moreover, teleophthalmology units have proven to be beneficial for screening not just in lower-income regions,[4–6] but also in rural and urban populations of developed countries.[7–11] Despite the availability of technology necessary for transmitting digital ocular images and remote interpretation, teleophthalmology is still in its infancy.[3,12]

Many residents of northern Manhattan, a borough of New York City, are Hispanic (71%) or African American (7%) who live below the federal poverty level (27%), and/or have a low level of education.[13] As mentioned above, given these demographics, the community is at a higher risk of developing the most common eye diseases. Between June and October 2018, the Edward S. Harkness Eye Institute of the Columbia University Medical Center conducted a teleophthalmology screening program using a GlobeChek kiosk. Previously, the same group of investigators conducted a similar project in the same neighborhood, both at fixed sites and in a mobile van, and the results of that community-based screening program showed that 25% of 8547 participants screened were glaucoma suspects, 15% were deemed to need further investigation of ocular diseases other than glaucoma, and 57% had never seen an eye doctor in their lifetime.[14]

A large fraction of the population from different socioeconomic backgrounds faces various types of barriers, including cost, time, and convenience barriers. Another barried emerges a lack of understanding the importance of proper eye care, which leads to a decrease in compliance with routine eye care for both low-income population groups but also high-income ones. Therefore,

From the *Columbia University Medical Center, Harkness Eye Institute, New York, NY; †New York University (NYU Robert Grossman) School of Medicine, NYU Langone Health, New York, NY; and ‡GlobeChek Enterprises, LLC, Vero Beach, FL.
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Address Correspondence and Reprint Requests to: Lama A. Al-Aswad, Department of Ophthalmology, New York University (NYU Robert Grossman) School of Medicine, NYU Langone Health, New York, NY 10017. E-mail: Lama.Al-Aswad@nyulangone.org.

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teleophthalmologic methods are helpful in all socioeconomic groups and eliminate these barriers.

There have been several logistical problems in the course of development of teleophthalmology. In this regard, GlobeChek kiosk is an innovative design addressing several of these problems and involves a simple setup of the required equipment needed for a comprehensive eye examination and provides easy accessibility for any type of population. In this study, the primary purpose was to test the GlobeChek kiosk, the first in the United States, at a location with high volume and accessibility and to explore its benefits and feasibility.

METHODS

This study adhered to the tenets of the Declaration of Helsinki and was approved by the Columbia University Institutional Review Board. A GlobeChek teleophthalmology kiosk (Fig. 1) was placed in a high traffic area in front of the emergency room of the New York Presbyterian Hospital Columbia University Campus for 4 months. Flyers and handouts were distributed to announce the scheduled time and location for free vision screening and brief systemic evaluation. Three staff members, including ocular technicians, and medical and college students, screened each participant as follows:

- Brief medical history-taking that included self-identification of ethnicity and race, address of residence, past medical, ocular and family histories, including specific questions about diabetes mellitus, hypertension, sleep apnea, high blood cholesterol, smoking, and dental examinations. This questionnaire was planned to help the evaluation of the risk factors for several eye diseases, and the answers were used to detect relative risk ratios (RRRs) for abnormal ocular, glaucoma, and anatomical narrow-angle findings. Additionally, 7 questions of the "center for disease control (CDC) Prediabetes Screening Test" were also included in the study, were scored and graded according to its point chart.[15] Finally, participants were also examined for:
  1. Height and weight measurement for the calculation of body mass index (BMI)
  2. Blood pressure (BP) measurement using an electronic sphygmomanometer
  3. Hemoglobn A1c (HbA1c) testing (Alere Afinion point-of-care assay, Abbott Park, IL)
- Next, participants were taken to GlobeChek Kiosk for four different types of screenings (Fig. 1):
  1. Visual acuity (VA) measurement using the Optec Plus (Essilor Instruments, Lewisville, TX)
  2. Intraocular pressure (IOP) measurement, autorefraction, autokeratometry, and pachymetry using the auto keratorefractor/tonometer from topcon (TRK)-2P, which is currently a non–Food and Drug Administration-approved device (Topcon Medical Systems, Inc., Oakland, NJ)
  3. Anterior and posterior segment optical coherence tomography (OCT) using the 3D OCT-1 Maestro (Topcon Medical Systems, Inc., Oakland, NJ)
  4. Nonmydriatic fundus photography using the 3D OCT-1 Maestro (Topcon Medical Systems, Inc., Oakland, NJ) (See Fig. 2)

Finally, 2 more additional measures are:

- IOP measurement via noncontact tonometry using the Reichert 7 Auto Tonometer (Cal Coast Ophthalmic Instruments, Inc., Torrance, CA)
- Peripheral visual field (VF) measurement using Humphrey frequency doubling technology (FDT)

GlobeChek is a globe-shaped kiosk that is <5 feet long and has a couple of openings for the participants to stand up and put their heads into the openings, rest their foreheads and chins on the visor. It can also be adjusted according to participants' heights, and it moves around a circular table; therefore, all tests can be

FIGURE 1. GlobeChek™ kiosk device, a flowchart of patient recruitment. BMI indicates body mass index; BP, blood pressure; FDT, frequency doubling technology; OCT, optical coherence tomography.

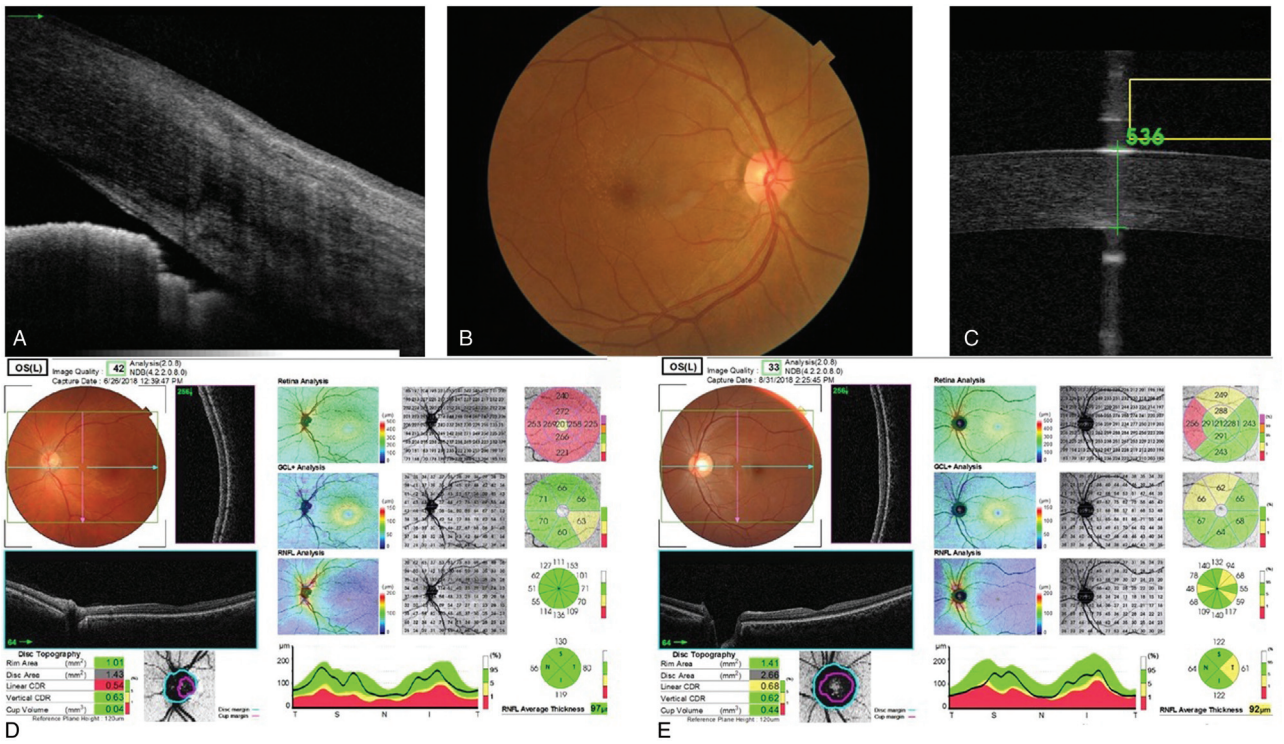

FIGURE 2. OCT imaging and image samples produced by GlobeChek.

administered at 1 location. It reduces examination duration significantly. In this study, one of the primary purposes was to evaluate GlobeChek's feasibility; however, only results obtained by FDA-approved devices are used for statistical analysis.

IOP measurements were first constructed by TRK-2P in GlobeChek (not-FDA approved) and subsequently recalculated by FDA-approved Reichert 7 Auto Tonometer. Similarly, pacimetric measurements were done by both TRK-2P and 3D OCT-1 Maestro in GlobeChek, and 3D OCT-1 Maestro's pacimetric measurements were used for statistical analysis.

In addition to pacimetric measurements, 3D OCT-1 Maestro was used for the evaluation of anterior and posterior segments. With the anterior segment optical coherence tomography (ASOCT) images, cornea-iris-anterior chamber-lens were evaluated, and anterior chamber angle (ACA) evaluations were done according to the both at 9 and at 3 o'clock side. With regard to the posterior segment OCT evaluation, retinal nerve fiber layer (RNFL) measurements, vertical cup to disc ratio (VCDR) ratio analysis, foveal evaluation, according to macular images, were conducted. Forty-five degree, non-mydriatic fundus photographies were taken using the 3D OCT-1 Maestro.

In addition to these comprehensive structural analyses, the participants were subjected to the peripheral VF test using Humphrey FDT Model 710- FDT for functional evaluation once finishing the GlobeChek examinations. FDT offers many advantages because it is very convenient to administer and interpret, and can even be performed in ambient light without the need to darken the room.[16] In this study, C 20 presentation patterns were performed in 45 seconds. Missing points and test reports (normal/suspect/abnormal), which were given by the instrument, were also taken into consideration for data analysis. Missing points at 0 were evaluated to be normal; between 1 and 2 missing points were categorized as suspect, $\geq$3 was denoted to be abnormal VF defect.

The data obtained were entered and transmitted via a secure Virtual Private Network connection to the Edward S. Harkness Eye Institute reading center. Following the store and forward method, an ophthalmologist or optometrist analyzed the data within 2 weeks of the initial screening according to the reading guidelines prepared by an experienced glaucoma specialist. The eye care professional then filled out their evaluations, and within 2 weeks participants received a printed copy of their results and recommendations for follow-up via postal mail or email just after evaluation process. Upon request, participants also received a list of local eye care professionals.

Next, within 2 to 4 months of the screening, the participants who have abnormal ocular findings were given calls, up to 3 times, by a patient navigator to ensure a follow-up visit with a local eye doctor had taken place. These follow-ups were done with special follow-up questionnaire forms that inquired about the attendance, reasons, and results of the examinations.

Definitions

Glaucoma Suspect

- IOP >21 mm Hg with corneal thickness taken into consideration by a physician.
- Glaucomatous appearance of the optic disc (defined as VCDR of $\geq$ 0.7, optic disc hemorrhage, superior or inferior notching) as determined by an examination of fundus photographs.

If neither of the aforementioned criteria were met, the participant was considered to be a glaucoma suspect if they met $\geq$2 of the following criteria:

- An abnormal OCT-RNFL and macular/ganglion cell analysis consistent with glaucoma (asymmetry between 2 optic discs, deterioration of the characteristic double-hump pattern on the

RNFL, superior-inferior asymmetry on the macular ganglion cell analyzer)
- Narrow or closed angle on anterior-segment OCT both side at 3- and 9-o'clock
- Abnormal VF with respect to machine report
- Generalized thinning of the nerve fiber layer based on OCT report

Narrow-Angle Suspects

Structurally assessed angles based on anterior-segment OCT and the degree of angle narrowing. If this condition is accompanied by IOP elevations or optic disc, OCT-RNFL, adverse macular/ganglion cell analysis, and VF test findings, the patient is categorized as a glaucoma suspect as well.

DR Suspects

Defined by hemorrhages or exudates on 45° fundus photography.

Macular Degeneration Suspects

Defined by Evidence of AMD on fundus photograph and/or posterior OCT such as drusens, retinal pigment epithelium (RPE) changes, neovascular dearrangments.

Alongside the aforementioned ocular conditions, retinal conditions (other than diabetic retinopathies and macular degenerations), choroidal lesions, unexplained VF defects, anatomical optic nerve head abnormalities, potential reasons that affect the transparency of the eye (like cataract, corneal pathologies, uveitis, vitritis) were accepted as "other eye conditions".

Finally, any type of ocular condition that includes glaucoma, narrow-angle, diabetic retinopathy, macular degeneration suspicious conditions and additionally "other eye conditions" was broadly defined as "abnormal ocular findings".

If the image quality is not well enough for definitive conditions, it is categorized as "unreadable images."

Diabetic State

- Healthy level: HbA1c under 5.3%
- Treading toward prediabetes: HbA1c between 5.4–5.6% and 6.4%
- Prediabetic state: HbA1c between 5.7% and 6.4%
- Diabetes: HbA1c $\geq$6.5%

BP Guidelines

- Low BP: systolic $\leq$90 mm Hg or diastolic $\leq$60 mm Hg
- Normal: $<$120/80 mm Hg
- Elevated: systolic 120 to 129 mm Hg and/or diastolic $>$80 mm Hg
- Stage 1 hypertension: systolic 130–139 mm Hg and diastolic 80–89 mm Hg
- Stage 2 hypertension: systolic $\geq$140 mm Hg or diastolic $\geq$90 mm Hg

BMI

- Normal range: 18.5–24.9
- Elevated: 25–29.9
- High: $\geq$30

The usual equation for calculating BMI [weight in pounds / (height in inches)^2] was adjusted to account for the fact that the participants were clothed ($-$2.65 for males; $-$1.76 for females).[17]

CDC Prediabetes Screening Test

- Low risk for having prediabetes: 3–8
- High for having prediabetes: $\geq$9

Statistics

Although this study was designed with a comprehensive methodology and there were multiple predictors for eye conditions, the limited time and the limited number of participants constrained the statistical analysis. RRR for each predictor and their corresponding *P* values were used for statistical inference. The risk calculation was performed for abnormal ocular findings, glaucoma suspects, narrow-angle findings group because of their substantive group numbers. On the contrary, DR suspects and macular degeneration suspects were not taken into consideration for risk calculation. Computerized statistical analyses were performed using STATA software (version 14, StataCorp, College Station, TX). The alpha level (type 1 error) was set to be 0.05.

RESULTS

A total of 397 participants consented, of which 71 participants were excluded from the study due not completing the screening. Reasons for not completing were time constrains, unwillingness to continue, or not willing to be imaged (fundus photographs, OCT, VF). Of 326 screened participants, 18 (5.52%) had unreadable images.

Table 1 presents summary of information including demographics and other patient characteristics, and several detected diseases both for the whole dataset and different subsets of the data.

According to the classification explained in the previous section, 133 (40.79%) participants were detected having a sight-threatening eye disease or condition during the screening in both eye, and 47 (14.41%) of the participants had $>$1 disease, whereas 192 (58.89%) participants had a normal examination. From the 133 (40.79%) with at least 1 eye disease, 70 (21.47%) had glaucoma, 37 (11.34%) had narrow-angle, 6 (1.84%) had DR, 4 (1.22%) had macular degeneration, and finally, 43 (13.10%) had other eye disease findings in either eye (Table 1). Seventeen participants from the narrow-angle suspects group had additional findings that led them to be classified as glaucoma suspects as well.

Since this was a community-based population screening study, the only inclusion criterion for the study was to be 18 years or older, and accordingly, all willing participants who may or may not have an ocular disease, were welcomed and evaluated with the same screening protocol. As shown in Table 2, although several participants had self-reported previous eye conditions, a newly identified disease rate is also quite high.

Table 3 shows various systemic examination findings among study participants, including HbA1c, systolic and diastolic BP, BMI, and CDC prediabetes screening tests. As expected, the highest value of HbA1c, systolic BP, BMI, CDC prediabetes score were measured in the DR group.

Table 4 shows various ophthalmologic parameters in study participants, including VA, IOP, central corneal thickness (CCT), VCDR (measured by reader and OCT), RNFL thickness, and VF. As expected IOP measurements in glaucoma suspects were higher than the other groups and the mean RNFL attenuation were lower

TABLE 1. Demographics and Patient Characteristics

Characteristic	Total[a] (N = 326)	Healthy Ocul. Findings (n = 192)	Abnormal Ocular Findings (n = 133)	Glaucoma Suspects (n = 70)	Narrow-angle Suspects (n = 37)	Diabetic Retinopathy Suspects (n = 6)	Macular Degeneration Suspects (n = 4)	Other Eye Condition Findings (n = 43)
Age, mean ± std	50.09 ±12.64	47.28 ±12.48	54.04 ± 11.79	54.01 ± 12.31	57.08 ± 9.27	55.00 ± 11.92	64.00 ± 8.91	55.12 ± 11.88
18≤ Age ≤ 40, n (%)	73 (22.39)	52 (27.08)	21 (15.78)	13 (18.57)	3 (8.10)	0 (0.00)	0 (0.00)	6 (13.95)
41≤ Age ≤ 64, n (%)	218 (66.87)	129 (67.18)	88 (66.16)	44 (62.85)	25 (67.56)	4 (66.66)	2 (50.00)	28 (65.11)
Age ≥ 65, n (%)	35 (10.73)	11 (5.72)	24 (18.04)	13 (18.57)	9 (24.32)	2 (33.33)	2 (50.00)	9 (20.93)
Sex, n (%)								
Female	194 (59.51)	118 (61.46)	75 (56.39)	40 (57.14)	19 (51.35)	2 (33.33)	2 (50.00)	27 (62.79)
Male	131 (40.18)	73 (38.02)	58 (43.60)	30 (42.85)	18 (48.65)	4 (66.67)	2 (50.00)	16 (37.21)
Ethnicity, n (%)								
African American	101 (30.98)	59 (30.73)	42 (31.57)	26 (37.14)	10 (27.03)	2 (33.33)	0 (0.00)	8 (18.60)
Asian	34 (10.43)	18 (9.38)	16 (12.03)	6 (8.57)	4 (10.81)	1 (16.67)	1 (25.00)	5 (11.63)
Caucasian	41 (12.58)	27 (14.06)	14 (10.52)	4 (5.71)	6 (16.22)	1 (16.67)	2 (50.00)	7 (16.28)
Hispanic	114 (34.97)	68 (35.42)	45 (33.83)	25 (35.71)	13 (35.14)	1 (16.67)	1 (25.00)	14 (32.56)
Other	32 (9.82)	18 (9.38)	14 (10.52)	8 (11.42)	4 (10.81)	1 (16.67)	0 (0.00)	7 (16.28)
Self-declaration								
Insurance, n (%)	286 (87.73)	164 (85.42)	121 (90.97)	59 (84.28)	34 (91.89)	6 (100.00)	4 (100.00)	41 (95.35)
Current smoker, n (%)	34 (10.43)	17 (8.85)	17 (12.78)	8 (11.42)	3 (8.11)	0 (0.00)	1 (25.00)	5 (11.63)
Sleep apnea, n (%)	28 (8.59)	14 (7.29)	14 (10.52)	11 (15.71)	1 (2.70)	1 (16.67)	0 (0.00)	4 (9.30)
Hypertension, n (%)	75 (23.00)	34 (17.70)	41 (30.82)	25 (35.71)	6 (16.21)	4 (66.67)	2 (50.00)	14 (32.55)
Diabetes mellitus, n (%)	40 (12.26)	17 (8.85)	23 (17.29)	11 (15.71)	2 (5.41)	6 (100.00)	1 (25.00)	7 (16.27)
Dyslipidemia, n (%)	46 (14.11)	23 (11.97)	22 (16.54)	13 (18.57)	4 (10.81)	3 (50.00)	0 (0.00)	9 (20.93)
Last dental exam, n (%)								
<1 y	230 (70.55)	136 (70.83)	93 (69.92)	45 (64.28)	25 (67.56)	4 (66.67)	4 (100)	29 (67.44)
>2 y	72 (22.08)	47 (24.47)	25 (18.79)	16 (22.85)	7 (18.91)	1 (16.66)	0 (0)	10 (23.23)
>5 y	23 (7.05)	8 (4.16)	15 (11.27)	9 (12.85)	5 (13.51)	1 (16.66)	0 (0)	4 (9.30)
Never	1 (0.30)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Last eye exam, n (%)								
<1 y	151 (46.31)	82 (42.70)	68 (51.12)	38 (54.28)	19 (51.35)	3 (50)	4 (100)	20 (46.51)
>2 y	111 (34.04)	72 (37.50)	39 (29.32)	23 (32.85)	9 (24.32)	1 (16.66)	0 (0.00)	10 (23.25)
>5 y	53 (16.25)	30 (15.62)	23 (17.29)	8 (11.42)	8 (21.62)	2 (33.33)	0 (0.00)	10 (23.25)
Never	11 (3.37)	8 (4.16)	3 (2.25)	1 (1.42)	1 (2.70)	0 (0.00)	0 (0.00)	3 (6.97)

among glaucoma suspects, DR suspects, and macular degeneration suspects groups. The mean CCT in patients with suspected glaucoma was similar to the mean CCT in healthy individuals, and there were not any interpretable differences among the groups. The VCDR in glaucoma suspects was larger on average by 0.11 compared with the healthy individuals. Overall and in all subgroups of participants, the VCDR was greater when assessed by OCT than when assessed by the readers.

In Table 5, the effect of all the ophthalmologic parameters was evaluated using an RRR calculation for three different groups. Besides the demographic characteristics (age, sex, ethnicity), the risk factors were grouped in 3 categories: as self-reported conditions, systemic findings, and ocular findings. And then, these risk factors were evaluated for 3 groups, that is, glaucoma suspects group, the abnormal ocular findings group, and finally the group with narrow-angle.

For glaucoma suspects, age ≥65, African American and Hispanic ethnicity, self-reported sleep apnea, personal history of high BP, not having a dental examination over 5 years, a HbA1c measurement of ≥6.5, BP measurements consistent with stage 2 hypertension, CDC score of ≥9 were found to be significant risk factors. As for the ocular parameters, all but CCT, including an IOP >21 mm Hg, VCDR >0.7, VF abnormalities, RNFL thinning, were significant.

In this study, almost half of the abnormal ocular finding group consisted of glaucoma suspects, and the remaining half

TABLE 2. Comparison of Self-Reported Diseases and Newly Detected Diseases

Condition	Disease Detected By Screening Total No. (%) (N = 326)	Self-Reported Within Condition (%) (N = 326)	Newly Identified Disease No. (%) (N = 326)	Self-Reported Disease, Not Identified by Screening No. (%) (N = 326)
Glaucoma (all)	70 (21.47)	4 (1.22)	64 (19.63)	4 (1.22)
Narrow-angle	37 (11.34)	X	X	X
Diabetic retinopathy	6 (<1)	1 (<1)	5 (<1)	*
Macular degeneration	4 (<1)	0 (0)	4 (<1)	0 (0)
Diabetes or prediabetes	110 (33.74)	39 (11.96)	71 (21.77)	1 (<1)
Hypertension	43 (13)	22 (6.74)	21 (6.44)	53 (16.25)

*Questionnaire asks about retinal disease, not specifically diabetic retinopathy—9 reported retinal disease.

X indicates not asked.

TABLE 3. Results of Systemic Examination Findings From the Telemedicine Protocol

Variable	Total (N = 326)	Healthy Ocular Findings (n = 192)	Abnormal Ocular Findings (n = 133)	Glaucoma Suspects (n = 70)	Narrow-Angle Suspects (n = 37)	Diabetic Retinopathy Suspects (n = 6)	Macular Degeneration Suspects (n = 4)	Other Eye Condition Findings (n = 43)
HbA1c, mean ± std	5.76 ± 1.22	5.57 ± 0.94	6.04 ± 1.50	5.94 ± 1.33	5.59 ± 0.48	9.27 ± 2.37	6.40 ± 2.14	6.14 ± 1.67
Healthy A1C (under 5.3), n (%)	118 (36.19)	83 (43.22)	35 (26.31)	20 (28.57)	11 (29.72)	0 (0.00)	2 (50.00)	12 (27.90)
Treading toward prediabetes (5.4–5.6), n (%)	91 (27.91)	53 (27.60)	38 (28.57)	19 (27.14)	13 (35.13)	0 (0.00)	1 (25.00)	12 (27.90)
Prediabetic state (5.7–6.4), n (%)	74 (22.69)	40 (20.83)	33 (24.81)	18 (25.71)	9 (24.32)	0 (0.00)	0 (0.00)	8 (18.60)
Diabetic (6.5 and Higher), n (%)	36 (11.04)	12 (6.25)	24 (18.04)	12 (17.14)	3 (8.10)	6 (100)	1 (25.00)	9 (20.93)
Systolic BP, mean ± std	124.60 ± 18.19	122.74 ± 17.22	127.22 ± 19.31	129.46 ± 20.99	126.30 ± 23.84	136.83 ± 8.33	134.75 ± 13.82	123.29 ± 15.64
Diastolic BP, mean ± std	78.27 ± 11.74	77.48 ± 11.23	79.28 ± 12.35	80.90 ± 13.45	78.08 ± 12.18	78.00 ± 10.70	82.25 ± 6.24	76.88 ± 11.72
Low BP, n (%)	5 (1.53)	1 (0.5)	4 (3.00)	2 (2.85)	2 (5.40)	0 (0.00)	0 (0.00)	2 (4.65)
Normal BP, n (%)	112 (34.35)	75 (39.06)	37 (27.81)	19 (27.14)	12 (32.43)	0 (0.00)	0 (0.00)	12 (27.90)
Pre HT, n (%)	120 (36.80)	70 (36.45)	50 (37.59)	23 (32.85)	14 (37.83)	3 (50.00)	2 (50.00)	19 (44.18)
Stage 1 HT, n (%)	68 (20.85)	38 (19.79)	29 (21.80)	16 (22.85)	5 (13.51)	3 (50.00)	2 (50.00)	8 (18.60)
Stage 2 HT, n (%)	20 (6.13)	8 (4.16)	12 (9.02)	10 (14.28)	4 (10.81)	0 (0.00)	0 (0.00)	1 (2.32)
BMI, mean ± std	28.67 ± 6.70	28.30 ± 6.49	29.22 ± 6.99	30.25 ± 7.72	27.45 ± 8.30	31.38 ± 5.72	24.88 ± 3.71	28.97 ± 6.42
Normal range (18.5–24.9), n (%)	105 (32.20)	66 (34.37)	39 (29.32)	19 (27.14)	15 (40.54)	1 (16.66)	3 (75.00)	13 (30.23)
Elevated (25–29.9), n (%)	107 (32.82)	69 (35.93)	37 (27.81)	18 (25.71)	14 (37.83)	1 (16.66)	1 (25.00)	10 (23.25)
High (≥30), n (%)	114 (34.96)	57 (29.68)	57 (42.85)	33 (47.14)	8 (21.62)	4 (66.66)	0 (0.00)	20 (46.51)
CDC prediabetes screening test, mean ± std	10.35 ± 4.59	9.55 ± 4.77	11.47 ± 4.05	11.90 ± 4.12	11.35 ± 3.45	13.33 ± 2.66	10.25 ± 4.50	11.19 ± 4.50
No risk (score is 0–2), n (%)	15 (4.60)	12 (6.25)	3 (2.25)	2 (2.85)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.32)
Low risk (score is 3–8), n (%)	90 (27.60)	66 (34.37)	24 (18.04)	9 (12.85)	6 (16.21)	0 (0.00)	2 (50.00)	11 (25.58)
High risk (score is ≥9), n (%)	221 (67.79)	114 (59.37)	106 (79.69)	59 (84.28)	31 (83.78)	6 (100.00)	2 (50.00)	31 (72.09)

BMI indicates body mass index; BP, blood pressure; CDC, center for disease control; HT, hypertension.

TABLE 4. Results of Vision Testing From the Telemedicine Protocol

Variable	Total (N = 326)	Healthy Ocular Findings (n = 192)	Abnormal Ocular Findings (n = 133)	Glaucoma Suspects (n = 70)	Narrow Angle Suspects (n = 37)	Diabetic Retinopathy Suspects (n = 6)	Macular Degeneration Suspects (n = 4)	Other Eye Condition Findings (n = 43)
VA (logMAR), mean ± std								
Right eye	0.07 ± 0.21	0.04 ± 0.17	0.13 ± 0.26	0.17 ± 0.30	0.09 ± 0.23	0.17 ± 0.22	0.08 ± 0.13	0.15 ± 0.27
Left eye	0.07 ± 0.21	0.05 ± 0.20	0.09 ± 023	0.11 ± 0.23	0.07 ± 0.22	0.18 ± 0.41	0.23 ± 0.34	0.11 ± 0.27
IOP, mm Hg, mean ± std								
Right eye	15.56 ± 3.86	14.85 ± 2.97	16.56 ± 4.69	18.44 ± 5.19	16.03 ± 4.51	14.33 ± 3.44	17.00 ± 2.45	14.26 ± 2.95
Left eye	15.63 ± 3.96	14.91 ± 3.12	16.63 ± 4.75	18.56 ± 5.38	16.27 ± 4.40	13.00 ± 2.00	16.75 ± 1.71	14.37 ± 2.56
CCT, μm, mean ± std								
Right eye	541.51 ± 36.98	538.84 ± 35.72	545.35 ± 38.70	546.84 ± 38.52	551.32 ± 37.48	545.50 ± 65.58	577.25 ± 35.32	541.21 ± 42.75
Left eye	542.43 ± 37.67	540.11 ± 36.45	545.77 ± 39.38	547.03 ± 39.53	551.62 ± 37.26	535.50 ± 59.88	587.50 ± 28.31	542.02 ± 42.20
Reader: VCDR, mean ± std								
Right eye	0.32 ± 0.16	0.29 ± 0.13	0.35 ± 0.19	0.42 ± 0.22	0.31 ± 0.17	0.34 ± 0.27	0.46 ± 0.18	0.29 ± 0.14
Left eye	0.33 ± 0.16	0.31 ± 0.14	0.36 ± 0.19	0.42 ± 0.21	0.34 ± 0.18	0.34 ± 0.25	0.59 ± 0.22	0.32 ± 0.15
OCT: VCDR, mean ± std								
Right eye	0.52 ± 0.21	0.50 ± 0.20	0.54 ± 0.23	0.59 ± 0.23	0.56 ± 0.22	0.49 ± 0.32	0.59 ± 0.35	0.48 ± 0.24
Left eye	0.53 ± 0.21	0.52 ± 0.20	0.54 ± 0.22	0.61 ± 0.20	0.56 ± 0.20	0.53 ± 0.22	0.46 ± 0.30	0.48 ± 0.24
RNFL, μm, mean ± std								
Right eye	103.89 ± 16.35	106.68 ± 10.96	99.85 ± 21.40	93.09 ± 23.17	105.92 ± 13.77	95.60 ± 15.34	85.50 ± 31.10	103.41 ± 18.02
Left eye	105.00 ± 15.98	107.37 ± 11.64	101.53 ± 20.31	96.52 ± 19.89	107.22 ± 13.39	82.00 ± 27.28	90.25 ± 33.66	103.73 ± 21.52
FDT-VF, mean ± std								
Right eye, average misses ± std	1.04 ± 2.87	0.19 ± 0.76	2.26 ± 4.09	2.99 ± 4.85	0.92 ± 2.33	2.50 ± 5.65	0.50 ± 1.00	2.86 ± 4.05
Left eye, average misses ± std	1.28 ± 3.15	0.21 ± 0.80	2.78 ± 4.39	3.26 ± 4.89	1.11 ± 2.80	5.00 ± 7.04	1.00 ± 2.00	3.79 ± 4.50

CCT indicates central corneal thickness; FDT VF, frequency doubling technology–visual field; IOP, intraocular pressure; std, standard deviation; OCT, optical coherence tomography; RNFL, retinal nerve fiber layer; VA, visual acuity; VCDR, vertical cup to disc ratio.

TABLE 5. Results of Relative Risk Ratio From the Telemedicine Protocol

	Glaucoma Suspect		Abnormal Ocular Findings		Narrow Angle	
	RRR (95%)	*P*	RRR (95%)	*P*	RRR (95%)	*P*
Age (relative to age group 18–40)						
40< Group 1 <65	1.13 (0.65–1.98)	0.66	1.40 (0.95–2.08)	0.09	2.79 (0.87–8.97)	0.09
Group 2 ≥ 65	2.09 (1.08–4.01)	0.03	2.38 (1.56–3.65)	0	6.26 (1.81–21.69)	0
Sex (relative to female)						
Male	1.11 (0.73–1.69)	0.62	1.15 (0.88–1.49)	0.31	1.40 (0.77–2.57)	0.27
Ethnicity (relative to white)						
African-American	2.64 (0.99–7.09)	0.05	1.22 (0.75–1.98)	0.43	0.68 (0.26–1.74)	0.42
Asian	1.81 (0.55–5.89)	0.33	1.38 (0.79–2.40)	0.26	0.80 (0.25–2.62)	0.72
Hispanics	2.25 (0.83–6.097)	0.11	1.16 (0.71–1.87)	0.56	0.78 (0.32–1.91)	0.59
Others	2.56 (0.85–7.56)	0.1	1.28 (0.72–2.29)	0.4	0.85 (0.26–2.77)	0.79
Self-Report conditions						
Lack of health insurance	0.73 (0.42–1.27)	0.27	1.38 (0.84–2.24)	0.2	1.55 (0.50–4.79)	0.45
Smoking	1.11 (0.58–2.11)	0.76	1.26 (0.87–1.81)	0.22	0.76 (0.25–2.34)	0.63
Sleep apnea	1.98 (1.19–3.32)	0.01	1.25 (0.84–1.86)	0.27	0.30 (0.04–2.08)	0.22
Personal history of high BP	1.86 (1.23–2.82)	0	1.49 (1.15–1.94)	0	0.65 (0.28–1.49)	0.31
Personal history of DM	1.33 (0.77–2.31)	0.31	1.50 (1.10–2.03)	0.01	0.41 (0.10–1.63)	0.21
Personal history of hyperlipidemia	1.39 (0.83–2.32)	0.21	1.21 (0.86–1.69)	0.27	0.74 (0.27–1.99)	0.55
Last dental exam (related to <1 y)						
last dental exam >2 y	1.14 (0.69–1.88)	0.62	0.86 (0.60–1.22)	0.4	0.89 (0.40–1.98)	0.78
Last dental exam >5 y	2.00 (1.13–3.55)	0.02	1.61 (1.15–2.26)	0.01	0.88 (0.85–4.72)	0.11
Last eye exam (related to last eye exam <1 y)						
Last eye exam >2 y	0.82 (0.52–1.30)	0.4	0.78 (0.57–1.06)	0.11	0.64 (0.30–1.37)	0.25
Last eye exam >5 y	0.60 (0.30–1.20)	0.15	0.96 (0.68–1.37)	0.84	1.20 (0.56–2.58)	0.64
Last eye exam never	0.36 (0.05–2.39)	0.29	0.61 (0.23–1.62)	0.32	0.72 (0.11–4.91)	0.74
Lack of regular eye doctor	1.11 (0.73–1.68)	0.63	1.19 (0.91–1.54)	0.2	0.85 (0.46–1.57)	0.6
Eye injury	1.34 (0.82–2.19)	0.25	1.19 (0.87–1.64)	0.27	0.95 (0.42–2.17)	0.9
Contact lens	1.33 (0.68–2.59)	0.4	1.20 (0.78–1.84)	0.42	0.33 (0.05–2.32)	0.27
Wear glasses	1.24 (0.78–1.98)	0.37	1.19 (0.89–1.60)	0.24	1.54 (0.75–3.15)	0.24
Vision change reported	1.42 (0.92–2.21)	0.12	1.17 (0.89–1.53)	0.27	0.93 (0.50–1.72)	0.82
Systemic findings						
BMI (related to normal range 18.5–24.9)						
BMI elevated (25–29.9)	0.93 (0.52–1.67)	0.81	0.93 (0.64–1.33)	0.7	0.92 (0.46–1.80)	0.8
BMI high (≥ 30)	1.60 (0.97–2.63)	0.07	1.35 (0.99–1.83)	0.06	0.49 (0.22–1.11)	0.09
Hb A1c (related to healthy A1C level (under 5.3)						
Hb A1c-treading toward prediabetes (5.4–5.6)	1.23 (0.70–2.17)	0.47	1.41 (0.97–2.04)	0.07	1.53 (0.72–3.26)	0.27
Hb A1c- prediabetic state (5.7–6.4)	1.44 (0.81–2.53)	0.21	1.50 (1.03–2.19)	0.03	1.30 (0.57–3.00)	0.53
Hb A1c- diabetic (≥6.5)	1.97 (1.07–3.62)	0.03	2.25 (1.57–3.23)	0	0.89 (0.26–3.03)	0.86
Blood pressure (related to normal blood pressure)						
Prehypertension	1.13 (0.65–1.96)	0.66	1.26 (0.90–1.77)	0.18	1.09 (0.53–2.25)	0.23
Stage 1 hypertension	1.39 (0.77–2.51)	0.28	1.29 (0.88–1.89)	0.19	0.69 (0.25–1.86)	0.46
Stage 2 hypertension	2.95 (1.62–5.37)	0	1.82 (1.16–2.83)	0.01	1.87 (0.67–5.21)	0.23
Low blood pressure (hypotension)	2.36 (0.75–7.44)	0.14	2.42 (1.45–4.04)	0	3.73 (1.13–12.39)	0.03
CDC Prediabetes Screening Test (related to score 0–2)						
Low-risk group (score 3–8)	0.75 (0.18–3.14)	0.69	1.33 (0.46–3.88)	0.6	0.48 (0.21–1.10)	0.08
High-risk group (score ≥ 9)	2.00 (0.54–7.41)	0.3	2.40 (0.86–6.66)	0.09	NA	NA
Score ≥9 (related to score 0–8)	2.55 (1.40–4.64)	0	1.87 (1.31–2.65)	0	2.45 (1.06–5.70)	0.04
Ocular findings						
IOP >21 mm Hg	6.21 (4.49–8.59)	0	2.47 (2.02–3.03)	0	1.22 (0.51–2.94)	0.44
VCDR ≥0.5 according to specialist	3.39 (2.30–4.98)	0	1.69 (1.31–2.18)	0	1.22 (0.60–2.46)	0.58
VCDR ≥0.7 according to specialist	5.49 (4.34–6.94)	0	2.39 (1.94–2.95)	0	1.38 (0.37–5.11)	0.63
VCDR ≥0.5 according to OCT	2.43 (1.26–4.68)	0.01	1.29 (0.92–1.79)	0.14	1.11 (0.55–2.67)	0.76
VCDR ≥0.7 according to OCT	2.79 (1.87–4.16)	0	1.48 (1.14–1.91)	0	1.70 (0.92–3.15)	0.09
VF (FDT) abnormality (in any eye)	3.34 (2.20–5.07)	0	2.55 (1.99–3.27)	0	1.21 (0.64–2.27)	0.56
RNFL <75 μm in either eye	3.59 (2.45–5.27)	0	2.33 (1.88–2.89)	0	0.37 (0.05–2.55)	0.31
RNFL <95 μm in either eye	3.78 (2.54–5.61)	0	2.04 (1.61–2.59)	0	1.02 (0.50–2.07)	0.95
CCT <535 μm in either eye	0.80 (0.52–1.23)	0.31	0.87 (0.67–1.14)	0.33	0.65 (0.34–1.23)	0.19
CCT <510 μm in either eye	0.83 (0.47–1.45)	0.52	0.88 (0.62–1.25)	0.49	0.63 (0.25–1.55)	0.31

BMI indicates body mass index; CCT, central corneal thickness; BP, blood pressure; CDC, center for disease control; DM, diabetes mellitus; FDT, frequency doubling technology; IOP, intraocular pressure; RNFL, retinal nerve fiber layer; RRR, relative risk ratio; VCDR, vertical cup to disc ratio; VF, visual field.

TABLE 6. Individual Follow-Up

Suspected Disease, n (%)	Reached, n (%)	Followed Up With Ophthalmologist, n (%)	Disease Confirmed, n (%†)	Additional Eye Problem Detected‡, n (%†)	Required Rx, n (%†)
Total*, n=133 (40.79)	105 (78.94)	71 (53.38)	33 (46.47)	16 (22.53)	11 (15.49)
Glaucoma, n=70 (21.47)	57 (81.42)	43 (61.42)	26 (60.46)	12 (27.90)	9 (20.93)
Narrow-angle, n = 37 (11.34)	27 (72.97)	19 (51.35)	8 (42.10)	2 (10.52)	0 (0.00)
Diabetic retinopathy, n = 6 (1.84)	6 (100.00)	3 (50.00)	2 (66.66)	1 (33.33)	1 (33.33)
Macular degeneration, n = 4 (1.22)	4 (100.00)	4 (100.00)	2 (50.00)	1 (25.00)	1 (25.00.79)

Rx indicates prescription for glasses.

*Some participants had multiple diseases.

†% based on patients seen by ophthalmologist.

‡Includes patients with multiple diseases and false-negatives.

included narrow-angle, DR, macular degeneration, and the other diseases. For the abnormal ocular finding group, age ≥65, personal history of high BP and diabetes mellitus, not having a dental examination over 5 years, a HbA1c measurement of ≥5.6, stage 2 hypertension and on the contrary, low BP, a CDC score of ≥9 were found to be significant risk factors.

As mentioned above, narrow-angle suspects include only the participants who have anatomically narrow-angle on both sides at 3 and 9-o'clock on ASOCT. For this anatomical narrow angles condition, the significant risk factors were age ≥65, low BP, and a CDC score of ≥9. None of the ocular findings were significant.

Of the 133 (40.79%) participants with ≥1 vision-threatening eye conditions (Table 6) the follow-up was successful for 105 (78.94%) of participants. Seventy-one (53.38%) of the participants followed up with an ophthalmologist of their choosing. Thirty-three (46.47%) of those participants had the disease confirmed by the ophthalmologist, as reported by the participant on follow-up questionnaires. Moreover, additional eye diseases were detected in 16 (22.53%) of those participants who followed up with an ophthalmologist, and 11 (15.49%) required new prescription glasses.

DISCUSSION

As predicted by the United Nations, the population of the world will surpass 9 billion by 2050.[18] Moreover, changes in the demographic pyramid imply that the proportion of elderly will increase significantly sooner than the rest of the population. Therefore, ophthalmologists will have a more substantial burden as they will need to detect and manage ophthalmological conditions in a larger proportion of the population.[19] Teleophthalmology will likely play a significant role in the near future not only in rural but also in highly populated metropolitan areas. With an increasing population and demographic shifts toward an older population, there is an increasing need for alternative, affordable, and convenient ophthalmic evaluation methods especially in large metropolitan areas. Therefore, in several countries, we have observed investments that make telemedicine available and accessible to the population (eg, Specavers in UK, Australia, and New Zealand).

GlobeChek has the potential to fill the aforementioned gap in health care access via telemedicine. It serves as a screening tool for the 4 leading causes of blindness with a relatively fast method (lasting at most for 20 minutes for the whole examination) without dilation and without having to touch the patient's eye, which is often a deterrent for regular eye examinations. Even though we are not presenting an exhaustive analysis here, this article provides a comprehensive teleophthalmologic evaluation of GlobeChek. Several areas that can be addressed in future studies are examining the cost-effectiveness of this method in addition to comparing it with traditional examination protocols. Moreover, a future study can also be conducted for a comprehensive analysis specifically designed to detect false-negative indications of this method.

We evaluated the demand and preferability of the GlobeChek kiosk in an urban-based teleophthalmology study and seek to provide a guideline for detecting the prevalence and risk factors for the most common eye diseases. In our study, 17.88% of consented subjects did not complete the full screening for various reasons. This indicates that the scanning period is critical in keeping the subjects in the study. Therefore, additional questions or screenings to improve data quality might actually harm community-based teleophthalmology studies.

Besides using comprehensive questionnaires, retesting IOP measurements with FDA-approved devices has been another time-consuming factor. Moreover, as indicated by Table 6, overall, there are other dropouts during the follow-up calls. We could reach a relatively large percentage of participants after the study. However, the percentage of participants who followed up with an ophthalmologist is substantially low (53.38%). There are several reasons for this low percentage and include difficulties to create incentives for subjects to go to an ophthalmologist (especially for those who do not have continuous health insurance) for follow-up and to inform us truthfully about their visits to ophthalmologists. These limitations might have affected the confirmation rates and constitute something to improve upon in future studies. One potential improvement could be that the follow-up examination by an ophthalmologist can be done immediately on site right after the study is completed. Another suggestion could be the setting up an EPIC integrated teleophthalmology study, which shows us the participants' prediagnostic ophthalmic diseases, systemic diseases, risk factors, follow-up rates, follow-up diagnosis, and parallel to that false-positive and false-negative results.

In Table 6, we also observe that of 326 participants, GlobeChek indicated a total number of 133 suspected diseases. However, only 71 patients were followed up by an ophthalmologist and 33 of the 71 diseases (46.47%) were confirmed by the physician. Defining a type II error as a failure to reject a false diagnosis and assuming that ophthalmologists always made a correct diagnosis and patients conveyed the reports to us correctly and truthfully, and patients with suspected diseases that we could not reach out do not affect the average statistics, we could argue that the power (ie, not making a type II error) of the GlobeChek was 46.47% overall, and it varies between 42.10% and 66.66% for different types of diseases. These numbers are a bit low considering that the general consensus for a power statistic should be >80%. Nevertheless, the somewhat seemingly low power might be affected by the potential invalidity of any of these 2 assumptions indicated above. Moreover, our sample size is large enough. Even if we hypothesize a target level of 21.47% for glaucoma suspects (70 suspects of 326 participants) or 11.34% for narrow angle, 1.84% for DR, and finally 1.22% for macular degeneration, the estimated sample size (for a one-sample proportion test) under a 90% power level (and a difference of 10% with an alternative hypothetical proportion) varies between 130 and 255, which is below our sample size of 326, even after dropouts.

Motivated by Pasquale et al's[20] study about the relationship between glaucoma and periodontal diseases, and considering Agrawal and Agrawal[21]'s criticism that diabetes might play an essential role in this relationship, we also conducted an RRR analysis to explore whether dental diseases or diabetes play a role in glaucoma. First, somewhat contrary with Pasquale et al's,[20] in our analysis, we did not find any significant risk increase associated with subjects that did not have a dental examination for >2 years. However, we also find that not having a dental examination for >5 years was associated with significantly more risk of both glaucoma and ocular diseases. For the next step, using the Mantel Haenszel method we also evaluated the claim Agrawal and Agrawal[21] made to see whether diabetes might play a role here. As the number of participants that had serious diabetes indication and did not have a dental examination for >5 years was low, the analysis did not show any significant interaction.

A broad literature review on teleophthalmology shows that a large number the teleophthalmologic studies did not include >2 ocular instrumentations,[23–25] and almost none of them have used OCT imaging.[22–28] Particularly, retinal studies in teleophthalmology limit their instrumentation to just a fundus camera.[25,27,28] We believe that our article encompasses the most enriched and comprehensive teleophthalmology model in literature.

The supremacy of the OCT in the identification of glaucoma and retinal diseases is indisputable. Therefore, we believe it will play an essential role in teleophthalmology in the near future. There are some recent examples of teleophthalmologic studies with an OCT such as Maa et al.[29] In this study, the authors partially inserted the OCT in the last step of a technology-based eye care clinical trial, however, they didn't provide the OCT images and fundus photographs to the physicians who made the in-person examinations. As a second step, they shared the participants' information and images with two different readers. They found that OCT not only leads to inconsistency between the face-to-face examiners' and readers' results but also reduced the confidential interval of the diagnosis between the 2 different readers. They argue that one potential explanation for this might be the lack of specific interpretation guidelines for OCT and inconsistent OCT interpretation due to lack of training. Besides, they pointed out that the small number of patients with AMD and incapability of their OCT device about macular ganglion cell analysis might have affected their results. Furthermore, they also mention the importance of the sequence of OCT imaging.

There is a great need for clarification on the value of OCT use in teleophthalmology, and we believe that our study contributes significantly to the literature in this regard. The mismeasurement of OCT in VCDR evaluation is not unexpected[30] and we illustrate this in panels D and E of Figure 2. The outputs were evaluated according to the reading guideline which was designed by glaucoma specialists, and a study protocol was created thoroughly incorporated with OCT. Unlike Maa et al,[29] the OCT machine that was used in this study (Topcon 3D OCT-1 Maestro) was fully capable of macular ganglion cell layer analysis and anterior segment analysis that give information about the anterior segment angle. These measurements were to define "glaucoma suspect" and "narrow-angle suspect" categories. Furthermore, RNFL (<75 μm) and CCT (<510 μm) cutoff values were determined for RRR calculations, and CCT measurements were used for IOP corrections. Besides that, it gives us evidence-based results for AMD and choroidal nevus, corneal scars, congenital abnormalities versus under the category of "other" eye conditions. Even though teleophthalmologic studies have not yet established a consensus upon the determinants of these rare findings,[22] we believe that the use of OCT in future studies will change that.

Another possible promising point of OCT use in teleophthalmology is ASOCT's superiority in objective, automatized, contactless, recordable evaluation of the anterior chamber angle (ACA). We believe that this might be a desirable alternative for ACA evaluation. Teleophthalmologic studies that are scanning large populations and include AC-OCT and IOP measures, significantly contribute to this direction of the literature.[31] Besides that, new research on deep learning based on fully automated analysis of AC-OCT images are showing us great need and improvement in ACA evaluation.[32]

In our study, every participant was scanned with OCT, and their ACA was evaluated for a narrow-angle on the basis of the study's guideline. Accordingly, 37 (11.34%) subjects are categorized as "narrow-angle suspects." Although this rate seems higher than the expectations for an average population, our RRR analysis showed us that our results are consistent with the pathophysiology of the disease. A narrow-angle is mainly a structural condition, and its mechanisms are generally based on iris replacement from back to front. An older age that affects the lenticular volume and low BP which in turn affect the anterior chamber volume were found to be significant risk factors for narrow-angle glaucoma.

Other advantages of the latest version of OCT machines are providing nonmydriatic fundus images simultaneously with posterior OCT images. In this study, posterior fundus images were taken in 2 different ways: the first one was simultaneous with posterior OCT, and the second one was stand-alone nonmydriatic color fundus photography. The best among these 2 were chosen and interpreted by an ophthalmologist or an optometrist at the reading center. Only 18 (5.52%) of our participants had unreadable images at the teleophthalmology kiosk. When we review the literature for unreadable images in teleophthalmology, Hark et al[33] and Silva et al[28] studies stand out among some others.

Hark et al[33] reported that unreadable images rate varies between 5% and 19.7%, as indicated in the literature, and ended up with their own rate of 17.1%, based on the reading of a nonmydriatic auto-focus hand-held camera. Investigation of this wide range showed us that there is a tremendous descriptive discrepancy for unreadable images throughout the studies. Moreover, Hark et al[33] described their unreadable image criteria according to the nonvisibility of macular or optic nerve disc images. However, the lower limit in their interval, that is, 5%, is based on a study by Ahmed et al,[34] where the authors required pupil dilation to obtain adequate imaging. Even though there are also other single-digit results of unreadable image rates in the literature, they all involve dilated fundus images.[35,36] Although mydriasis improves image quality and reduces the unreadable image rate, it affects IOP and ACA, increases examination time, and creates inconvenience for the patients. Due to these concerns, we have not used pupil dilation in our study.

Silva et al[28] emphasized that an ungradable image rate for DR or diabetic macular edema was dramatically affected by instrumentation. In this respect, nonmydriatic ultrawide field (UWF) imaging of fundus provides more qualified images for diagnosis according to the nonmydriatic multifield photography. Ultrawide field imaging not only increases the sensitivity, specificity for disease detection, but also diminished the ungradable image rates for DR and diabetic macular edema from 32.5% to 6.1%, and 31.1% to 7.6%, respectively.

Investigation of unreadable images in teleophthalmologic studies indicated that there are many parameters related to unreadability, such as whether the study has been conducted in a rural or urban area,[37] the skills of the operator,[38] patient cooperation,[33,38] instrumentation incapabilities,[33,39] and mydriasis of the eye.[40] Acknowledging all these different factors, the critical point in a teleophthalmologic study should be taking care of all these causes and limiting the unreadability of ocular causes. Reduction of the unreadability rate is essential for an extensive public scanning program with a nonmydriatic imaging. In addition to diminishing the substantial unnecessary burden of financial cost, it will also provide a convenient and reliable basis for patients and health care systems. In this regard, Silva et al[28] and our study with upgraded featured instrumentation, will contribute to the literature with a single-digit unreadable image ratio and reflect the improvement of getting high-quality images.

This study has a few limitations. It was not designed with a consecutive clinical and comprehensive eye examination. So, the rate of follow-up examinations done by ophthalmologists was considerably limited. Follow-up visit results were obtained from the participants through telephone conversations by using special follow-up questionnaire forms. Therefore, we relied on participants' self-reports about disease confirmation or false-positives. Several areas that can be addressed in future studies are examining the cost effectiveness of this method and comparing and contrasting with traditional examinations. Moreover, a further study can also conduct a comprehensive analysis specifically designed to detect false-negatives or its indications.

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