Clinicians' Perspectives on Using Mobile Eye Fundus Cameras to Screen Diabetic Retinopathy in Primary Care

Cristiana Braga
Human-Centred Design
Fraunhofer Portugal AICOS
Porto, Portugal
cristiana.braga@fraunhofer.pt

Sílvia Rêgo
Human-Centred Design
Fraunhofer Portugal AICOS
Porto, Portugal
silvia.rego@fraunhofer.pt

Francisco Nunes
Human-Centred Design
Fraunhofer Portugal AICOS
Porto, Portugal
francisco.nunes@fraunhofer.pt

***Abstract*—Diabetic retinopathy is a serious complication of diabetes that causes visual impairments. The condition is already the leading cause of blindness in industrialised countries and is expected to grow in the next years. Diabetic retinopathy is treatable if diagnosed in early phases, but current screening approaches are only reaching half the patients with diabetes. Mobile eye fundus cameras have been proposed to expand screenings and reach more patients, however, there is little knowledge about the impact of mobile eye fundus cameras in clinical care or of the perspective of clinicians on using these. Drawing on interviews with clinicians, this paper outlines the potential of mobile eye fundus cameras and presents implications for design to better suit these devices to primary care settings.**

***Index Terms*—mobile eye fundus camera, diabetic retinopathy, diabetes, healthcare**

I. Introduction

Diabetic retinopathy is a medical complication of diabetes that can cause dark or empty areas in vision, blurred vision, vision loss, or even blindness [1]. The condition is caused by the detrimental impact of high blood sugar on the blood vessels of the retina, and is likely to evolve with time. Nearly all type 1 diabetes patients and 77% of type 2 diabetes patients will have diabetic retinopathy 20 years after their diabetes diagnosis [2]. Despite being treatable, diabetic retinopathy is already the leading cause of blindness in industrialised countries [2], and is expected to grow even more due to the rapid growth of diabetes worldwide [3].

To help diagnose diabetic retinopathy early and reduce its impacts, clinical guidelines recommend annual eye examinations to all patients, from the year of diagnosis (type 2 diabetes) or 3-5 years after (type 1 diabetes) [4]. Following recommendations for annual examination, multiple countries have implemented diabetic retinopathy screening programs, often making use of tele-Ophthalmology [5]. However, less than half of individuals with diabetes worldwide attend the diabetic retinopathy screenings [6], [7]. The main obstacle is the lack of access to specialised eye care due to costs, distance, or availability of professionals [6], [8]; but studies also argue that effective patient outreach strategies, that communicate the importance of screening programs, are not yet in place [6], [7].

Recent years have seen the launch of multiple mobile eye fundus cameras [9]–[16]. These devices enable clinicians to acquire images of the retina and forward them to ophthalmologists. Since mobile eye fundus cameras can be used opportunistically when patients visit their primary care clinic or in home visits, they hold the promise of increasing the reach of diabetic retinopathy screenings. However, there is little understanding of how clinicians perceive the introduction of these devices in primary care and of the implementation challenges these devices might face.

This paper explores the perspectives of clinicians regarding implementing mobile eye fundus cameras in primary care. Drawing on interviews with different clinicians, who had a chance to use a mobile eye fundus camera in our laboratory, we detail the voiced advantages and challenges to the implementation of these devices in primary care. The contribution of this paper resides in the description of the clinicians' perspectives and the design implications that arise from considering these.

II. Background

A. Diabetic Retinopathy and Screening

Diabetic retinopathy is a microvascular complication of diabetes that evolves as the blood vessels of the retina are damaged by high blood glucose [17]. In early phases, diabetic retinopathy is asymptomatic, but, as it progresses, patients start experiencing symptoms. First issues to appear are microaneurysms, haemorrhages, or hard exudates, which lead to blurred vision and vision obstructions. In the most advanced phase, referred as proliferative diabetic retinopathy, there can be bleeding from new abnormal vessels, retinal detachment, macular oedema, and swelling/thickening of the macula which can cause vision loss and blindness [17]. The signs of the condition can be detected by observing the fundus of the eye and thus annual retinal observation is crucial [17].

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TABLE I
EXAMPLES OF MOBILE EYE FUNDUS CAMERAS AND THEIR CHARACTERISTICS.

	EyeFundus-Scope A008 [9]	FOP [10]	Optomed Smartscope pro [11]	Paxos Scope [12]	Peek Retina [13]	PHELCOM Eyer [14]	Volk Pictor Plus [15]	Zeiss VISUSCOUT 100 [16]
Technology	smartphone and lenses	smartphone and lenses	dedicated device	smartphone and lenses	smartphone and lenses	smartphone and lenses	dedicated device	dedicated device
Field of view	40^{o}	45^{o}	40^{o}	-	20^{o}	45^{o}	40^{o}	40^{o}
Resolution	12.3MP	-	5MP	8MP	-	12MP	5MP	5MP
Photo storage	device, cloud	device, cloud	device	device, cloud	device	device, cloud	device, cloud	device
Pupil dilation needed	no	no	no	no	yes	no	no	no
Telemedicine	yes	yes	no	yes	yes	yes	no	no

The most used approach[1] to screen diabetic retinopathy is telemedicine-based and has three steps. First, eye technicians or optometrists capture images of the retina using table-top eye fundus cameras [2]. Second, they select images and send them digitally to ophthalmologists, for example using the electronic medical record. Third, ophthalmologists analyse and classify images for the presence of diabetic retinopathy [19], [20]. This approach is implemented in the screening programs of the United States (EyePACS), United Kingdom (NHS Diabetic Eye Screening Program), France (OPHDIAT), Portugal (Programa Nacional de Rastreio de Retinopatia Diabética), and The Netherlands (Eyecheck) [18], [21]–[23].

Despite the offer of screening programs in multiple countries, half of the individuals with diabetes do not attend the diabetic retinopathy screenings in their area [5] due to access issues and lack of outreach strategies [6]–[8]. People who use a wheelchair or are bedridden can face difficulties in being screened with conventional tabletop retinal cameras due to the inability to sit and stay in upright head position during the procedure [24]. People who live in the countryside, in isolated villages, or who cannot easily travel to populous cities are also often excluded because the price of table-top eye fundus cameras makes them scarce items, that are rationed and placed where they can reach the highest number of patients possible [25]. Moreover, there are many individuals with diabetes who disregard screening programs because they are not aware of the potential consequences of diabetic retinopathy [6], [7].

Overall, there is great need to find ways for timely identifying at-risk patients [26], be it through changes in diabetic screening programs or creating chances for opportunistically screening individuals with diabetes.

B. Mobile eye fundus cameras

To improve access and adherence to diabetic retinopathy screenings, multiple mobile eye fundus cameras have been developed and launched. Advancements in electronic miniaturization and processing power have made it possible to transform traditional table-top eye fundus cameras into mobile handheld solutions that are potentially effective and highly portable [25], [27]. Moreover, some technologies already enable non-mydriatic image acquisition[2] [28], [29], which is an advancement over some traditional table-top cameras.

Examples of mobile eye fundus cameras include FOP [10], Optomed Smartscope pro [11], Paxos Scope [12], Peek Retina [13], PHELCOM Eyer [14], Volk Pictor Plus [15], and Zeiss VISUSCOUT 100 [16], all of which are characterised in Table I. Mobile eye fundus cameras consist of handheld devices that include lenses to focus images on the retina, a screen to preview images, and a computing processing unit to support the acquisition. Some solutions use a smartphone as a preview screen and computing processing unit, while others present themselves as one dedicated device. The area of the retina captured by each device is distinct, with some mobile eye fundus cameras reaching 45^{o}, while others can only acquire images covering 20^{o}. Image resolution also varies between 5 and 12 Mega Pixels (MP). Acquiring images is similar for all models and requires approaching the users eye, focusing the macula and/or optic disc, and pressing a button.

Mobile eye fundus cameras do not need to be operated by eye care specialists, instead, they are built for primary care clinicians (or non-medical staff) [18], [28]–[33]. With minimal training, clinicians can collect images of the retina opportunistically during routine medical appointments or home visits, to support the diabetic retinopathty (tele-Ophthalmology) screening [12], [13], [18], [27], [28], [34], [35], or their referrals to Ophthalmology [11], [14]–[16].

Mobile eye fundus cameras have been used in multiple validation studies. Most studies focused on assessing validity measures of image acquisition quality against a reference table-top camera (e.g., [10], [13], [24], [36]) or other screening approaches (e.g., [24], [36]). However, there is little under-

[1]Other approaches for screening diabetic retinopathy include fluorescein angiography, retinal photography with polaroid film or ophthalmoscopy [5], [18]. Independent of the technology, the diagnosis or classification of retinal images is usually performed by ophthalmologists [5], [17].

[2]It is common to use eye drops to dilate the pupils of the patient as that can expedite image acquisition. However, patients need to wait for the effect of dilation to wear off before driving or other activities, which is less convenient.

standing of how mobile eye fundus cameras are used in the field and the perspectives of clinicians on using such devices. We know that clinicians have a short learning curve [12], [31], that the impact that these devices can have in terms of time in clinical flow is reduced [12], and it is important to secure good WiFi and illumination conditions [12]. Nevertheless, more research is needed to understand the potential mobile eye fundus cameras have in clinical care, as existing reviews focus solely on accuracy performance (e.g. [37]).

III. Methods

To understand the perspectives of clinicians on using a mobile eye fundus camera in primary care, we conducted in-depth interviews [38]. Interviews[3] were focused, qualitative, and loosely structured. We first invited participants to talk about their experience with patients with diabetes, their familiarity with diabetic retinopathy and retina observation, and their relationship with information and communication technologies in the workplace. Then, participants used a mobile eye fundus camera to capture retinal images of members of the research team. Using the device enabled participants to get a glimpse of how the technology worked and imagine how it could be implemented in the care settings they were familiar with. Even though participants used the mobile eye fundus camera in the laboratory, it was enough to spark discussions about clinical care processes, the diabetic retinopathy screening program, technical infrastructures, or even patients' characteristics and role. Thus, after using the device, participants were invited to reflect about the potential advantages, challenges, and implementation issues that might arise when getting such device into primary care practice. Moreover, participants were offered space to bring to discussion other topics of relevance.

Participants used EyeFundusScope A008 [9], a mobile, low-cost, and non-mydriatic eye fundus camera developed by our institute. EyeFundusScope A008 is composed by a Nexus 5X smartphone, a set of lenses and electronic components, all of which supported by a 3D printed case (see Figure 1 and Table I). EyeFundusScope A008 was designed to be operated in ambulatory by clinicians who are not specialised in Ophthalmology. The device includes infrared illumination and the smartphone has a dedicated app to guide the clinician and send images to ophthalmologists for image classification and diagnosis. EyeFundusScope A008 is an experimental medical device that is about to enter clinical validation studies.

In total, we involved 15 clinicians (8 males and 7 females), of which six family medicine doctors, one resident doctor in nephrology, one surgeon, one intern doctor, five nurses working in different contexts, and one physiotherapist. The age of participants ranged between 24 and 63 (AVG = 37, SD = 11). Experience of participants was also very different, ranging from just starting clinical work up until 37 years of experience (AVG = 11, SD = 11). No participant had previously used eye fundus cameras, however, doctors had prior experience with the ophthalmoscope – a handheld optical device to observe the retina. We used a convenience sample, recruiting participants through personal contacts and José de Mello Saúde – a health care provider partner in our project. Inclusion criteria consisted of clinicians who worked in Portuguese healthcare institutions and had regular contact with patients with diabetes. Exclusion criteria consisted of ophthalmologists, as these are not potential users for most mobile eye fundus cameras.

[3] Interviews occurred in the context of EyeFundusScopeNEO, a project that was evolving and validating a mobile eye fundus camera. In face of scarce information about the experiences and perspectives of clinicians regarding mobile eye fundus cameras, we decided to pursue this study.

Fig. 1. Participant using EyeFundusScope A008 during interviews.

Our analysis followed the Thematic Analysis method [39]. We audio-recorded each of the interviews and iteratively coded transcriptions using Scrivener software. In total, we recorded nine hours of audio recordings, excluding time using the device. Data analysis co-ocurred with data collection and subsequent participants were asked questions raised by previous ones. Constant comparison of settings, participants, and excerpts, helped enrich the analysis. Meaning saturation [40], or the nuanced and in-depth understanding of qualitative material, was achieved with the 15th interview. Analysis was led by the first author, with regular discussions with the remaining authors and other members of the project team.

All participants provided informed consent, having heard information about the project and the mobile eye fundus camera, and the reasons for the interview.

IV. Results: Clinicians' perspectives on using mobile eye fundus cameras in primary care

Most participants saw great potential in mobile eye fundus cameras. Even though participants had never used or heard of this type of device, they immediately saw the potential to improve the diabetic retinopathy screening program currently implemented in Portugal. Moreover, they considered mobile eye fundus cameras as yet another option in their toolbox, with which they would be able to diagnose other conditions of the retina (e.g., intracranial hypertension and glaucoma) or that are evidenced by signs in the retina (e.g., diabetic nephropathy and hypertensive retinopathy).

The references to the national diabetic screening program were common in the interviews as participants were familiar with this public health initiative. The national screening program implemented in Portugal is telemedicine-based and has the objective to screen all individuals with diabetes every year. However, in practice, table-top eye fundus cameras are restricted to some regions of the country, where they rotate between high population areas. Consequently, there are many individuals with diabetes who have never been invited to the screening program.

The remaining of this section details the most relevant themes mentioned by participants, including: the potential to enable earlier diagnosis, the possibility to extend eye examinations to more people, the challenges to interpret images and the potential to use the device for learning, multiple user profiles, and difficult patients to use the device with.

A. Earlier diagnosis of diabetic retinopathy

The most highlighted advantage of mobile eye fundus cameras was the potential to speed up diagnosis. According to participants, the number of existing ophthalmologists in Portugal is not enough for the rising number of individuals with diabetes. The tele-Ophthalmology process is useful for selecting the most urgent cases to follow, but not enough patients have their retinas photographed, which means that Ophthalmology clinics in public hospitals are full with individuals with diabetes who do not have diabetic retinopathy. Mobile eye fundus cameras could be the means for increasing the number of patients who are screened, thus helping ophthalmologists focusing on the most urgent cases, and reducing the wait to appointments and treatment.

> *We can have a very early diagnosis. If it [using a mobile eye fundus camera] is a habit. That is, we should not evaluate diabetes patients only when the patient has complaints. Without a doubt, a patient who goes [to an ophthalmologist] with an exam will have an answer sooner than someone who still has to do the evaluation.* P5, Nurse, 50 years old

P5 saw great potential in using mobile eye fundus cameras to perform regular eye examinations. Instead of waiting for an Ophthalmology appointment or the yearly screening program, mobile eye fundus cameras could be used opportunistically, when clinicians were visited by their patients. P5 argued that when patients do not have to wait for photographing their retina, there are higher chances that the condition is diagnosed at an earlier phase. Moreover, acquiring images of the retina opportunistically during appointments would reach the patients that miss the screening programs due to lack of awareness of the impact of diabetic retinopathy[4], and who would potentially have a late diagnosis.

B. Integration in diabetes monitoring visits

Participants also considered that mobile eye fundus cameras could be easily integrated into existing diabetes monitoring appointments that occur every three months. Every three months, patients see the family nurse and the family doctor, to perform exams, discuss the current state of the condition, and plan adjustments to self-care or treatment, which could be an appropriate time for acquiring images of the retina.

> *This [to use mobile eye fundus camera] is not a problem at all. It could be the nurse that sees patients when they arrive and measures their blood pressure, their weight, heart rate...* P1, Resident nephrologist, 28 years old

P1 was strongly convinced that mobile eye fundus cameras could be easily integrated into diabetes appointments. After performing other measurements or tests, clinicians would acquire images of the retina and remotely send them to ophthalmologists for analysis. Image acquisition could occur every six months to enable regular condition followup and, at the same time, avoid increasing the length of every diabetes monitoring appointment. P1 believed that the system would be used by both nurses and doctors, depending on how they divided the work in diabetes monitoring appointments, but he expected nurses to use the system more often as doctors were usually under more time pressure.

There is also the potential for delivering personalised care to patients with mobile eye fundus cameras. If ophthalmologists signal the need to closely following a patient, primary care clinicians can schedule sessions with the patient and monitor them. In fact, primary care institutions are responsible for accompanying the overall health of their patients, and monitoring when to send them to specialist care is one of their responsibilities. Adopting mobile eye fundus cameras can ensure that primary care clinicians have effective tools to screen, monitor, and refer patients to Ophthalmology.

C. Expand eye fundus examinations to more people

Mobile eye fundus cameras were also seen as a way to bring eye examinations to more patients. In particular, the portability of these devices would help to achieve the promise of screening programs – to reach all patients. People with reduced mobility would benefit from mobile eye fundus cameras as the device can be brought to them and thus avoid mobility obstacles. This would be useful for people who are bedridden or who use wheelchairs [24], but also people who cannot drive or have other mobility problems. Our participants also mentioned temporary situations when people benefit from not moving. P10 brought one such example to the discussion.

> *Let's suppose: it's a gastric cancer. Because of the chemotherapy, the patient develops diabetes. Automatically, we require a retinopathy consultation for him where he is surveilled. (...) However, the [eye] exam does not occur within the Oncology institution.* P10, Nurse, 63 years old

Having had gastric cancer, the patient of P10 was probably weak to be moving around, but since the hospital did not have a table-top eye fundus camera, they would probably have to take him to another institution. With a portable solution, the nurse would be able to screen the patient where they were and avoid the potential impact of the travel on the patient's health.

Mobile eye fundus cameras also hold potential to reach remote populations. As mentioned in the background section,

[4]There is a large percentage of patients that miss screening programs, but the attendance to diabetes monitoring consultations is extremely high as patients feel these encounters have an important impact on their health.

table-top eye fundus cameras are placed primarily in areas that cover large portions of the population. The devices cannot be easily moved as they have to be calibrated for a specific table. However, and as participants reminded, a mobile eye fundus camera does not face the same issues and can be brought to more remote areas to screen patients.

Another population group that could benefit from this kind of device are prisoners, who are not covered by the current diabetic retinopathy screening program. According to P14, taking prisoners to healthcare institutions is logistically complex and extremely expensive, which often results in late diagnosis and health complications. However, if clinicians who work in prisons could use the EyeFundusScope, they could refer patients to Ophthalmology in early phases of the condition.

D. Challenges to interpret images and potential to learn

Despite the advantages that participants viewed in EyeFundusScope, they feared not having enough knowledge on the retina to make the most from mobile eye fundus cameras. According to participants, the medical training in Ophthalmology is scarce and the opportunities to observe patients' retinas are rare. Among the interviewed participants, only doctors had practical sessions during their university education, and these were restricted to one or two afternoons doing retinal observation with an ophthalmoscope[5], which means that they mostly remember images of eye diseases from books.

> *The problem is that I don't know how to evaluate the image... whether this image is serious or not... whether it is urgent or not. (...) I can only tell if there are very characteristic issues.* P1, Resident nephrologist, 28 years old

The limited training in observing the retina makes doctors like P1 uncertain about explaining issues they observe in the retina. Even though doctors might suspect that something is pathological, they struggle to describe their observations in their (text) referral to Ophthalmology, and since the ophthalmoscope cannot acquire images, their referral cannot be evaluated and prioritised by ophthalmologists.

> *When we have doubts, we refer [the patient] to somebody. (...) It's difficult to use the ophthalmoscope. (...) Nobody uses it, because it does not allow to save images, it's not possible to discuss, it's not possible to... If you have doubts in this image, and you want to discuss it with someone, to prove our decision based on the image (you can't).* P1, Resident nephrologist, 28 years old

The images seen in the ophthalmoscope are only seen by the doctor in the examination room, so unless another doctor is available to visit them and discuss, they will not be able to learn from others. Interviewees hypothesised that when having doubts, they could send images to ophthalmologists or experienced colleagues, to help them interpret and analyse images. These exchanges would improve the doctors' knowledge about eye diseases and promote collaborations in care.

[5]The ophthalmoscope is a handheld instrument used by ophthalmologists, family doctors, and other clinicians to observe the retina. Most doctors we interviewed argued that the ophthalmoscope was hard and unconfortable to use, due to the need to hold the device extremely close to the patients' eye.

E. Doctors and nurses as potential users

During the interviews we asked participants which healthcare professionals should use the mobile eye fundus camera in primary care. Most participants argued that both nurses and doctors could use the device, while others had stronger opinions about choosing one profile over the other.

Some clinicians saw acquiring an image of the retina as a medical procedure, that required a doctor to be involved.

> *We are not just acquiring an image. We are seeing the eye fundus. The image comes from the sequence of seeing the eye fundus. The only one who has training to observe the eye fundus is the doctor.* P6, Medicine Intern, 38 years old

P6 argued that only doctors had the necessary training to observe the retina, because while approaching the device and focusing the image, operators were making a diagnostic assessment of their observations. While the image was the end result, the observations performed to acquire it were equally important to inform or contextualise the diagnosis. However, most interviewed participants attributed an "operational" role to the user, arguing that they would only capture images and send them to ophthalmologists, without any analysis or interpretations. Participants who viewed the device in this way were in favour that any clinician could use it.

Other participants considered the criteria of healthcare staff availability to think about who should use the device.

> *I think this could be useful, because nurses can do it if they are trained. (...) I think that doctors using this device would be unnecessary, in the sense that it would make them lose more time. It's a matter of training.* P4, Surgeon, 42 years old

According to this participant, doctors should not acquire images of the retina because they should focus on the activities that require their specialised knowledge and experience. Two participants even mentioned that doctors could reject to operate the EyeFundusScope because they consider it an operational task that should be delegated to nurses.

F. Difficult patients to use the device with

While interviewing participants, we invited them to reflect on experiences they might have had throughout their professional experience that could resemble using the EyeFundusScope. When thinking about those experiences, participants recalled that it was hard to use the ophthalmoscope to observe the eyes of both older people and children since they required additional effort to make them understand and follow instructions. Also, it is difficult to make some older people and children stay still for long periods of time. Observing the eyes of older people can be so challenging, that participants confessed that they frequently refer older people with diabetes directly to the Ophthalmology without even trying themselves to observe the retina. Mobile eye fundus cameras can minimise this issue. By capturing an image of the retina, clinicians can observe it for the required time without keeping the patient in the same position, as when using the ophthalmoscope. Without a tool like EyeFundusScope, clinicians feel they do not have the necessary tools to observe the retina of their older patients and refer them directly to Ophthalmology.

> *The [older] person must be well positioned, otherwise the patient will not collaborate. Often [the difficulty] is to keep the same position for a while. (...) I felt easier [while using EyeFundusScope] when the head [of the volunteer] was straight than when he moved his head back. Because the tendency of the eye is to go up and then we have more difficulty in centering the image.* P5, Nurse, 50 years old

P5's professional experience corroborated the problem regarding observing the eyes of older people. She argued that one solution would be to use a chair with a headrest, which would enable young and old patients to be more stable and comfortable during the acquisition. Other challenging scenarios would include patients with brain tumours, as they could require a second professional to help support their heads during acquisition, or patients with cataracts or reduced pupils due to opioid-based therapies, as mobile eye fundus cameras would show a more reduced area of the retina.

V. Discussion

The findings from this paper reaffirm the potential of mobile eye fundus cameras to be used in primary care and positively contribute to the screening of diabetic retinopathy [10]–[16]. These insights echo prior research, adding examples of how clinicians see the potential implementation of these devices.

Our results confirm that minimal training can unlock the benefits of mobile eye fundus cameras to non-specialists [6] and that, while ophthalmologists are expected to diagnose the condition [6], care responsibility and followup are under the responsibility of the family doctor [8]. Training was previously mentioned as important to remote screening work [8], but having the relevant tools to support learning of clinicians was of utmost importance to the clinicians we interviewed.

This study was, to our knowledge, the first to gather the perspectives of clinicians on using mobile eye fundus cameras in primary care. Even though previous work has uncovered practical issues of using these devices in the field, e.g., short learning curve [12], [31], reduced impact on clinical flow [12], and importance of WiFi and illumination [12], perspectives of clinicians' were not systematically studied.

This work has three main limitations that might prevent our results from translating to other settings. First, all participants worked in the same country, which means that the comments about care processes and the healthcare system, might only apply to Portugal or other similarly organised south European countries. Second, all participants used the same mobile eye fundus camera, which means results are deeply influenced by the advantages and inconveniences participants saw in that particular model. Third, participants used the device in a simulated environment, and acquiring images in clinical care might present further issues.

A. Implications for design

Guarantee that technology can be used in different clinical pathways. While mobile eye fundus cameras can be used to support image acquisition in existing screening programs, they can be useful as well to observe patients when issues appear, or to closely monitor complex cases. In practical terms, it might be appropriate to send screening program images to a panel of ophthalmologists for image classification, but if a patient is being followed closely, the image should go to a specific ophthalmologist that is following their case. In essence, it is crucial that the device and surrounding infrastructures are designed in a way that embraces these possible alternative uses.

Promote learning and discussion. The clinicians we involved had limited knowledge about the retina but were interested in learning and playing an active role in the monitoring and diagnosis of eye conditions. Mobile eye fundus cameras could be used in connection with Ophthalmology training programs to enable non-Ophthalmology specialists to improve their knowledge and autonomy in monitoring or diagnosing eye conditions. Moreover, and supporting participants' suggestions, it would be important to provide clinicians with appropriate ways to discuss specific clinical cases with more experienced clinicians and ophthalmologists. These tools would ensure operators have appropriate channels for learning and discussing clinical cases that are essential in this context.

Ensure mobile eye fundus cameras are tested with older people and children. Our participants referred that older people and children would be probably difficult to observe using mobile eye fundus cameras. This is concerning for a system that is meant to be used on all types of patients. Moreover, the amount of older adults with diabetes is very considerable and having a technology that does not perform according to standard among these users can fall short. For this reason, mobile eye fundus cameras should be validated to work appropriately in practice in older people and children.

VI. Conclusions and future work

This paper presented clinicians' perspectives regarding the implementation of a mobile eye fundus camera into primary care. Having tried a mobile eye fundus camera, clinicians argued the potential to enable earlier diagnosis, the possibility to extend eye examinations to more people, the challenges to interpret images and the potential to use the device for learning, the possibility of using the device by doctors and nurses, and difficult patients to use the device with. Based on these insights, we derived three implications for design.

Future work will evaluate the use of EyeFundusScope in clinical practice, to understand if clinicians' perspectives are maintained throughout use and if other relevant issues appear.

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