Original Article

Role of teleophthalmology to manage anterior segment conditions in vision centres of south India: EyeSmart study-I

Neha Misra[1], Rohit C Khanna[1,2,3,4], Asha L Mettla[1], Srinivas Marmamula[1,2,5,6], Varsha M Rathi[1], Anthony V Das[7]

Purpose: To study the role of teleophthalmology (TO) in the diagnosis and treatment of anterior segment conditions (including adnexal conditions) in rural areas. **Methods:** This is a pilot study of 5,604 patients, who visited primary vision centres (VCs) for 1 week from 1-7 September 2018. The patients were examined by a vision technician (VT) to identify those who may need teleconsultation. The centres were located in 16 districts of four Indian states of Andhra Pradesh, Telangana, Odisha, and Karnataka. The demographic profile, along with the role of teleconsultation was reviewed. **Results:** Teleconsultation was advised in 6.9% of the patients, out of which 59.6% were referred to a higher level of care, and 40.4% were treated directly at the VC. Teleconsultations were higher among males (7.0% as compared to 6.6% in females), though not statistically significant ($P = 0.55$). Teleconsultation was higher in the older population, that is, 60 years and above (14.5%); those with severe visual impairment (VI) (21%) and blindness (31.1%); and in the states of Telangana (11%) and Andhra Pradesh (6.3%). It was noted that 45% of the patients who underwent teleconsultation had pathologies related to ocular surface, cornea and lid, and adnexa-related conditions. **Conclusion:** Teleconsultation has a significant role in the management of anterior segment conditions in bridging the gap between the patients and ophthalmologists in rural India. TO can also play an important role in the diagnosis and management of anterior segment, lid, and adnexa-related pathologies.

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"*Tele*" is a Greek word meaning "distance" and "*mederi*" is a Latin word meaning "to heal." The World Health Organization (WHO) defines telemedicine as, "the delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities."[1] The main aim of teleophthalmology (TO) is to minimize unnecessary referrals to an advanced centre and provide quality care closer to the communities. As more than half of the population needing eye care in middle- and low-income countries reside in the rural areas, it is the need of the hour to use the current technology, communication devices, and imaging capabilities to allow a broad spectrum of coverage in rural communities, providing screening and necessary referrals. The cost inflation in health care, a substantial gap in the availability of medical care between the high and the low socioeconomic countries and the disparity in quality of care between the middle- and low-income and high-income nations makes it even more difficult for rural communities to access health care.[2] Therefore, it is essential to look at the various advantages of TO such as cost reduction for both the patients and the ophthalmologists; comprehensive patient evaluation to minimize test replications; and avoiding unnecessary referrals.[2-4]

In India, TO consultations have a great potential in reaching the remote rural populations; and addressing the challenges of distance and access to quality eye care. The usefulness of TO has been demonstrated in the diagnosis of retinal conditions, such as diabetic retinopathy (DR).[5] In addition to retinal conditions, TO has also been used for neuro-ophthalmology, emergency teleconsultations, suspicious nerve cuppings, and uveitis.[4] However, the use of TO in adnexa-related conditions or anterior segment conditions like infections is limited. A study by Rayner *et al*. showed that certain adnexal conditions such as congenital and involutional ptosis could be accurately assessed using telemedicine.[6]

[1]Allen Foster Community Eye Health Research Centre, Gullapalli Pratibha Rao International Centre for Advancement of Rural Eye Care, [2]Brien Holden Eye Research Centre, L V Prasad Eye Institute, Hyderabad, India, [3]School of Optometry and Vision Science, University of New South Wales, Sydney, Australia, [4]School of Medicine and Dentistry, University of Rochester, Rochester, NY, USA, [5]Brien Holden Institute of Optometry and Vision Science, [6]Wellcome Trust/ Department of Biotechnology India Alliance Research Fellow, [7]Department of EyeSmart EMR and AEye, L V Prasad Eye Institute, Hyderabad, Telangana, India

Correspondence to: Dr. Rohit C Khanna, L V Prasad Eye Institute, L V Prasad Marg, Banjara hills, Hyderabad - 500 034, Telangana, India. E-mail: rohit@lvpei.org

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According to WHO, corneal diseases are a major cause of blindness in the world after cataract and glaucoma.[7] In India, 6.8 million people have a severe visual impairment in at least one eye due to corneal diseases and 1 million of these have bilateral involvement.[8] Gupta *et al*. noted that corneal blindness due to infectious keratitis was commonly reported in the rural population, particularly among those who are below poverty line, illiterate; and those using traditional methods to cure an eye condition (crushed plants, animal saliva, urine) which leads to ocular toxicity.[7] Prevention, early detection of the eye condition, and prompt treatment can help to control the burden of this dreaded anterior segment condition in the rural areas. India is a middle-income country with most of the population residing in rural areas; and corneal infections are a silent epidemic prevalent in these areas which have limited access to eye care. To address this situation and save the eyes, TO may be useful in seeking remote access to a specialist opinion, and early management of patients with corneal infections.

TO was also found to be beneficial in reducing unnecessary outpatient appointments with a specialist when it was used to triage referrals. A recent study showed that TO could reduce between 16 and 48% of face-to-face appointments.[9,10] Most of the TO services are delivered through asynchronous methods (store-and-forward of images); while some use a combination of real-time and store-and-forward methods; and fewer use synchronous methods (videoconferencing).[9] At our institute, we have developed a teleconsultation platform, called "eyeSmart App," which is used for teleconsultation at the primary level of care. It is a tablet-based application and can be also be used with smartphones.

This pilot study was designed with the following objectives

1. To understand the demographics and ocular profile of those undergoing teleconsultation,
2. To understand the role of TO in diagnosing and treating anterior segment conditions (including adnexal conditions),
3. To describe various anterior segment ocular conditions that can be diagnosed and treated.

Methods

Our pyramidal model for eye care delivery has a centre of excellence (CoE) at the top catering to 50 million population followed by tertiary centres (TC), each for 5 million population. At the next level, there are secondary centres (SC) covering 0.5–1 million population, followed by vision centres (VC) at primary level for 50,000 population, and vision guardians (VG) for 5,000 population. The functions at each level of the pyramid are clearly delineated and demarcated. CoE and TCs are located mainly in urban areas and the SCs and VCs are located in rural areas. A network of 100 VGs, 10 VCs, and 1 SC cover half million population, which is called a village vision complex (VVC). At present, the network covers four Indian states of Andhra Pradesh, Telangana, Odisha, and Karnataka and includes one CoE in Hyderabad, three TCs in Bhubaneswar, Visakhapatnam, and Vijayawada, 20 SCs, and 180 VCs.

The SCs are run by one or two ophthalmologists who are trained at a TC or COE for a year. Patients from SCs are referred to as TCs or COE only for advanced care and management of complex problems. The VCs are manned by a vision technician (VT). VT is the local youth who have completed high school and are trained for 1 year to provide primary eye care, including eye examination, refraction, dispensing spectacles, and appropriate referrals among all age groups.

We built an in-house electronic medical record (EMR) system known as eyeSmart EMR. Over the last 9 years, the EMR system has been implemented across the entire network. At the VC level, all VCs in the network have been digitized with the eyeSmart EMR app. Teleophthalmology and video calling are additional services provided by the eyeSmart EMR system. The eyeSmart EMR app is installed on an android tablet (iBall Slide Brace XJ) and connected to the slit-lamp biomicroscope (Carl Zeiss SL 115). The app helps in capturing the demographic data, clinical information, and images of the eye for a TO consultation through the cloud. This tablet has a good camera that can capture high quality images and hence can be used for TO consultation. Camera specification includes 8 MP AF rear camera with LED flash and 5 MP front camera for video chatting. The slit-lamp illumination is utilized for capturing the pictures and the illumination is 15 V, LED of the Carl Zeiss slit-lamp. The tablet coupled with Skypelite provides an excellent platform for a teleconsultation from the VCs. The internet connectivity is established on the tablet through a 3G network SIM card. The video conferencing tool, Skype, is used for all the TO consults (Skype, Microsoft Corp, Redmond, USA). For optimum patient management and communication with the higher centres, a referral system is put into place whereby the VT decides on either direct referrals or teleconsultations using the eyeSmart App. The VTs are trained to understand and follow the guidelines developed for teleconsultation. In brief, following conditions required teleconsultation—lid-related abnormalities, ocular surface abnormalities, red-eye, corneal pathologies, pupil and iris abnormalities, and lens-related pathologies. Based on the type of eye condition, the images can be of two types: an external image mainly for conditions that affect the eyelids and conjunctiva, and slit-lamp images for conditions that involve cornea and anterior segment of the eye. External images of the adnexa may also be required for conditions such as ptosis, squint, and lid abnormalities. All the TO consultations from these VCs are received at the TO command centre (TOCC) stationed in the CoE.

Fig. 1 shows the flow of patients to VCs as well as how the teleconsultation process works. The patient's demographic details are first registered by the VT on the tablet by using the eyeSmart EMR app. The preliminary examination is then performed, which includes chief complaint, present and past illness, systemic history, family history, and previous surgical history. This is followed by a general examination, recording the visual acuity, objective and subjective refraction, slit-lamp examination, and finally spectacle prescription. Based on the diagnoses, the relevant images are captured using the tablet attached to the eyepiece [Fig. 2]. The EMR of the patient along with ocular images are then synchronized online and shared with TOCC through the app for an ophthalmologist's opinion. The VT referring the patient also sends the information related to the ocular condition or any query to the TOCC. The patient is then connected to the ophthalmologist present at the TOCC through a video call using Skypelite services available on the tablet. The ophthalmologist at the TOCC reviews the clinical information and images and provides a diagnosis for the ocular condition. The nature of the disease and the possible interventions (medical or surgical) are discussed with the patient. The patient is then referred to the SC or

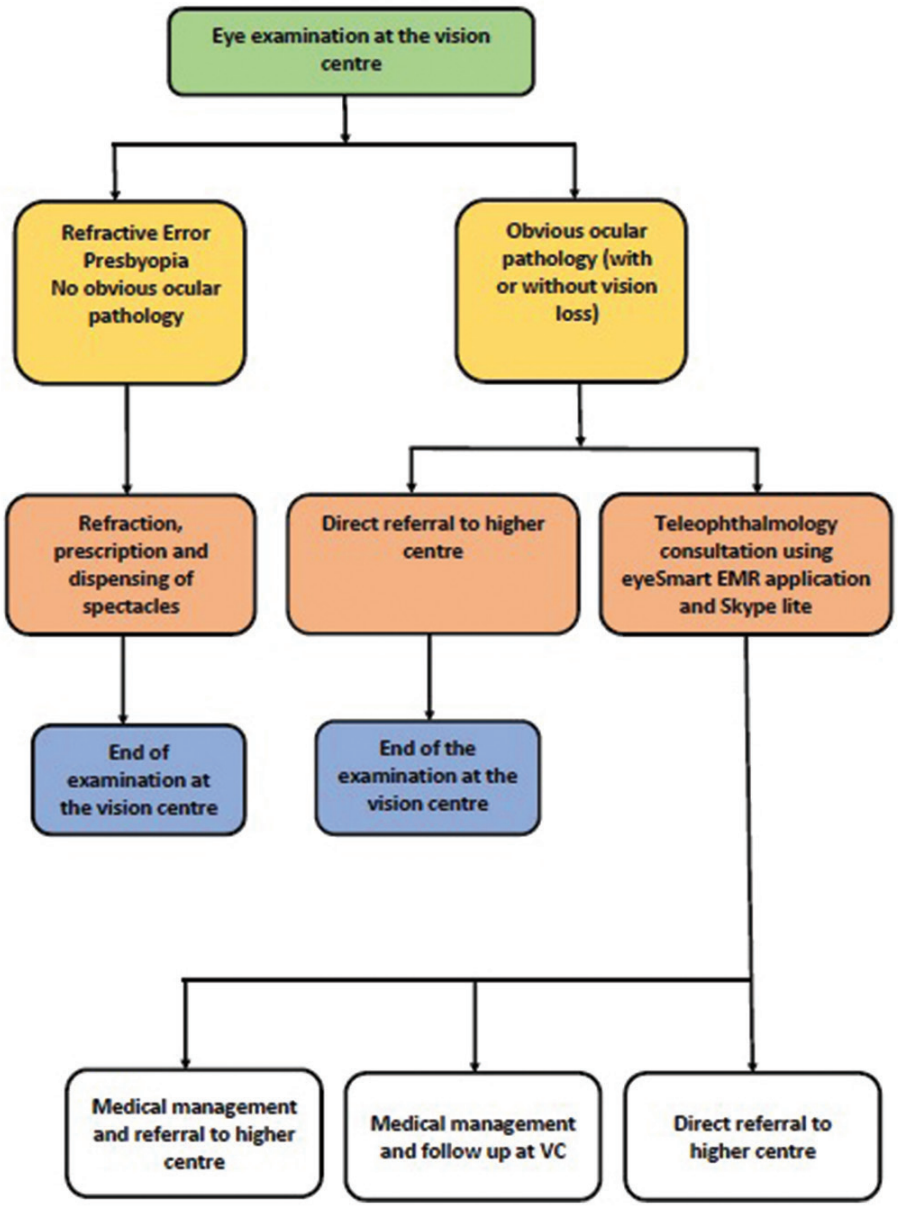

Figure 1: Flowchart depicting how teleconsultation works at vision centre (VC)

TC, through the eyeSmart EMR app, for further medical or surgical management if needed. The advice given by the ophthalmologist is synchronized via the cloud to the eyeSmart EMR app for documentation.

For our pilot study to assess the role of teleconsultation in diagnosing and treating anterior segment conditions (including adnexal conditions), we reviewed all the patients visiting all the VCs in one week from 1st to 7th September 2018. VCs that were well-equipped with EyeSmart tablets and good connectivity for communication were included in the study. The VCs are located in 16 districts, in four Indian states of Andhra Pradesh, Telangana, Odisha, and Karnataka.

Results

During the 1-week period, from 1st to 7th September, 2018, 5,604 outpatients visited the VCs. A total of 4,710 patients were seen in Andhra Pradesh, 577 patients in Telangana, 119 patients in Odisha, and 198 in Karnataka. Of the total number of patients screened, 3,099 (55.3%) were males and 2,505 (44.7%) were females. Of the total patients seen, 4,667 (83.3%) were treated at the VC level (including screening for refractive error); 384 (6.9%) patients had teleconsultation; and remaining 553 (9.9%) were directly referred to the next level of care. Out of the 384 teleconsultations, 229 (59.6%) were referred to a higher level of care and 155 (40.4%) were treated at the VC [Fig. 3].

Table 1 shows the demographic difference between those who had teleconsultation versus those who did not have teleconsultation. Teleconsultation was higher in males (7.0%), compared to females (6.6%), though not statistically significant ($P = 0.55$). Teleconsultation was also higher in an older population, that is, 60 years and above (14.5%); those with severe visual impairment (VI) (21%) and blindness (31.1%); and in the states of Telangana (11%) and Andhra Pradesh (6.3%).

Table 1: Demographic difference between those having teleconsultation versus those having no teleconsultation done

	Teleconsultation done *n*=384	Teleconsultation not done *n*=5220	Total *n*=5604	*P*
Age in years				
0-15	35 (6.64%)	492 (93.35%)	527 (100%)	<0.001
16-35	104 (5.42%)	1816 (94.58%)	1920 (100%)	
36-59	125 (5.45%)	2168 (94.55%)	2293 (100%)	
>60	120 (14.46%)	710 (85.54%)	830 (100%)	
Gender				
Male	218 (7.03%)	2881 (92.97%)	3099 (100%)	0.55
Female	166 (6.63%)	2339 (93.37%)	2505 (100%)	
Visual impairment (VI)*				
Normal	249 (5.63%)	4170 (94.36%)	4419 (100%)	<0.001
Mild VI	39 (11.17%)	310 (88.83%)	349 (100%)	
Moderate VI	61 (11.60%)	465 (88.40%)	526 (100%)	
Severe VI	17 (20.99%)	64 (79.01%)	81 (100%)	
Blind	14 (31.11%)	31 (68.89%)	45 (100%)	
States				
Andhra Pradesh	308 (6.32%)	4569 (93.68%)	4877 (100%)	<0.001
Telangana	64 (11.03%)	516 (88.97%)	580 (100%)	
Odisha	10 (8.40%)	109 (91.60%)	119 (100%)	
Karnataka	2 (7.14%)	26 (92.86%)	28 (100%)	

*Visual impairment categories (vision in better eye): Normal vision=6/12 or better, mild VI=less than 6/12-6/18, moderate VI=6/18 to less than 6/60, severe VI=6/60 to less than 3/60, blind less than 3/60

Table 2: Diagnosis by the ophthalmologist of all the teleconsultation done

Diagnosis	Teleophthalmology consultation done (*n*=384)
Emmetropia	33 (8.59%)
Lens-related condition*	147 (38.28%)
Refractive error	16 (4.16%)
Ocular surface pathologies**	116 (30.20%)
Lid and adnexa@	33 (8.59%)
Unexplained vision loss	15 (3.90%)
Corneal pathologies^	24 (6.25%)

*Lens-related pathology included cataract, aphakia, pseudophakia, and posterior capsular opacification, **Ocular surface pathologies included conjunctivitis, limbitis, abrasions, foreign body, and pterygium, ^Corneal pathologies include keratitis, epithelial defects, corneal foreign body, corneal opacities, corneal erosions, @Lid and adnexa-related conditions included ptosis, acute and chronic dacryocystitis, globe related pathologies, meibomianitis, and blepharitis

Of the total patients seen, though 404 (7.2%) had a history of diabetes or hypertension, only 48 (11.9%) had teleconsultation.

Table 2 shows the diagnosis for the 384 teleconsultations made by the ophthalmologist at the TOCC. For better understanding, ocular surface pathologies (conjunctivitis, limbitis, pterygium, conjunctival abrasions, and foreign bodies) and corneal conditions (keratitis, corneal foreign body, epithelial defects, corneal opacities, and erosions) are termed as anterior segment-related pathologies. The lid and adnexa-related conditions that were teleconsulted, included ptosis, acute and chronic dacryocystitis, globe-related pathologies, meibomianitis, and blepharitis. Lens-related conditions included cataract, pseudophakia, aphakia, and posterior capsular opacification. The most common diagnosis according to the ophthalmologist present at the TOCC was lens-related (38.3%) followed by ocular surface pathologies (30.2%), lid and adnexa-related pathologies (8.6%), and corneal pathologies (6.3%). One hundred and seventy three (45.1%) of the patients that were referred for a teleconsultation had anterior segment-related problems, and 8.5% were diagnosed as emmetropic. Ocular surface-related conditions, corneal pathologies, and lid and adnexa-related conditions could be easily managed with TO, by sending the images to the TOCC for diagnosis and management. This not only saves time for the patient but also for the allied health personnel and the ophthalmologist.

Discussion

In the past, a survey conducted by Woodword *et al*. at the University of Michigan Kellogg Eye Centre showed that although most providers did not practice telemedicine, over half of them were comfortable managing eye care consultations that included patient's photographs over the internet.[11] However, recently the use of telemedicine for providing care has increased. In a study conducted in Chennai, eye care screening camps were organized by a team of optometrists, social workers, administrative staff, technology experts, and ophthalmologists and teleconsultation was done. About 71% of the patients had refractive errors, 15% had cataract, 7% were detected with retina problems, and 7% had other ocular diseases. Some of them were referred to the base hospital to undergo specific tests to confirm the diagnosis.[12] Similar TO connections were established between Edendale Hospital in Pietermaritzburg (South Africa) and Moorfields Eye Hospital in London. There were 113 consultations over 12 months, and of these 90 patients were examined to determine the

Figure 2: Vision technician taking images for teleophthalmology consultation

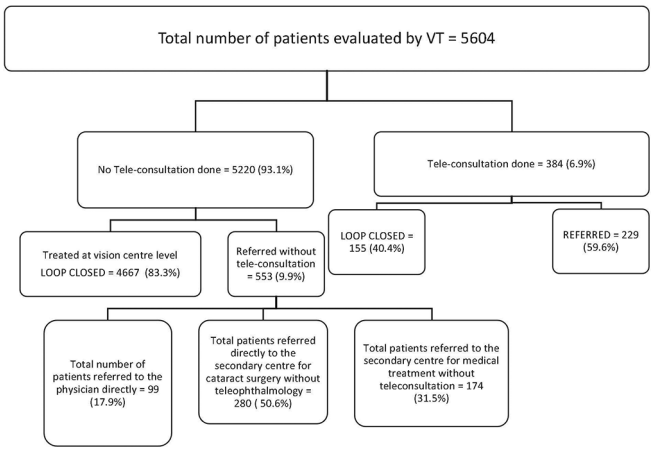

Figure 3: Flowchart showing data associated with teleconsultation

impact of TO. The impact was found to be definite in 24% of the cases, and possible in 22% cases, while there was no impact in 53%. A higher proportion of posterior segment and neuro-ophthalmology cases were seen whereas a low percentage of anterior segment pathologies were seen.[13] Verma *et al*. highlighted the role of TO in adnexal and orbital diseases with a 2.9% detection using teleconsultation.[14]

It has been established that VT has an effective role at the primary level of eye care. Good levels of agreement in refraction, disease detection, and referral were achieved by VT in a study conducted by Paudal *et al*., where the clinical competency of 24 VTs at 24 VCs was assessed.[15] In another study, excellent agreement was found for the detection of cataract, refractive error, and corneal pathologies by the VT.[16] In our pilot study, the VT who is specially trained for a year at an SC or TC had screened 5,604 patients for various eye conditions including refractive errors. Of these, 4,667 (83.3%) were managed without teleconsultation or referrals. The remaining were either referred directly (9.9%) or had teleconsultation (6.9%). Of those with teleconsultation, 40.4% were diagnosed and treated at the VC level thus avoiding referral to the next level of care. Among all the patients that were sent for teleconsultation, 45% had pathologies related to ocular surface, cornea and lid, and adnexa-related conditions. This was followed by lens-related conditions (38.3%). Compared to a study by Varma *et al*., we found a higher prevalence of anterior segment pathologies (ocular surface pathology and corneal pathology) along with the lid and adnexa-related pathologies.[14]

In terms of cost-effectiveness, Kumar *et al*. reported that the TO services are cost-effective for the patients in the rural areas as a substitute for regular eye care at the higher centres.[17] According to Newton, telemedicine proved to be less expensive compared to routine in-person examinations, for small clinical care facilities in New York. The reduced expenses on equipment more than compensated for an increased cost of skilled technicians.[18] Sharafeldin *et al*. did an economic review of TO screening for DR, glaucoma, and ARMD, which provided supportive evidence for the cost-effectiveness of TO; potentially increasing screening accessibility, especially for rural and remote populations.[19] Though we did not do any formal cost-effectiveness analysis, in our study we assumed that there was a significant saving on time and cost of travel, and avoiding loss of wages for these patients.

In our study, teleconsultation was higher in an older population, that is, 60 years and above and in those with severe VI and blindness; whereas in a study conducted by Verma *et al*., most of the patients belonged to the economically productive age group of 21–40 years.[14] Verma *et al*. found that 25.7% of the patients had potentially sight-threatening conditions without access to ophthalmic care,[14] and our findings were also similar. Teleconsultation was also higher in the state of Andhra Pradesh possibly due to more footfalls in VCs located in this state. Of the total patients seen, 404 (7.2%) had a history of diabetes or hypertension, and only 48 (11.9%) had teleconsultation. This indicates that all patients who visit these VCs need screening for diabetes and hypertension, and also teleconsultation for further management. While 72% of India's 1.2 billion people live in rural areas, over 70% of the doctors practice in urban areas.[3] The aging population is increasing, with consequent increase in numbers of blindness and ocular comorbidities; however, there is a limited access to care for most middle- and low-income countries. As we move into the future, TO would help to bridge that gap. It will allow clinicians to detect eye-related morbidities and provide care to patients in rural, remote, and hard-to-reach locations.[20]

One of the limitations of our study was that about 9.9% of the total patients who could have been managed through teleconsultation at the VC itself were referred directly by the VT to a higher centre for further review and management. We note that some of these patients could have been teleconsulted and the loop closed at the VC level itself, thus avoiding further referrals and making the intervention cost-effective for the patient. Hence, there is a need to revisit the referral criteria. Though the VT findings were validated in our previous studies,[15,16] there is also a need to revisit it again. Similarly, there were variations in TO consultation between three states that need further exploration. It is also likely that there was a compliance issue related to referral uptake from VCs to SCs or TCs/CoE. For a better understanding, it is necessary to further analyze the data on patients referred to advanced centres and the subsequent diagnosis and management. For those who did not comply to referral services, a different mechanism has to be designed to ensure consultation at a higher level as well as uptake of services.

Conclusion

EyeSmart app is a helpful tool in establishing an ocular diagnosis and providing timely intervention. It is useful in connecting patients in rural areas with ophthalmologists and to overcome the barriers of distance, time, and costs. Moving ahead, the scope of teleconsultations could include posterior segment problems also; increasing access to care and its cost-effectiveness. Apart from this, we need more studies from middle- and low-income countries to look at the efficacy of TO in screening for anterior segment conditions.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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