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Smartphone Aided Funduscopy in Albino Rabbits

Gayathri K [a++*], Syam K. Venugopal [a#], John Martin K. D. [a#], Anoop S. [a†], Lucy K. M. [b†] and Shynu M. [c‡]

[a] *Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Sciences Kerala Veterinary and Animal Sciences University (KVASU), Mannuthy, Thrissur, Kerala- 680651, India.*
[b] *Department of Veterinary Anatomy, College of Veterinary and Animal Sciences Kerala Veterinary and Animal Sciences University (KVASU), Mannuthy, Thrissur, Kerala- 680651, India.*
[c] *Department of Veterinary Biochemistry, College of Veterinary and Animal Sciences Kerala Veterinary and Animal Sciences University (KVASU), Mannuthy, Thrissur, Kerala- 680651, India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author GK designed and performed the study, collated the literature, results analysis and documentation, wrote and prepared the manuscript. Author SKV supervised and mentored the study, scrutinized and corrected the manuscript. Author JMKD supervised and guided the study, Author AS supervised and guided the study, scrutinized and corrected the manuscript, Authors LKM and SM co- supervised and guided the study, scrutinized and corrected the manuscript. All authors read and approved the final manuscript.

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[++]*Doctoral Student;*
[#]*Professor and Head;*
[†]*Professor;*
[‡]*Associate Dean and Professor-Head;*
**Corresponding author: E-mail: ghayathry@gmail.com;*

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ABSTRACT

Aims: The methodology, utility and clinical feasibility of using a smartphone camera to obtain images of ocular fundus of albino rabbits with ocular hypertension and normotension were studied**.** A comparative analysis of fundus images obtained from two popularly used smartphone models, android and iOS device was performed on 36 adult albino rabbits.

Study Design: A cross-sectional study involving two cohorts of ocular hypertensive and normotensive albino rabbits.

Place and Duration of Study: Department of Veterinary Surgery and Radiology, College of Veterinary and Animal Sciences, Mannuthy for an eight-week period (2023).

Methodology: A total of 36 adult albino rabbits (18 males and 18 females; age range 6- 8 months of age) with ocular normotensive eyes and unilateral ocular hypertension-induced models were used. The conscious animals were gently restrained in an acrylic restrainer. Instillation of topical mydriatic solution (tropicamide 0.8% and phenylephrine 5%) facilitated visual examination and enhanced field of view along with auxiliary condensing lenses of 20 and 40 Diopters. A comparison of fundus images obtained from two popularly used smartphone models, android and iOS devices was performed on 36 adult albino rabbits.

Results: Fundus images comprising the optic nerve head and peripapillary retina were obtained with adequate spatial resolution and detail. The variation between optic disc of ocular hypertensive eye revealed mild edema and cupping of optic disc. Normal merangiotic retina and optic disc were clearly obtained in normotensive rabbit eyes. The iOS device used in this case yielded better images in resolution and field of view compared to the android version used in this case.

Conclusion: Smart phone funduscopy offered good detail in contrast and resolution even in amelanotic eyes of albino rabbits using inbuilt technology without the need for an external adapter or sophisticated additional software. It is an animal-friendly futuristic solution for digital documentation, telemedicine, teaching and clinical prognosis formulation.

Keywords: Smart phone funduscopy; rabbit; optic disc; merangiotic fundus; iOS apple iPhone; android phones.

ABBREVIATIONS

OS : oculus sinister (left eye)
OD : oculus dexter (right eye)
iOS : iPhone operating system
ONT : ocular normotensive
OHT :ocular hypertensive
D : Dioptre
IAEC : Institutional Animal Ethical Committee
CCSEA : Committee for Control and Supervision of Experiments on Animals

1. INTRODUCTION

An exclusive fundus camera is a sophisticated, delicate and rather expensive device used to capture images of the retina and optic disc of the eye. It requires proper restraint of the animal to obtain a good image. Hence, in the case of veterinary patient side examination, high equipment-cost and adaptability often pose challenges for the usage of the device. As an effective alternative, a smartphone fundus photography has often been cited as a feasible tool. The contemporary iOS and android cameras offer ample spatial resolution, magnification, illumination and depth perception. The provision of multiple lenses suited for each of the aforesaid functions helped to obtain a sophisticated image for ocular examination, transfer of clinical cases for referral opinions, teaching and documentation from the images and videographs of the ocular posterior segment and the fundus. This can be used with gentle restraint even in a conscious animal.

The advent of technological advancement has facilitated access for common people to acquire and effectively use handy, portable quality resolution cameras in smartphones. Therefore, good quality photographs can be electronically captured, digitally documented, stored, shared, edited and transferred quickly and cheaply even by amateur photographers.

Haddock *et al.,* [1] have reported the successful use of smartphone, iPhone 4 or 5 and a 20D condenser lens to capture fundus images in both humans and rabbits. It was stated that the system had aided to consistently obtain high-quality fundus photographs in human patients and in animals using readily available instruments that were portable with simple power sources. Kanemaki *et al*., [2] performed fundus photography in dogs and cats using an iPhone 6, akin to indirect ophthalmoscopy along with adjunct 15,20,28 and 40D condensing lenses. Two special image capture applications and special filters (two types of neutral density filters) were used but had obtained upside-down images. It was reported that 40D lens offered the widest field of view. The utility of this technique in client communication and teaching in small animal ophthalmology was highlighted. Balland *et al*., [3] worked on capturing fundus images in five dogs, cats and rabbits using the use of an optical device (D-EYE) attached to an iPhone 5. Posterior segment structures through images and videographs were documented. Flashlight artifacts were reported and the procedure was found to be easy and videos facilitated documenting dynamic phenomena in the posterior segment of eyes.

Most reported literature of smartphone fundus photography in animals has reported the use of auxiliary adaptors, software, filters and mounts. Compared to previous published literature, the current study focused on using a smartphone without investments on special adaptors, filters or other equipment to reduce cost and to explore the possibility of solely using a simple available handy device accessible to everyone in daily life. The familiarity of the device being used by their human caregivers could also possibly reassure the animals to feel a sense of security or familiarity when the device is held upto them for video graphing the fundus or for posterior segment examination when awake and alert.

The fundus is the interior surface of the eye opposite the lens which includes the optic disc and retina. Examination and image capture of the fundus in various animal species is a daunting task. The conscious or sedated animal must have its pupils in maximum dilation prior a proper fundus examination. This is usually achieved with mydriatic or cycloplegic eyedrops. The corneal surface and lens material must be transparent to capture the fundus image transpupillary.

The significance of this study is that it helps with clinical examination of the fundus which is pivotal for the following reasons:

- Afflictions of optic disc and retina must be diagnosed at the earliest to prevent further damage and for better prognosis
- Damage to retina and optic disc impairs vision more severely than afflictions of anterior segment
- Professional expertise is necessary to examine and assess lesions on fundus

The practical utility of using a smartphone aided fundus image capture is enumerated as follows:

i. Easy to learn, use and digitally document lesions of adnexa, intraocular structures and fundus
ii. Images are easy to be stored, transferred and edited as they are in digital formats
iii. Easily available, cheaper alternative to fundus camera
iv. Easy to refer to a specialist (telemedicine), for teaching and training; documentation
The study aimed to

- assess the technique and feasibility of smart phone aided funduscopy in albino (amelanotic eyes) rabbits
- document fundus images from ocular normotensive and hypertensive eyes in albino rabbit models
- comparison of fundus images obtained using two popular smart phone models: iOS and android
- study fundus images obtained using two different adjunct condensing lenses: 20D and 40D

2. MATERIALS AND METHODS

This study required very few materials like smart phone (iOS or android operating system), condenser lens (20D, 40D), cycloplegic or mydriatic eye drops, animal restrainer (optional), ambience: dim lit, micropore tape (to soften flashlight intensity). In this study, Tropicamide (0.8 % tropicamide and 5% phenylephrine solution as Trophtha-P®, Optho Pharma, Prayagraj, India) eyedrops were used to dilate the pupil. One drop was instilled in each eye 15 minutes prior to examination.

All animals were pre-examined to be clinically normal and reared in standard conditions as per CCSEA guidelines and principles of laboratory animal care and were subsequently rehabilitated post study.

1. All the conscious rabbits were gently towel restrained or kept in an acrylic restrainer in normal sternal recumbency or a bunny loaf position. One drop of cycloplegic eyedrops was instilled into conjunctival fornix of each eye, 15 minutes before the examination
2. Condenser lens of 20D or 40D was held close to the eye by non-dominant hand of the examiner, with little finger resting on upper eyelid. A no- contact approach was also practised in few cases and found practically feasible
3. Focal distance adjustments: initially the camera phone was backed away at seven centimetres or a palm's length away from lens and then kept advancing closer gradually to discover best suited focal length for the examiner to focus on the fundus of the stationary patient eye (Fig.1, Table 1)
4. Image capture and documentation: position of optic disc was identified by shifting the lens and camera in tandem with hand and eye-coordinated movements
5. Study design: cross-sectional study comprising 36 New Zealand white rabbits, aged 6- 8 months, equal number of males and females with (n=18) ocular normotensive and (n=18) ocular (OS-left eye) hypertensive (induced topically with 0.1% betamethasone sodium phosphate for a period of 56 days) were studied at eighth week.
6. The fundus photographs were collated and observed for variations in cup to disc ratio, rim thinning, oedema or discolouration of papilla and peripapillary retinal anomalies
7. A comparison between images obtained using android and iOS operating system models was also studied.

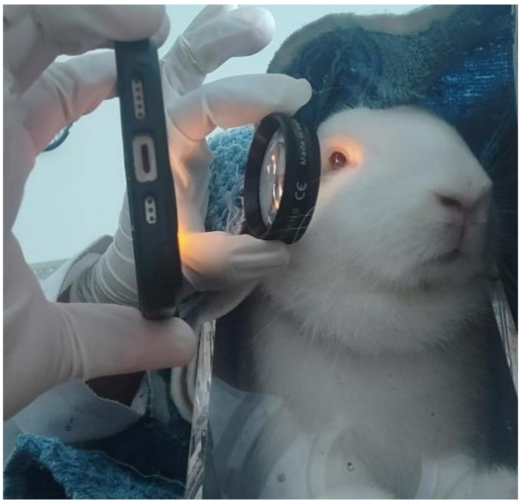

Fig. 1. Methodology: capturing a fundic image using a smartphone and condensing lens (40D) from dilated right eye of a conscious albino rabbit

Table 1. Specifications of condensing lenses used and utility

Condensing lens power	Angular magnification	Field of view	Working distance from cornea (average)	Utility
20 D	3.13x	46°	5-7 cm	Commonly used for fundus examination of felines and canines
40 D	1.67x	69°	1-2cm	Higher power lens used for rodents and rabbits (smaller eyes/globe)

** Condensing lenses used: 20D- Kashsurg, Kashmir surgical works, Ambala, India and 40D-Bawa enterprises, Ambala, India*

3. RESULTS AND DISCUSSION

The smartphones in conjunction with condenser lenses provided optimum resolution and image capture even for the amelanotic *i.e*. lesser natural colour contrasting, pale eyes of albino rabbits. This study employed one model each of iOS and android smartphones and the results obtained were exclusively between these two models (Fig. 2 and Fig. 3). There are various models of smartphones which have varied specifications and settings and offer a different image quality with similar techniques.

This study aimed to highlight the ease and efficacy of smartphones as an adjunct to condensing lenses, in photo documenting fundus images. Domestic and feral or wild veterinary patients may all, not be amenable to close-quarters examination using a standard funduscope which has to be used for examination of eye in contact with periocular structures. For examination and study of optic disc and retina of veterinary patients, domestic, feral and wild, unless strictly restrained or sedated, it may not be practically possible in clinical practice by professionals and students. To most animals the smartphone being a handy, inconspicuous instrument in the hands of humans, offered an unprecedented advantage with magnification and artificial lighting to aid retro illuminated examination of fundic structures.

The results of the smartphone aided funduscopic study in rabbits are detailed in Tables 2 and 3.

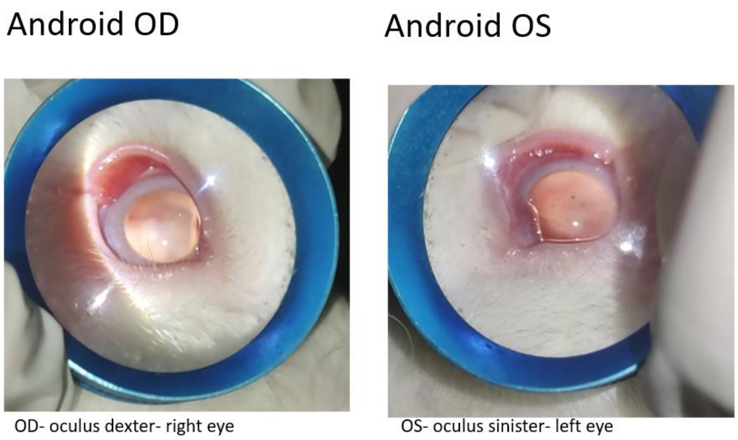

Fig. 2. Funduscopic images obtained using android phone and 20D condensing lens from right and left eyes of albino rabbit

Fig.3. Funduscopic images obtained using iOS phone and 20D condensing lens from right and left eyes of albino rabbit

Table 2. Inference from analysis of fundic structure and character studied in eyes of albino rabbit

SN	Fundic structure	Structures examined	Observational INFERENCES (n=36)
1	Optic disc (optic nerve head or papilla)	1. Cup to disc ratio 2. Sharp margins 3. Pink and healthy optic disc rims, neuro retinal rim	All normal study except for mild optic disc oedema and cupping in ocular hypertension-induced left eyes of rabbits of test group(n=18)
2	Retina (peripapillary)	Distribution, vascular pattern, vessel diameter, discolouration, oedema, detachment	Normal study

Fundus type: Merangiotic fundus, Location: superior fundus –temporal quadrant

Table 3. Inference from three sets of comparisons based on the objectives of the study

SN	Comparison sets	Results obtained
1	Between Android and iOS cameras 1)Android phone model: moto g40® fusion plus, Motorola Mobility LLC, IL, USA 2) iOS phone model: iPhone 14 Pro®, Apple Inc., CA, USA	• Resolution, inbuilt flashlight, depth analysis – all ranked iOS superior to the android phone used in this study • iOS had a 3D resolution better (inbuilt LiDAR sensor) • Both were used with 1x zoom • 4 layers of micropore tape to soften flashlight was used
2	Between 20D and 40D lenses	Higher power lens gave lesser angular magnification but wider field of view
3	Between topically induced ocular hypertensive (unilateral-OS* only-betamethasone sodium phosphate 0.1% solution) at 8 weeks	The ocular hypertensive left eyes (OS) revealed mild oedema and cupping of optic disc (differentials: glaucomatous optic neuropathy, papilledema, optic neuropathy non - glaucomatous)

** OS- oculus sinister, left eye*

Smart phone fundus photography or funduscopy of amelanotic eyes (lesser natural contrast) was found to be captured in quite good resolution and detail. The variation between the normal fundus of control eye and a mildly papilledematous fundus in the ocular hypertensive eye was well observed by this technique in the rabbit eyes (Fig. 4).

This imaging modality of smartphone funduscopy has also been documented as a good tool for glaucoma patients and post glaucoma-surgical imaging in humans [4]. The retinal vasculature and changes in the optic disc and rim can be studied systematically in veterinary patients with posterior segment diseases like glaucoma. This technique of funduscopy has also been proven in a cohort of human diabetic retinopathic patients [5].

This study substantiated that dimly lit ambience was found best suited for dilated fundus examination and funduscopy. The availability of a rheostat or use of special applications or software could have better-controlled light and camera settings. The use of adapters or mounts would have facilitated the adjustment of lighting angle, focus and field of view. Many such ready-to-use commercial or custom-made adapters have been cited to be feasible in literature [6]. This study also verified that the artefact of flashlight of phone camera reflection was a trivial limitation in smartphone funduscopic imaging.

The medical micropore tape in single or multiple layers was used to soften the inbuilt flashlight intensity emitted from the smartphone which was similar to the technique used in human patients on smartphone funduscopy [1].

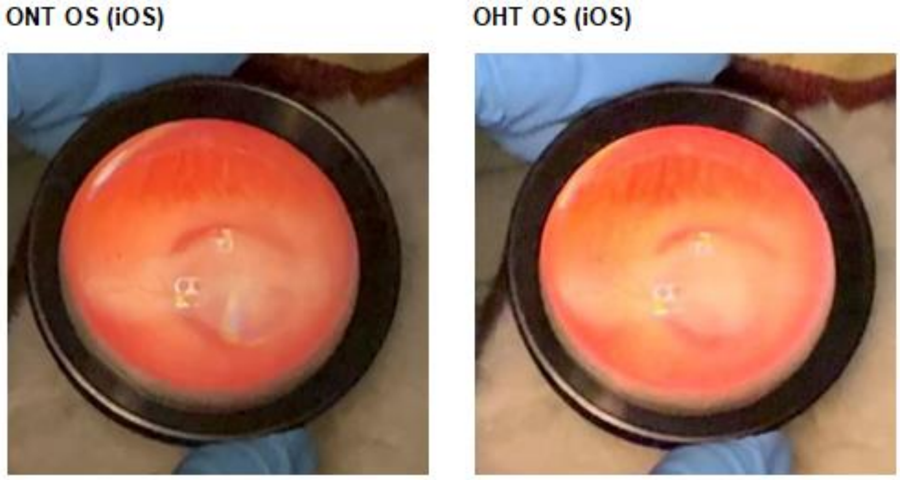

Fig. 4. Fundus image captured using iOS device and a 40D lens from the OS (left) eye of an ocular hypertensive (OHT) rabbit (test) and an ocular normotensive (ONT) rabbit (control)

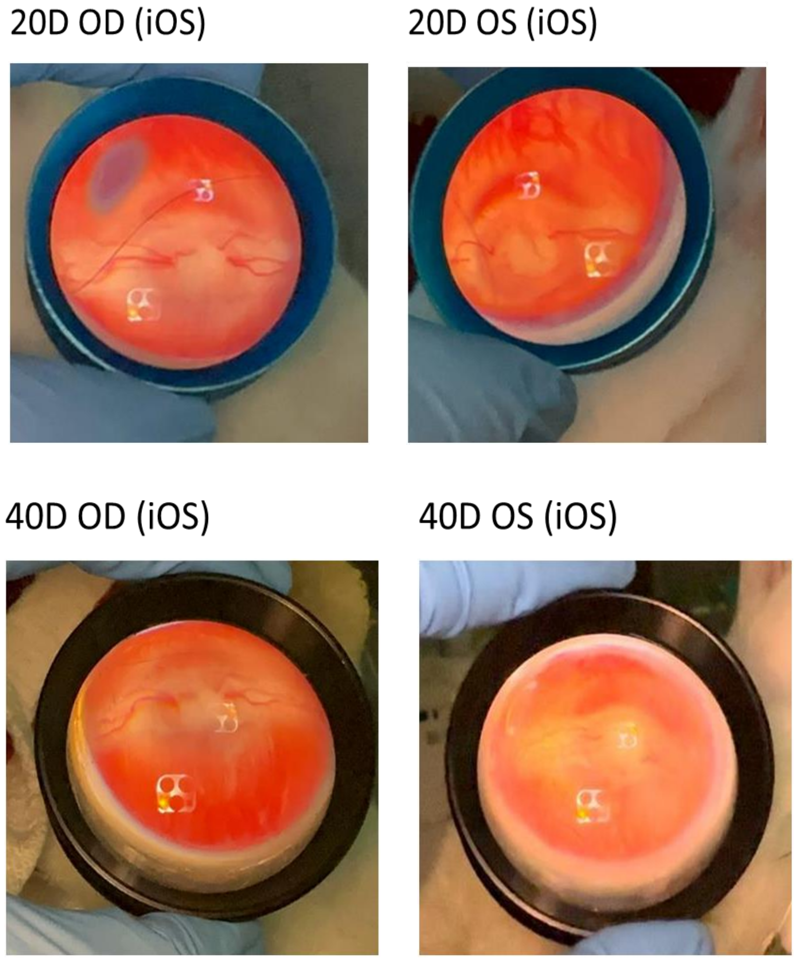

Fig. 5. Fundus images with optic nerve head and peripapillary retina obtained from both eyes (OD and OS) of an albino rabbit using 20D and 40D condensing lenses adjunct with iOS device

In this study, the smartphones were used without adapters or mount heads for funduscopy, and it was found efficacious to do so, as it did not alarm the veterinary patient.

Adaptors, custom made retinal cameras and hardware and specific software have been found feasible and effective in human ophthalmic practice in lieu of the conventional fundus cameras [7].

This study was a smartphone funduscopy imaging effort in which adequate visual resolution was obtained with inbuilt hardware and software of the smartphone models used. Depth perception and stereopsis of the inbuilt camera system helped assess the shallow areas of fundus and changes of the optic disc rim.

The use of 20D lens helped to capture only a smaller area of fundus at a time in this study. Wider field of view and detail was obtained using 40D lens (Fig. 5). A videograph to obtain a complete survey of the optic disc and peripapillary retina was recorded from different angles so as to collate the data and make inferences. Similar to the usage of a slit lamp to study various areas of the anterior segment in tandem, fundus photography helped obtain images from different angles, which when collated, gave a completed montage. This technique was also quoted in human ophthalmology practice [8].

All models of iOS and Android versions may not be congenial for fundus imaging and ophthalmic examination. This study mentions only two specific smartphone models and needs further research to extrapolate to other species and other phone camera models.

The feasibility, safety and efficacy of the technique of smartphone funduscopy for conscious veterinary patients (albino rabbits) with gentle restraint were reaffirmed in this study. Teleophthalmology and telemedicine could be facilitated by the use of this technique [9].

A sophisticated fundus camera may not be available at all times in the clinical scenario and by the veterinary patient side. A smartphone is commonly used in households by pet parents and most pets are familiar with and unafraid of its proximity. Hence, it can be used in conscious animals under gentle restraint [10].

4. CONCLUSION

Smartphone funduscopy was proven as a practically feasible option for early assessment of posterior segment afflictions by professionals and novices or students in pet animal eyes. This offered good detail in contrast and resolution even for amelanotic eyes using inbuilt technology. It is a pet and vet -friendly, futuristic solution for digital documentation, telemedicine, teaching and clinical prognosis formulation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ETHICAL APPROVAL

The study was approved by the Institutional Animal Ethics Committee (IAEC) of the College of Veterinary and Animal Sciences, Mannuthy, Kerala and all guidelines of IAEC (Proj. No. CVAS/MTY/IAEC/23/38 dt 15.03.2023) and Committee for Control and Supervision of Experiments on Animals (CCSEA), Government of India were adhered.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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