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Evaluation of Fundus Examination of Hunting Dogs' Eyes Using a Smartphone-Based Camera

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Abstract: Fundus imaging with a smartphone-based camera has been reported in a limited number of literature, particularly in patient groups (pediatric/geriatric ie.) considered to be incompatible. In this study, by examining both eyes of 20 hunting dogs, multiple shooting series (20 sequential shooting automatic series with 1-second interval) and video sequence (a video that started shooting at 30-second and/or 60-second intervals) were recorded. The patients were first examined without any intervention. Afterwards, mydriatic drops were applied and the examination was repeated within the effective period. During the examination, optic disc nerve head, tapetum lucidum, non-tepatal region, retinal vessels, and choroid vessels were visualized in the posterior segment. Focal light artifacts were common when photographing the tapetum lucidum. The minimum light intensity was chosen to display the tapetum lucidum. No significant difference was observed between the examinations performed before the mydriatic drop and the examinations performed after the mydriatic drop. Further studies are recommended to formally assess clinical benefit.
Keywords: *D-EYE, Dog, Retinal examination, Smartphone-based camera.*

Akıllı Telefon Tabanlı Kamera Kullanarak Av Köpeklerinin Gözlerinin Fundus Muayenesinin Değerlendirilmesi

Özet: Akıllı telefon tabanlı telefon ile fundus görüntülenmesi özellikle uyumsuz olarak kabul edilen hasta gruplarında (pediatrik/geriatrik vb.) pratik bir şekilde görüntülerin elde edildiği sınırlı sayıdaki literatürde bildirilmiştir. Bu çalışmada 20 av köpeğinin her iki gözü incelenerek çoklu fotoğraf serisi (1 saniye aralıklarla 20 ardışık otomatik çekim serisi) ve video görüntüsü (30 saniye ve/veya 60 saniye aralıklarla kaydedilen video) kaydedilmiştir. Hastalar önce herhangi bir müdahale olmaksızın muayene edildi. Daha sonra midriyatik damlalar uygulandı ve etkili süre içinde muayene tekrarlandı. Muayenede optik sinir başı, tapetum lucidum, nontepatal bölge, retina damarları ve arka segmentte koroid damarlar görüntülendi. Tapetum lucidum'un fotoğrafını çekerken fokal ışık yapaylıkları yaygındı. Tapetum lucidum'u görüntülemek için minimum ışık yoğunluğu seçildi. Midriyatik damla öncesi yapılan muayeneler ile midriyatik damla sonrası yapılan muayeneler arasında anlamlı bir farklılık gözlenmedi. Klinik faydayı resmi olarak değerlendirmek için daha ileri çalışmalar önerilir.
Anahtar Kelimeler: *Akıllı telefon tabanlı kamera, D-EYE, Köpek, Retinal Muayene.*

Introduction

Photographing the fundus is a standard method for documenting ocular fundus findings, and fundus photography is traditionally performed in a clinical setting using a fundus camera (Haddock and Quin, 2015; Khanamari et al., 2017). The biggest limitation of current imaging systems is the equipment is not portable and expensive (Maamari et al., 2017; Games and Ledbetter, 2019). Recently, the growing popularity of smartphones, high-resolution cameras, large data storage capacities, ease of image capture and sharing have led to the widespread use of smartphones in ophthalmology (Haddock and Quin, 2015; Ryan et al., 2015). In smartphone-based fundus imaging, the coaxial flashlight of the smartphone camera and a strong, high-resolution hand lens form an ophthalmoscopy-like system capable of recording digital fundus images (Khanamari et al., 2017). Although it is a complementary diagnostic tool by veterinary ophthalmology specialists, it is a unique, simple, and affordable application that provides photo-video documentation of retinal changes and allows consultation sharing in many clinical settings where retina imaging was previously not possible (Kanemaki et al., 2017; Russo et al., 2015).

Eye examinations of animals with systemic disease help narrow the differential diagnosis list. Diseases affecting the vascular and nervous systems are partially prone to ocular manifestations. In cases where ocular blood flow is very high, the probability of affecting the uveal and retinal vascular system increases, and hematogenous neoplastic cells and/or infectious organisms may arise in this area (Ofri, 2008). Ocular pathologies can be identified by a smartphone-based fundus imaging system. With clinical examination, cataracts, glaucoma, age-related maculopathy, chorioretinal atrophy, scar, systemic disorders (hypertension or diabetic retinopathy), retinitis pigmentosa, posterior vitreous detachment, and retinal detachment can be detected (Russo et al., 2014). When a fundus is displayed, a mydriatic agent should be used for comfortable viewing of the peripheral retina (Russo et al., 2015). Dynamic events such as venous circulation and uveal cysts floating in the vitreous cavity are visualized by video recording, which is an advantage of smartphone-based fundus imaging systems (Balland et al., 2017). The D-EYE digital ophthalmoscope is a fundus camera that can be attached to smartphones and used in conjunction with a Health Insurance Portability and Accountability Act (HIPAA) compliant application (Russo et al, 2014). D-EYE is an adapter that attaches magnetically to the smartphone and captures high-resolution fundus images with an approximate 20° field of view (Anonym, 2020). Through the D-EYE system, clinicians can share images stored digitally via an existing cloud system to get expert opinions without organizing a clinical visit (Mamtora et al., 2018).

This study aims to increase the limited literature knowledge about smartphone-based fundus imaging in the veterinary field, to confirm the availability of D-EYE devices in the incompatible patient group in the veterinary field, and the use of a mydriatic agent in examinations with D-EYE device.

Material and Method

Animal care and use: All procedures were approved by Burdur Mehmet Akif Ersoy University Animal Ethics Committee.

Equipment: Nowadays, the use of mobile devices to display the fundus is especially common in human medicine. Given the convenience and accessibility it provided during fundus examination, D-EYE® was selected for imaging, consisting of a meta cell shell and original optical systems provided by Galileo Diagnostics Corporation (Galileo Genclis, Nancy, France), and was used for evaluation of the fundus. In this study, a prototype D-EYE® was used on the iPhone 5 model. D-EYE was introduced to the market with a metal frame compatible with Apple (iPhone 5, iPhone 5s and iPhone 6; Apple Inc., Cupertino, CA, USA) and Samsung (Galaxy S4 and Galaxy S5; Samsung, Taegu, South Korea) brand phones. This metal frame is a bumper designed to fit the outer mold of the phone, allowing the smartphone to be fully aligned with the optics of the D-EYE. The metal frame allows easy installation of the D-EYE, via two neodymium magnets. D-EYE consists of special lenses, polarizing filters, a beam splitter, a diaphragm, and mirrors in a configuration that reduces light reflections, aligns the LED light beam, and compensates for corneal glare. The optical path of the D-EYE allows fundus imaging with the camera lens of the smartphone. There are two polarization filter combinations that significantly reduce corneal reflection with cross-polarization. To reduce the intensity of light emitted by the flash, an aperture is added to the device.

Photo and video recording: In order to create a photo and video recording with D-EYE, an application called "D-EYE" is required, which can be used on both iOS and Android platforms. "Retina scan" is selected after login to the application. The patient's descriptive information is entered, and then the operator chooses Oculus Dexter (OD) (right eye) or Oculus Sinister (OS) (left eye). Image recording and video recording called "multishot" can be taken with the application. By the multishot feature, the number of shots and intervals can be adjusted, an automatic serial photo recording consisting of 20 consecutive shots can be taken at 1-second intervals. When the video recording will be created, the duration of the video recording can be adjusted from the settings. After the start button is pressed, recording starts when the image becomes clear thanks to the autofocus and focus locking features via the autofocus system (AF) button. In addition, if the iPhone is examined with a smartphone, the light intensity of the phone LED can be checked with a scale under the application screen.

Examination protocol: Twenty hunting dogs brought to Burdur Mehmet Akif Ersoy University Veterinary Faculty Animal Hospital Surgery Clinic due to minor operative interventions were included in this study. Informed consent was obtained from the animal owners during the study. Before creating mydriasis of all dogs, fundus examinations of the right and left eyes were done with D-EYE and the multishot series and video series were recorded. During the examination, the next step is to create a full 5-minute break three times mydriasis with tropicamide 0.5% (0.5% Tropamid; Science Ilac San. Tic. A.Ş., Istanbul, Turkey) was dropped. After the animals were kept in a dimly lit environment for 20 minutes, fundus examinations of their right and left eyes were done with D-EYE and the multishot series and video series were recorded. All animals were examined in a dimly lit hall and records were created. The animals were conscious during the examination and an assistant was holding the animals. The light intensity was adjusted by moving from left (minimum level) to right (maximum level) with the slider available in the application. Minimum light intensity was preferred to display tapetum lucidum. During the imaging of the non-tapetal region, medium and high light intensities were selected. In animals where the autofocus algorithm failed to achieve a sharp image; the focus was locked to infinity before aiming at a distant object (several meters). When the subject appears clearly on the screen, AF is locked by pressing the AF button. Records were created by following the same method for each animal. Images were checked at every stage and repeated if not satisfactory.

Results

Of the hunting dogs included in the study, 18 were female and 2 were male. The average age of dogs is 1.97±0.21 years. In the study, fundus pathologies were not found in dogs.

Throughout the study, the smartphone was held by the left hand while performing the right eye examination, and by the right hand while performing the left eye examination. In cases where autofocus could not lock the fundus, it was locked to infinity for the first time as described earlier and the examination was repeated. The smartphone was positioned at 1-2 cm from the patient's eye. A safe distance has been established between the clinician and the patient being examined. With this distance, the clinician was able to easily observe the movements of the animal under examination. The fundus of the examined eye was examined in real-time on the phone screen before recording. When the fundus image was captured, the record button was pressed. Animals are expected to stand still during the fundus examination. Although it is difficult to perform fundus examination in moving temperament-hunting dogs, fundus images that can be interpreted with D-EYE were recorded within 1-3 minutes.

As shown a Figure 1 the optic nerve head, tapetum lucidum, non-tapetal region, retinal vessels, and choroid vessels were seen in the posterior segment structures. In the tapetum lucidum examination, the best image was obtained with minimum light intensity and in the cassette-free region examination, the best image was obtained with maximum light intensity. Focal light artifacts were common in tapetum lucidum photographs. As shown a Figure 2 these light artifacts are usually placed dorsally on the image. During the examination, the fundus was artificially hyperreflective. Video recordings and artificial hyper-reflective findings were easily distinguishable from true hyper-reflective findings. In fundus examination, we thought that we could detect a localized inactive chorioretinitis adjacent to the optic nerve in 1 case. However, as shown a Figure 3 through the video recording of the case, we

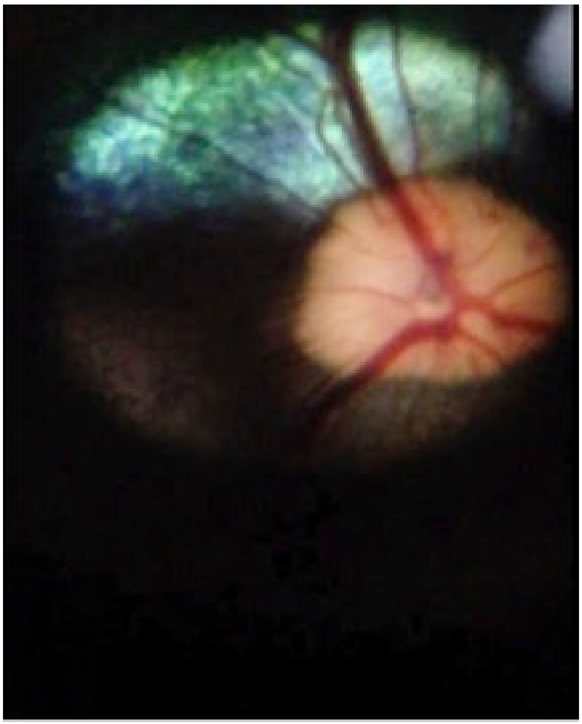

Figure 1. The anatomical structures of the posterior segment were observed during the examination: optic disc nerve head, tapetum lucidum, non-tapetal region, retinal vessels, and choroid vessels.

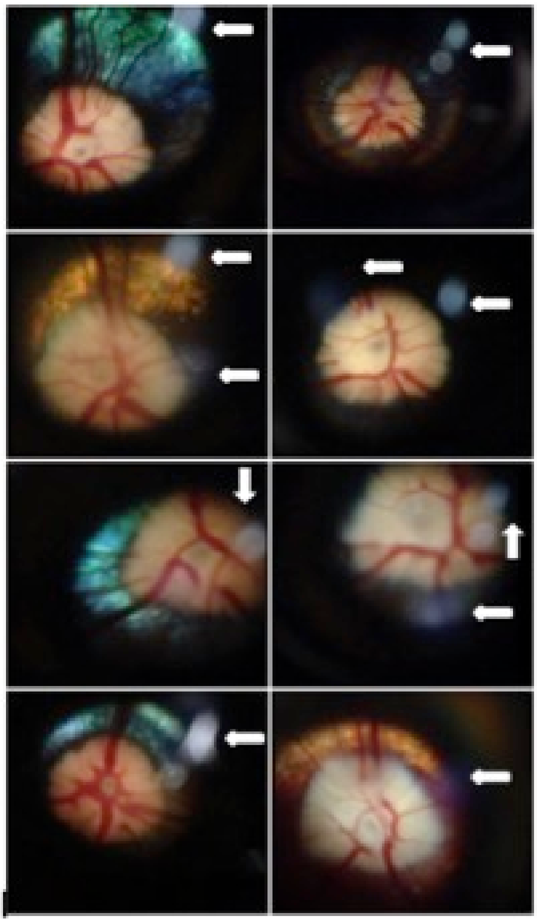

Figure 2. Focal light artifacts are common when tapetum lucidum is photographed (Shown with white arrow).

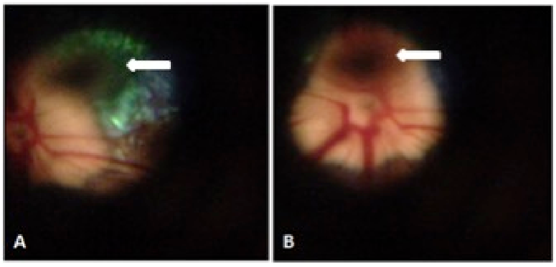

Figure 3. Hyporeflective light artifact that acts as a pathological finding when tapetum lucidum is photographed.

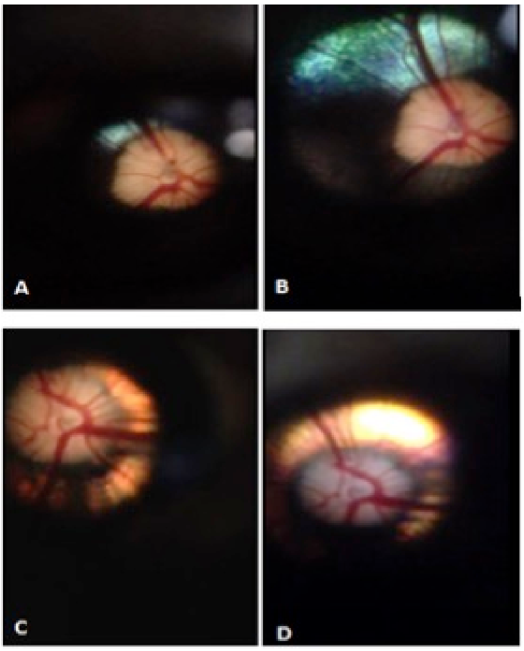

Figure 4. No significant difference was observed between the examinations performed before the mydriatic instillation and the examinations performed after the mydriatic instillation. However, in fundus photographing, the field of view is wider with a mydriatic drip. A-C: fundus photograph by examination without dripping mydriatic, B-D: fundus photograph by examination dripping mydriatic. While the field of view is expanded in B, no significant expansion is observed in D.

determined that the area with this hyporeflexivity was a camera-induced study. Video recordings allowed the display of dynamic events. With the videos recorded during the examination, hyper-reflective events and artificial hyper-reflective pathologies, as well as mild artifacts and pathologies can be distinguished.

Non-tapetal fundus was examined, no pathogenicity was encountered. The color of the non-tapetal fundus, which did not feature reflexivity, varies between black (65%) in 13 dogs and brown (35%) in 7 dogs. In some cases, the non-tapetal region adjacent to the tapetum lucidum had a pale and browner appearance than the ventral non-tapetal region. This was not a sign of pathogenicity. When examining the bulbar part of the optic nerve head, the color varied from pinkish white to dark pink. No pathogenicity could be determined. Hyaloid vessels displayed a healthy appearance in all fundus images.

No significant difference was observed between the examinations performed before the mydriatic vaccination and the examinations performed after the mydriatic vaccination. Peripheral visualization of the tapetal fundus was easier during examinations with a mydriatic drip. As shown a Figure 4, it was observed that the part of the fundus displayed in the studies with dripping mydriatic was relatively larger.

Discussion

With the advances in technology, the use of mobile devices as a medical diagnostic tool is becoming increasingly common. Taking advantage of the easy portability of mobile phones, the size of its data storage capacity, and wireless connectivity, it is thought that smartphone-based fundus imaging will play an important role in clinics soon (Maamari et al., 2013; Shen and Mukai, 2017). Khanamiri et al. (2017) compared the quality of the fundus images taken with a smartphone and the quality of the images taken using traditional fundus cameras, and there was no significant difference between the images. Fundus photography can be done in a clinical setting using fundus cameras, but the expensive and immovable equipment is the major disadvantage of this method (Khanamiri et al., 2017). Miniaturization and improvement of internal photographic equipment (etc. lenses, sensors, lighting systems, and autofocus systems) have made smartphone-based fundus imaging very powerful tools. An example of a small optical device that can be connected to a smartphone is the D-EYE module (D-EYE Srl, Padova, Italy). Smartphone-based fundus imaging systems have been described in both humans and animals (Balland et al., 2014).

Although the ophthalmoscopic technique used by the D-EYE for imaging the fundus is not replaced, it is very similar to that of direct ophthalmoscopy (Balland et al., 2014). The absence of a safe distance between the patient and the clinician during direct ophthalmoscopy is a disadvantage of direct ophthalmoscopy (Gelatt et al., 2013). Besides being easy to use in the field conditions, D-EYE provided easy visualization of the fundus especially in children and the elderly, which are considered incompatible patient groups (Anonym, 2020). In our study, we used puppy dogs as an incompatible patient group to test the effectiveness of D-EYE in the veterinary field. The time to record fundus images was determined as 2-3 minutes as a result of the examination we performed with D-EYE in puppies with a highly mobile temperament. We think that D-EYE may be the reason for preference in ophthalmological examinations in the veterinary field, especially inpatient groups that are incompatible and cannot be transferred to the clinic. There is also an arms distance between the clinician and the patient, which can be considered safe during the examination. In this way, the clinician can easily observe the animal's movements.

Light safety limits for ophthalmic instruments are determined in humans by the International Standards Organization (ISO 15004-2.2). In this respect, smartphone fundus photography is a safe technique (Khanamiri et al., 2017). Kim et al. (2012) compared the light levels produced by standard indirect ophthalmoscopes and used in smartphone fundus photography (Kim et al., 2012). In this study, the light produced by the standard indirect ophthalmoscope was shown to be 10 times brighter than the light used by the iPhone 4. In the D-EYE application, the iPhone LED light, which is darkened by polarizing filters and diaphragm, and carried through the diverging lens, is 15 and 24 times less for thermal and photochemical hazards, respectively, than the light used in indirect ophthalmoscopy. As a result, the retinal exposure of smartphones is less than 1 degree from an indirect ophthalmoscope. Both are within the safety limits of the thermal and photochemical hazards defined by ISO when tested under conditions simulating routine fundoscopy (Kim et al., 2012). Haddock and Qian (2015) although the light intensity and energy levels of the iPhone 5 are higher than that of the iPhone 4, they think that it is far below the danger limits.

In this study, it was observed that focal light artifacts were common in the tapetum lucidum and that the fundus exhibited hyper-reflective properties during the examination. Similarly, Balland et al. (2017) showed that the tapetum area is overexposed and the fundus is artificially hyper-reflective. They reported that artifacts did not cover the entire tapetal region, and their size varied and appeared as smooth areas with no visible details. Also, it was stated that light artifacts were not observed in the examination of the subalbinotic fundus and non-tapetal region. The iPhone's focus and exposure automation algorithms were sometimes overwhelmed by the tapetum lucidum. Exposure problems have manifested themselves as light artifacts in images. This problem can be solved by turning off autofocus and manually focusing to infinity through the application. The dynamic range of the fundus of the carnivores (the difference between the brightest and darkest areas) is quite evident. Therefore, a wide and high-definition sensor is required, which is suitable for the dynamic range of the fundus of carnivores. In contrast, the relatively small size of the iPhone sensor may be responsible for overexposure in the tapetal region (Balland et al., 2017). Kanemaki et al. (2016) suggested that in fundus photographs, 2 small bright spots reflected from the front and back surfaces of indirect lenses can affect the image. For this reason, to prevent overexposure while recording images, the light intensity should be decreased when photographing the tapetal region, and they stated that the light intensity should be increased when photographing the non-tapetal region. In contrast, although high image resolution is set during video recording, it has been suggested that image resolution may be low due to low light (Kanemaki et al., 2017). Gomes and Ledbetter (2019) reported that enlightenment artifacts may be present in all images due to the physics of light passing through an indirect lens, but this affects less than 1% of the photographs collected (Gomes and Ledbetter, 2019). With our study, we determined that mild artifacts resulting from this overexposure can be confused with retinal pathologies. In videos, hyper-reflective areas can be displaced and usually placed dorsally. This suggests that areas that appear to have hyper-reflectivity can be caused by the phone's LED light. Also, it was detected a camera artifact that can cause an incorrect assessment of the images of a case thanks to the video recording feature. As a result of the displacement of the area that appears to be hyporeflective in fundus images, we observed that this is a product of the camera. For this reason, it was argued that the video recording feature offers a dynamic examination opportunity during the examinations with D-EYE and is extremely important in distinguishing pathologies.

Examinations in the smartphone-based fundus imaging system can be performed with or without using mydriatic (Anonym, 2020). Ryan et al. (2015) reported that in both methods, pathogenicity that threatens vision can be detected. However, there is a lower sensitivity in detecting diseases such as diabetic retinopathy in smartphone systems, especially when mydriatic is not used (Ryan et al., 2015). Russo et al. (2015), a limitation of the D-EYE system is inadequate in visualizing the peripheral retina (Russo et al., 2015). Baeza et al. (2009) argue that there is a linear ratio between pupil patency and fundus photo quality (Baeza et al., 2009). In contrast, Shen et al. (2017) stated that physiological dilation, which is a part of standard ophthalmic practice, has significant disadvantages. First, ophthalmologists are not accustomed to using dilatation drops. In addition, regardless of expertise, pharmacological dilation tends to be inconvenient for both the medical doctor and the patient, dilatation drops take about twenty minutes to take effect, and the patient experiences blurred vision and light sensitivity for up to several hours after dilatation. Also, pharmacological dilation prevents physical examination of the pupil over the next few hours, which is an undesirable effect when monitoring patients with critical neurological disease. Finally, the risk of provoking acute angle-closure glaucoma insensitive eyes with the use of expanding eye drops is a small but real risk. Given these drawbacks, it is more useful for pediatric ophthalmologists, although the comfort of examining with a prototype camera without using a mydriatic is difficult to align (Shen and Mukai, 2017). Ryan et al. (2015) think that the direction to be developed for this technique is to improve the imaging of the peripheral fundus (Ryan et al., 2015).

It was claimed that the D-EYE system offers some practical advantages over desktop fundus photography and other portable ophthalmic imaging devices. The first of these; is a lightweight, compact and inexpensive device that facilitates ophthalmoscopic examination. It provides the opportunity to examine patients who cannot be brought to the clinical environment around them with their portability. It allows a safe distance between the patient and the clinician. Last time; it offers the opportunity to work more harmoniously with the group of patients who have difficulties during the examination. Light intensity and quiet operation, which can be easily adjusted with the application, give the patient minimum discomfort. Third; data can be stored clinically and shared for consulting purposes via wireless connection and cloud storage. Although the quality of the photos is lower than the quality of the photos obtained with fundus cameras, the veterinarian will be very useful as a complementary diagnostic tool on the field. It is among the advantages of allowing ophthalmoscopic scanning without the need for mydriatic use. A limitation of the device is that the peripheral retina cannot be fully visualized without using the mydriatic during examinations. The device needs to be developed to show the peripheral retina more comfortably. Finally, the D-EYE system is a complementary and useful screening method because of its ease of use, data storage, portability, allowing mydriatic examination in routine scans, and allowing patients to examine without stress even in patients not compatible with the veterinarian.

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