

COST EFFECTIVE SLIT LAMP CAMERA SYSTEM

by

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Has been approved


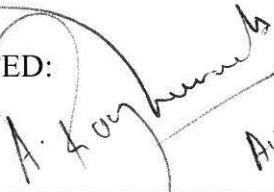
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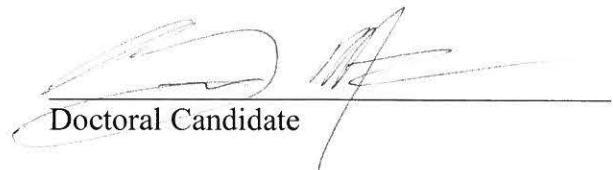


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COST EFFECTIVE SLIT LAMP CAMERA SYSTEM

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ABSTRACT

Background: Slit lamp mounted anterior segment camera systems can improve patient care by allowing the examiner to directly compare anterior segment findings from one exam to the next. This research project seeks to determine if an affordable alternative can be developed by designing a mount to couple a compact, readily available, and cost effective camera to a slit lamp ocular. **Methods:** Inexpensive and readily available parts were ordered to construct mounting hardware specific to a slit lamp microscope. This mount was used to attach a GoPro Hero4 Session action camera to a Marco slit lamp microscope and images captured with this system were then subjectively compared to images captured using the Stingray F-146 camera system through the same slit lamp microscope. In addition, the GoPro camera system was mounted to a Haag Streit BM900 slit lamp and images were captured through this microscope and compared to images from the Hitachi HV-D30 compact 3-CCD camera through the same microscope. Sample photos were taken and compared qualitatively to determine if an action camera could make for a cost effective slit lamp imaging system. **Results:** The GoPro slit lamp camera system takes adequate images for gross findings, but falls short of more expensive imaging systems for more subtle images. **Conclusions:** While commercially available slit lamp camera systems are capable of providing higher quality images of subtle anterior segment findings, the low cost of action cameras and readily available mounting hardware make them an excellent option for practitioners looking to increase the quality of their documentation without the investment inherent with current slit lamp camera systems.

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CHAPTER 1

INTRODUCTION

Ocular photography is regularly used in clinical care to document disease progression from one visit to the next, for patient education, and to communicate findings with other health care practitioners¹. These photographs enhance medical record keeping, and provide evidence of previous findings which can influence future treatment options and outcomes. In addition, as telemedicine continues to become more advanced and more widely practiced, ocular photography continues to become more important than ever². Anterior segment imaging has historically been captured using slit-lamp specific camera systems involving a camera mounted in the inner workings of the microscope itself, and utilizing a beam splitter to divert some of the light from one eyepiece to the camera sensor, thus capturing an image. While these systems are reliable and take high quality images, they are also extremely expensive.

As digital camera systems become more compact, and more affordable, it may no longer be necessary to invest in expensive slit-lamp specific anterior segment cameras to achieve high resolution photographs of the ocular surface. Multiple devices have already been designed to couple standard smartphone cameras to slit-lamp eyepieces with some success. As early as the 1970's practitioners were investigating ways to mount pre-existing cameras to slit-lamp microscopes³. Due to the visual nature of their profession, dermatologists have been working to integrate camera systems into clinical practice for many years. One study by dermatology suggests that in order for an image to be useful clinically, it must exceed a resolution of 768x512⁴. This is now easily achievable with today's consumer grade digital cameras.

Action cameras are a new product in the camera market. These cameras are extremely compact, rugged, and affordable and offer high resolution photography and high definition

videography at a nominal price. Their compact nature, high quality imaging, and affordable price point made them a standout selection when the researchers were searching for an alternative to more expensive slit-lamp imaging systems. Among the action camera market, the GoPro Hero4 Session camera was selected due to its price point, size, and the large variety of readily available mounting hardware. In addition to these characteristics, GoPro action cameras come Wi-Fi and Bluetooth enabled, giving the practitioner the ability to instantly and wirelessly transfer images and video from the camera to a desktop on the practices network, eliminating any potential violations of HIPPA seen with camera mounts utilizing practitioners' personal cell phones.

CHAPTER 2

METHODS

A GoPro Hero4 Session was purchased and a mount was constructed using a GoPro bicycle handlebar mount and a series of straight arm extenders readily available for low cost on the internet. This camera was then mounted on a Marco slit-lamp microscope and a short video capture was taken. This video was then examined using editing software (Quik) that was designed for use with GoPro cameras and is available free of charge. Using Quik, still images were selected from the video capture representing a diffuse image of the iris, a parallelepiped image of the cornea, a diffuse image of the conjunctiva, and an image of the lid margin. Similar images of the same eye were taken using the same slit-lamp microscope with the Marco IDoc2 camera system. These pictures were then subjectively compared for image quality. Similar example images were also taken from a Haag Streit BM 900 slit-lamp using the Hitachi HV-D30 compact 3-CCD camera. A second short video capture was taken using the GoPro camera system on this microscope, in order to eliminate any difference in microscope optics from the comparisons. It is not the intention of this study to compare images from the already available camera systems to one another, but to determine if an action camera can be utilized to capture images of a comparable quality to either camera.

CHAPTER 3

RESULTS

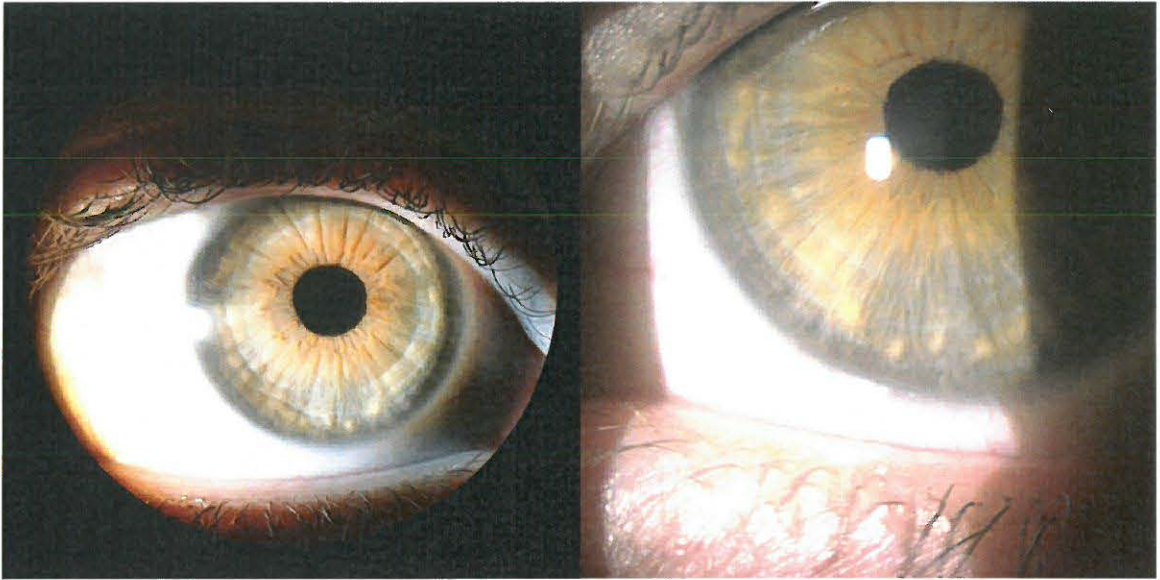


Figure 1: (Left) Diffuse illumination of iris taken using GoPro camera system through Marco slit lamp microscope. (Right) Diffuse illumination of iris taken using Marco IDOC2 camera system through Marco slit lamp microscope.

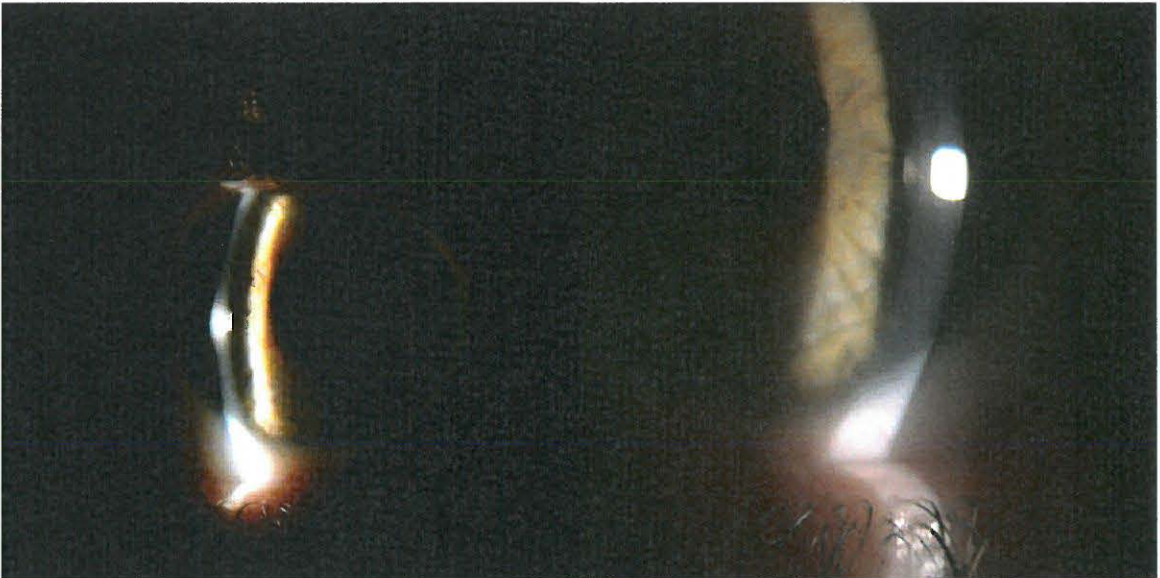


Figure 2: (Left) Parallepiped of cornea taken using GoPro camera system through Marco slit lamp microscope. (Right) Parallepiped of cornea taken using Marco IDOC2 camera system through Marco slit lamp microscope.

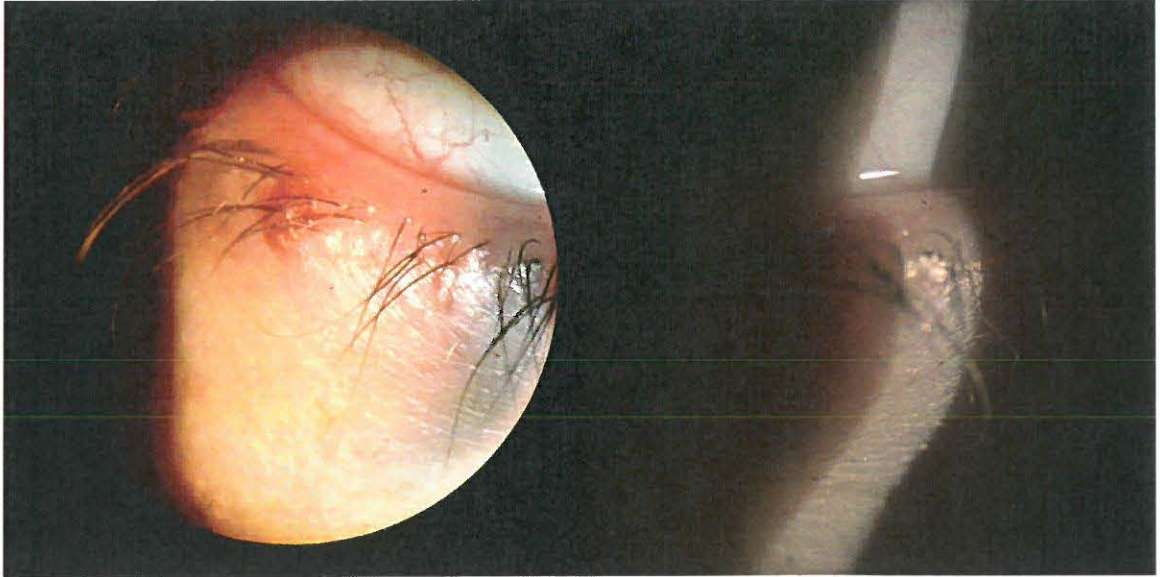


Figure 3: (Left) Diffuse illumination of lid margin taken using GoPro camera system through Marco slit lamp microscope. (Right) Parallelepiped of lid margin taken using Marco IDOC2 camera system through Marco slit lamp microscope.



Figure 4: (Left) Diffuse illumination of conjunctiva taken using GoPro camera system through Marco slit lamp microscope. (Right) Diffuse illumination of conjunctiva taken using Marco IDOC2 camera system through Marco slit lamp microscope.

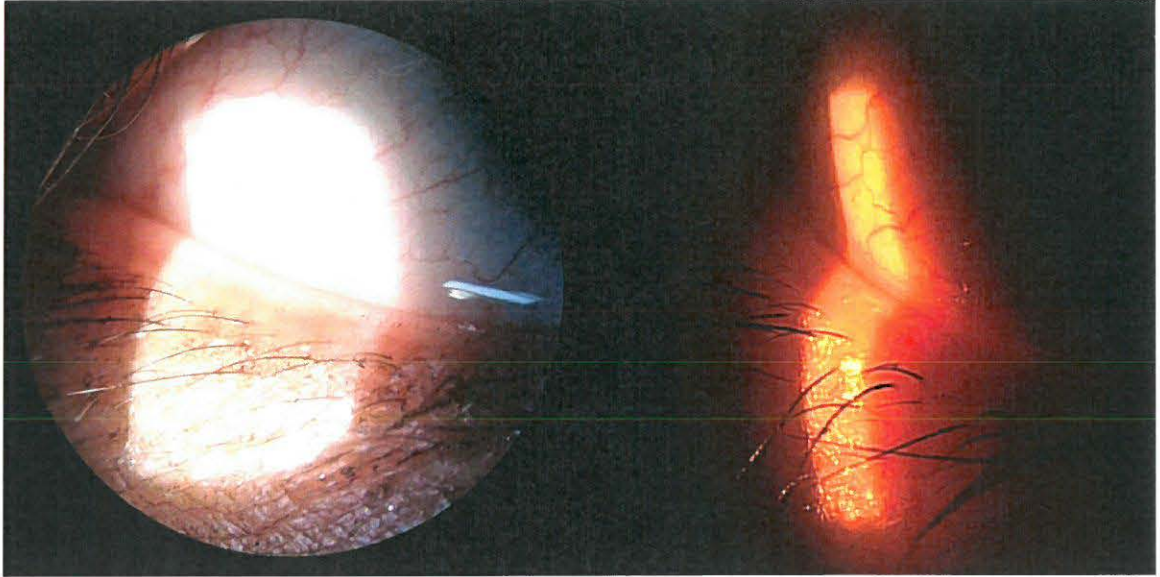


Figure 5: (Left) Diffuse illumination of lid margin taken using GoPro camera system through Marco slit lamp microscope. (Right) Parallelepiped of lid margin taken using Haag Streit camera system through Haag Streit BM 900 slit lamp microscope.

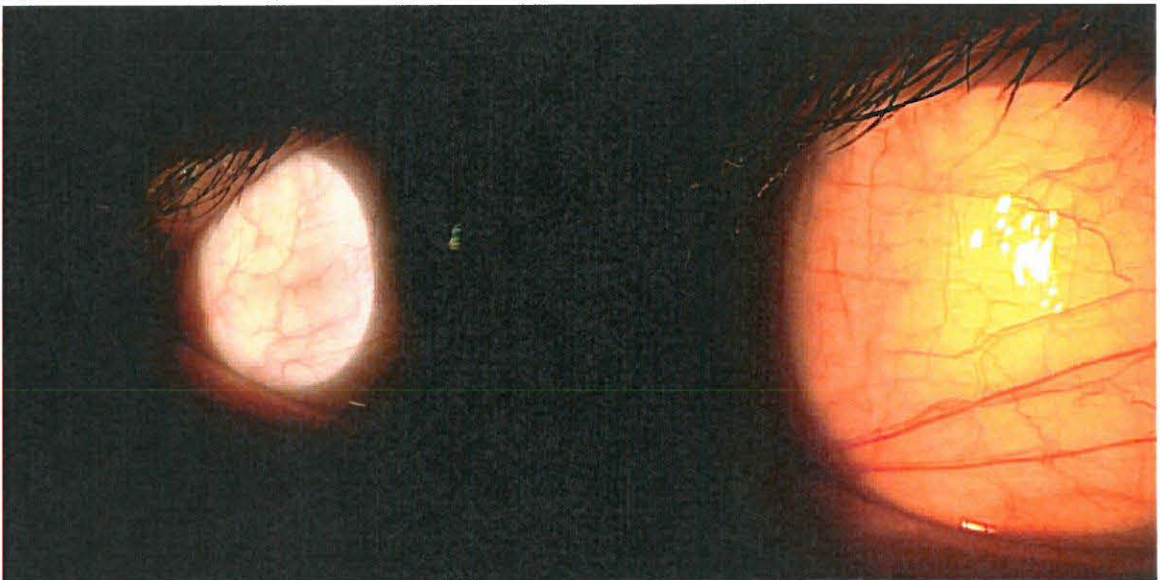


Figure 6: (Left) Diffuse illumination of conjunctiva taken using GoPro camera system through Marco slit lamp microscope. (Right) Diffuse illumination of conjunctiva taken using Haag Streit camera system through Haag Streit BM 900 slit lamp microscope.

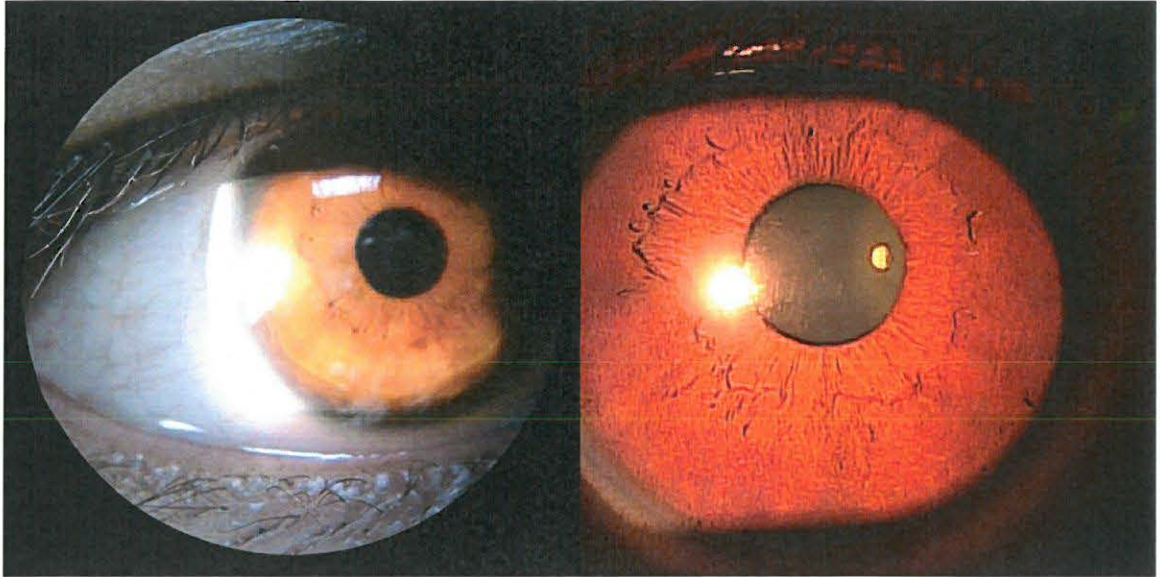


Figure 7: (Left) Diffuse illumination of iris taken using GoPro camera system through Marco slit lamp microscope. (Right) Diffuse illumination of iris taken using Haag Streit camera system through Haag Streit BM 900 slit lamp microscope.

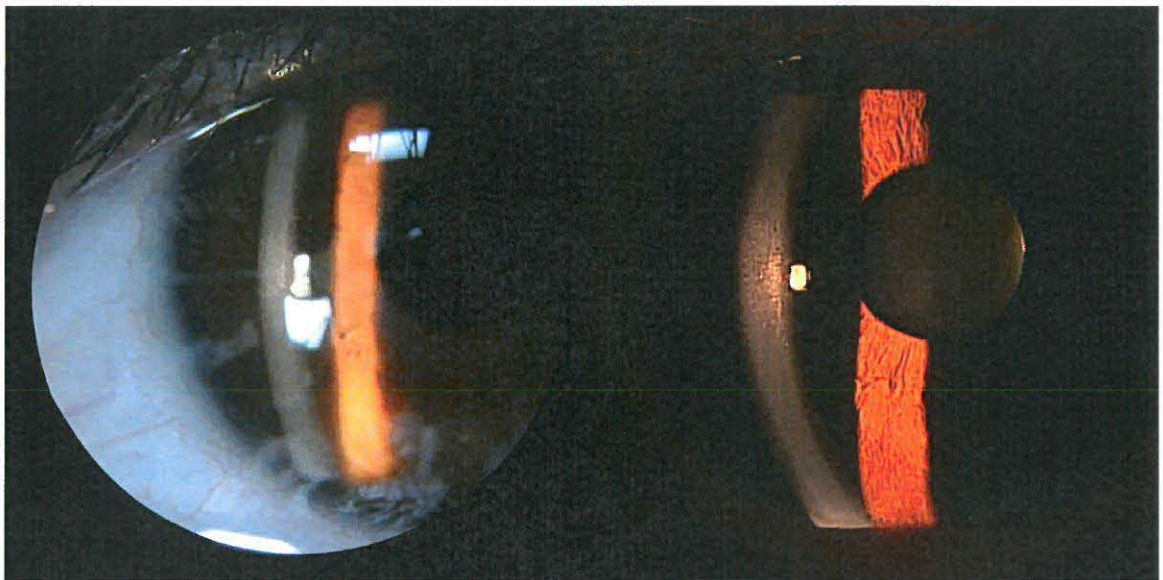


Figure 8: (Left) Parallelpiped of cornea taken using GoPro camera system through Marco slit lamp microscope. (Right) Parallelpiped of cornea taken using Haag Streit camera system through Haag Streit BM 900 slit lamp microscope.

CHAPTER 4

DISCUSSION

When compared with the Marco IDOC-2 camera system, the GoPro camera system struggled to capture detailed image of the cornea as seen in Fig. 2, mostly due to the automatic focusing feature of the GoPro camera. When attempting to image the clear cornea, the GoPro's automatic focusing feature had a tendency to automatically focus on the Iris (as seen in Fig. 1), as the software driving this automatic focusing is unable to find sufficient landmarks on the cornea in which to focus. In addition, the GoPro camera system struggles with its ability to image targets in bright direct illumination when that target is surrounded by relative darkness, such as in Fig. 3 and Fig. 4 when the conjunctiva or lid margin are in direct illumination. Because of this, the GoPro system provided better images when in diffuse or indirect illumination. These issues inherent with the GoPro system are overcome using the Marco camera system, as it does not use an autofocus system, and the Charge Coupled Device (CCD) design of the Stingray F-146 camera allows for greater dynamic range than the Complementary Metal-Oxide-Semiconductors (CMOS) design of the GoPro system. Despite these shortcomings, the GoPro system is capable of shooting 2560x1440 video at 30 frames per second. This is significantly higher resolution and frame rate than the IDOC system which is capable of shooting 1388x1038 video at 15 frames per second. This means that the GoPro system has a 1.8 times higher resolution than the much more expensive IDOC system.

When compared to the Haag Streit imaging system, the GoPro suffers the same shortcomings as in the previous comparison, and in fact one of these shortcomings is magnified when comparing the Haag Streit system to the GoPro system. While the IDOC camera's CCD design made it more capable of collecting images with a large variation in illumination in the same image the Hitachi HV-D30 camera utilizes a 3 CCD design, improving its dynamic range

even more, creating images of substantially greater quality in situations of bright direct illumination, such as Fig. 5 and Fig. 6. This is noticed more acutely in this comparison because the Haag Streit BM900 slit lamp does not have a traditional rheostat to control illumination, but rather a switch allowing for three different illumination levels, all of which appeared to be too intense for the GoPro's limited dynamic range. This meant that it was sometimes necessary to turn on the room lights to balance out the dramatic difference in illumination levels in the same frame. Turning on the room lights naturally increased the amount of glare and reflections from the ocular surface (see Fig. 7 and Fig. 8), and so taking high quality images of brightly illuminated surfaces became very difficult. The resolution advantage of the GoPro system over the Haag Streit system is even greater however, as the GoPro captures 2560x1440 resolution at 30 frames per second, while the Hitachi HV-D30 captures 752x582 resolution at 30 frames per second. This means that the GoPro has a 3.4 times higher resolution than the significantly more expensive Haag Streit system, and this difference is easily noted.

Cost is an important factor in any technology that a physician may wish to integrate into his or her clinical routine. The GoPro camera system has a clear advantage in this regard, as the total cost to implement was \$111.47 including the camera, mounting hardware, and editing software. The Marco IDOC system's total cost to implement was \$11,599.00 including a beam splitter, the camera itself, connecting hardware, and necessary software. The Haag Streit system's total cost to implement was estimated to be \$12,899. When compared with the Medicare reimbursement for external ocular photography (92285) in the "rest of Michigan" (0820299) MAC is \$20.42⁵. This means that in order for the investment into the IDOC camera system to be recuperated, a physician in the "rest of Michigan" must bill Medicare for external ocular photography 569 times. In order for the investment into the Haag Streit camera system to be recuperated, Medicare must be billed 632 times. And for the investment into the GoPro system to be recuperated, a physician must bill Medicare only 6 times. It is important to note that Medicare

defines the CPT 92285 as being bilateral, meaning that reimbursement is for photography of both eyes.

The IDOC camera system and the Haag Streit camera system both utilized camera controls by way of the desktop computer to which they were connected. This made capturing high quality images somewhat difficult due to the need to control focus with the slit-lamp, and other aspects of the image with the desktop. One advantage of the GoPro camera system was that it could be controlled by a smart phone, which could be placed on the slit-lamp table to be controlled while manipulating the slit-lamp controls. This also aided in feedback of images since the smart phone could be more easily observed while lining up the subject. One significant advantage of the slit-lamp specific cameras was that they allowed the practitioner to image the eye stereoscopically while capturing images. This made focusing the slit-lamp much easier than with the GoPro system which limited the practitioner to using only the other available ocular. Another advantage of the GoPro system is that it can be easily changed from one slit lamp to the next, allowing a practitioner to take images from multiple slit lamps in the same practice with a single camera. Due to the design of the other camera systems tested, it would be highly impractical to regularly change the camera from one microscope to the next. One feature of the GoPro system that was of concern is that these cameras use fisheye lenses, which distort the periphery of the image in order to capture a wider shot. Findings that are well centered however, are relatively unaffected by this distortion. Due to the nature of capturing images through the slit lamp ocular, all images are well centered and unaffected by fisheye distortion.

This study has shown that the GoPro Hero4 Session can be a great cost effective alternative to more expensive anterior segment camera systems for practitioners who wish to improve their quality of documentation and better follow anterior segment conditions over time. While this system is no replacement for more sophisticated anterior segment imaging systems when subtle findings need to be documented accurately, it is more than capable of imaging many anterior segment conditions, and due to its low cost, may be better suited financially for many

practitioners. In addition, its compact nature, ability to be quickly changed from one microscope to the next, and the low cost to implement make the GoPro camera system an excellent option for mission trips, where space and cost are of greater concern. This type of camera system is also well suited for geographic locations in which access to eye care professionals may be limited, and in which telecommunication may improve patient outcomes. One study showed that a technician trained to use a slit-lamp on only five eyes can take images using a digital camera mount that accurately document subtle findings⁶. This indicates that a camera system such as the GoPro system described here could also be used by untrained technicians in remote areas for use as a diagnostic aid in telemedicine.

Improvements to this study could be made by including a greater number and range of slit lamp camera systems, especially including one of the increasingly popular smart phone camera mounting devices, by imaging anterior segment pathology rather than unremarkable eyes, by adding an external light source to the GoPro camera system to improve lighting conditions, and by collecting quantitative data from captured images rather than qualitative data. One study involving the use of consumer grade digital camera suggests that when utilizing the correct filter and light source, near-infrared photos can be taken to document iris trans-illumination defects as well as to image Meibomian gland drop-out using a traditional consumer grade digital camera⁷. It is possible that by utilizing the methods outlined in that study an inexpensive and readily available meibomian gland imaging system may be developed from the camera and mounting system designed in this study. An appropriate follow up study would then be to compare this meibomian gland imaging system to commercially available meibomian gland imaging systems.

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