Glauco Dtex Eye Glasses: Early Diagnostic Device for Glaucoma Detection

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Abstract

Glaucoma is the second cause of vision loss and blindness, not only in developing countries deal with it, but developed countries also face it. The main problem of blindness from glaucoma is a lack of recognition, to clarify, the patients do not know whether they have glaucoma or not. As time pass by, it continues to develop from time to time, and most of the patients will realize about it when it has developed into a severe stage. According to the ophthalmology research, if the area ratio between the optic cup to the optic disc is greater than 1/3, patients will be classified as having glaucoma. The aim of this research is to develop the device to capture the image of the optic disc. Then, the image provided by the prototype, with the aid of image processing algorithm based on the area ratio of the optic cup to the optic disc, can be used to classify glaucomatous patients from healthy individual. From the result, the captured image of the optic disc, the location of the optic nerve head is clear. The image of the optic disc apparently shows brighter and dimmer section, which represents the optic cup and optic disc respectively. The image can be used for analysis of opened angle glaucoma via image processing algorithm, which are provided by many researchers [1,19,21,22].

Keywords : Glaucoma, Ophthalmoscope, Diagnosis, Optic cup, Optic disc

I. INTRODUCTION

Glaucoma is a chronic and irreversible neuro-degenerative disease which can be classified by the iridocorneal angle [1], [2]. Simple name of the iridocorneal angle is angle [3]. Open-angle (OAG), closed-angle (AAG), and developmental categories are types of glaucoma, which are further divided into primary and secondary types [2]. In case of primary open-angle glaucoma (POAG), patients may have elevated intraocular pressure or without it [2]. In Asia, a lot of patients who have open-angle glaucoma, the intraocular pressure is almost the same as people who are healthy [4].

In this study focuses on open-angle glaucoma that sometimes called as an insidious onset, which takes slow progression over months to years [5], [6]. It is the commonest form of disease and painless [5], [7]. Because of its painless, so patients do not aware of damage to the eye until it is in the final stage, and visual impairment has occurred [7].

The objective of this research is to develop the prototype to capture the image of the optic cup and optic disc. In addition, the authors believe in the quote, prevention is better than cure, which in the case of glaucoma, there is no way to cure. So, this prototype is aimed to diagnose the people before they get into severe stage and are totally blind. Furthermore, in the case that the doctors need to diagnose the patients who are in rural area, this prototype is also a good choice as it is a portable with very lightweight. After the image is captured by the prototype, with the aid of image processing algorithm based on the area ratio of the optic cup to the optic disc, can be used to classify glaucomatous patients from healthy people. Nevertheless, the image processing algorithm is created based on many theories, which are provided by many researchers.

II. LITERATURE REVIEW

Glaucoma is one of the leading eye disease that brings the blindness to the patient without notice. There are several factors which affect the growth of glaucoma, but the main problem is glaucoma takes time to develop itself gradually. Hence, it is hard to be noticed by the patients whether they have glaucoma or not. Furthermore, the lack of knowledge about glaucoma is also another reason that people don't aware of themselves. In Ebonyi, Nigeria, where is the developing country, a sample group of people, 402 people were asked about glaucoma with 12 Yes/No questions in 2016 [5]. From the result of research, 27 (6.7%) had good knowledge, while 375 (93.3%) had poor knowledge [5]. So, it can be seen that people in developing countries had poor knowledge about glaucoma, which may be the reason to explain an increasing number of people who will have glaucoma. However, an important issue that we can't ignore is risk factors which have several factors that contribute and affect people to be glaucomatous patients [8]. From the Journal of Optometry, age had relative relationship with risk, which means as people have grown older, risk of having glaucoma is also rising [4], [8]-[10]. Next factor is gender, from a Bayesian meta-analysis, it was shown that men tend to have open-angle glaucoma [11]. Third factor is genetic and family history. Family history demonstrated that it carried a relative risk of 2.1 times as being associated with OAG [9]. Although family history plays an important role of glaucoma risks, the closeness of relationship of a patient is another crucial factor, more closeness means higher risk [4], [11]. Final factor, myopia, is also a significant glaucoma risk factor [4], [12] - [17]. Furthermore, in case of glaucomatous patients, glaucoma development and progression rise with the degree of myopia [17].

To identify whether patients have glaucoma or not, they need to have a proper diagnosis which performed

by an ophthalmologist. Normally, five common tests are used to diagnose glaucoma, Tonometry, measure an intraocular pressure, Perimetry, measure how wide you can see, Gonioscopy, measure an iridocorneal angle, Pachymetry, measure the corneal thickness which affects to an intraocular pressure, and Ophthalmoscopy, see the shape and color of the optic nerve. In this paper decided to use ophthalmoscopy, to visualize the posterior segment of the eye, by focusing on optic nerve [18].

In ophthalmoscopy, optic disc and optic cup are crucially important to an analysis. From ophthalmology research, it classifies the patient to be glacomatous patient if the patient has the area ratio between an optic cup to an optic disc more than 1/3 [1], [19]. Furthermore, radius ratio between an optic cup to an optic disc can also be an indicator as same as the area ratio with 1/3. From the Fig. 1, it can be observed that an optic cup is smaller and brighter than an optic disc. In addition, some ophthalmologists call the optic disc as optic nerve head (ONH).

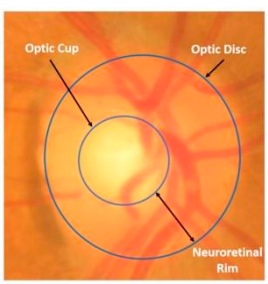

Fig. 1. Image of Optic Cup and Optic Disc [20]

III.RESEARCH METHODOLOGY

We have developed many prototypes based on various theories. In this paper, two main prototypes are presented chronologically. Based on the direct ophthalmoscope, in the first prototype, the body of the device is made from the PVC trapezoidal wire duct, 18 mm x 1 m. For the lighting, the 0.022 Watts LED light bulb is the light source, and the power supply is a 3-button cell. Two holes are drilled for inserting the endoscope and the LED light bulb respectively. The top view of the device is illustrated in Fig. 2.

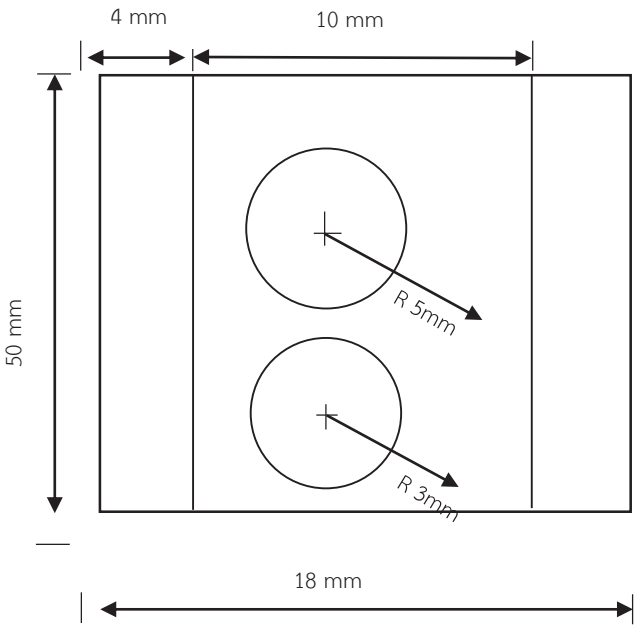

Fig. 2. Top view of the first prototype

As can be seen from Fig. 2, there are bigger hole on the top, while the smaller hole is below. The radius of two holes are drilled respect to the cross-sectional area of the endoscope, and the LED light bulb. The outer diameter of endoscope and the LED light bulb are 8 mm and 5 mm respectively. Therefore, the holes are set to be drilled as 10 mm and 6 mm in in term of diameter.

For final prototype, we also use the direct ophthalmoscope as the model for our prototype. However, we decide to cut some parts of the direct ophthalmoscope and modify from the first prototype to be more user-friendly. We also change the light bulb from LED to be the incandescent light bulb which is used in the direct ophthalmoscope. The main reason that we decide to change the light bulb is the intensity and the brightness of the light which LED light may be harmful to the eyes. The body of the final prototype is also modified which is provided as below.

The final prototype is divided into 4 parts which are equipment, specification of main equipment, design of the prototype, and how to operate the device.

A. Equipment

The prototype consists of 9 apparatuses as following.

1. 2.5V Halogen Lamp
2. Stamp Paper Clip
3. Wi-Fi Endoscope
4. 3/8 Inch Grey Agricultural PVC Pipe, 6 cm in length
5. x10 Folding Hand Loupe Lens
6. 2 pieces of 1.5V AA Batteries
7. 3V AA Batteries Holder with Lead
8. 1 set of dual crocodile clip wire
9. The eye glasses frame

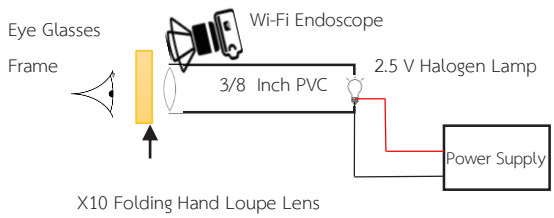

Fig. 3. Schematic Diagram of Glauco Dtex Eye Glasses

B. Specification of lamp and wi-fi endoscope

1. Halogen lamp is for Mark Ⅱ Classic ophthalmoscope Medical Devices (Pvt). Ltd
2. Wi-Fi Endoscope
   - 2.1 Cable Length: 1 m
   - 2.2 Camera Head Outer Diameter: 8 mm
   - 2.3 Lens: 2 Megapixels CMOS camera
   - 2.4 Resolution: HD 720p
   - 2.5 Frame Rate: 30FPS
   - 2.6 Viewing Angle: 70°
   - 2.7 Effective Focal Distance: 4-6 cm
   - 2.8 Battery Capacity: 800mAh
   - 2.9 System Requirement: IOS/Android

C. Design of the prototype

Based on the direct ophthalmoscope, the illumination and viewing optical system. By cutting off lens 1 and aperture view, use 3/8 inch grey agricultural PVC pipe to be the canal for the light. At the initial point of the pipe is the position of the lamp, while at the exit side of the pipe is where the lens is located. To get the fundus image, the slope is needed because if the endoscope is parallel to the pipe, the photo cannot be seen at the light show on the object. The slope is a stamp paper clip. 2 pieces of 1.5V AA batteries are the power supply for the lamp.

D. How to use the device

The procedure of using this device can be divided into 2 parts, which are endoscope part and lamp part.

1. Endoscope part

a. Connection between receiver and sender is connected via Wi- Fi. By pressing the button as shown in Fig. 4.
b. The Wi- Fi box requires charging with USB cable at the port as indicated in Fig. 4.
c. Connection between the endoscope and Wi- Fi box at the port which is shown in Fig. 4.
d. Android and IOS system, application "HD Scope" is required, which can be downloaded in Play Store and App Store respectively.
e. All record will be in video for ease of use.
f. After record the video, this recorded video is needed to save in mobile phone or computer.

g. Choose the best part of the video and take a screenshot.

h. Enlarge the screenshot to get bigger photo or can crop in computer.

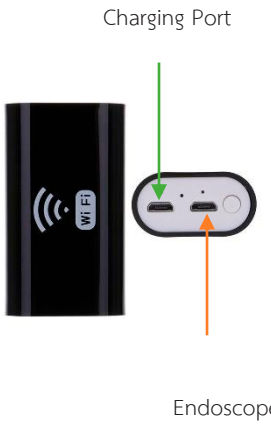

Fig. 4. Wi-Fi Box of The Endoscope

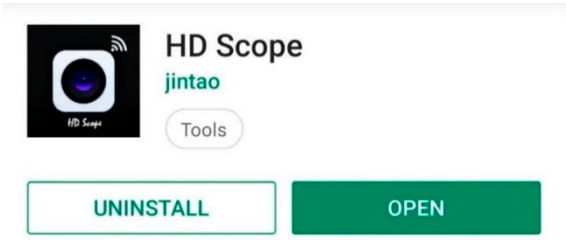

Fig. 5. HD Scope Application

2. Halogen Lamp part

Connection between the power supply and the lamp is connected via red and black dual crocodile clip wire.

E. Flow diagram to classify glaucomatous patients

As shown in Fig. 6, captured optic nerve head image from the prototype is the input, which is transferred to the image processing algorithm. After image processing finished, glaucomatous patients and normal can be classified.

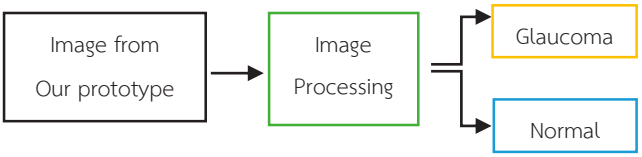

Fig. 6. Flow Diagram of Classification of Patients

IV. RESULTS AND DISCUSSION

The images provided by two prototypes are presented and compared as shown in Fig. 7 and Fig. 8, respectively. In Fig. 7, and Fig. 8, the optic nerve head is cropped using window photo program. By observation, the brightest area is located in the center of the image, while the dimmer part is at the edge of the image. The results agree with the studies observed by other research [1], [19].

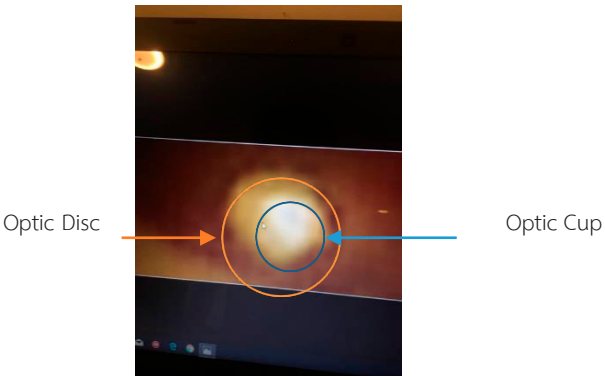

Fig. 7. Image of the Optic Nerve Head from the first prototype

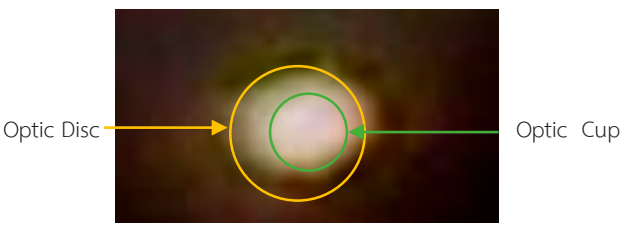

Fig. 8. Image of the Optic Nerve Head from the final prototype

It can be observed that the results from both prototypes are similar, but the color of the images is quite different. From Fig. 7, the color of the image is

brighter, since the LED light bulb provides the higher level of brightness and intensity compared to the incandescent lamp. As the result, we can see the clearer optic cup and optic disc. However, the distance between the eye and the device also has to be taken into account. From several experiments, if the distance of the device is closer to the eye, then the image is going to be brighter and has clearer details. The temperature of the light bulb also affects the color of the image. The image of the first prototype (Fig. 7) presents the warmer tone than the final one (Fig. 8). Furthermore, as the final prototype uses the PVC pipe to be the body of the device, light from the light bulb travels inside the pipe, which also loses energy during travelling, resulting in the less brightness and intensity, although the light pass the hand loupe lens, but it cannot compensate the loss.

From the flow diagram in Fig. 6, various techniques in image processing have been developed by many researchers. Objective of these techniques is to classify normal people from glaucomatous patients using fundus image [1], [19], [21], [22]. The principle of image processing technique is image segmentation. Based on the flow diagram in Fig. 6, an input image is the image that is captured by our prototype. Next step is pre-processing, which some researchers enhance and filter the image [21]. After pre-processing, optic disc will be extracted from the image, which some algorithm may also extract special feature, for example, texture and intensity [22]. Using glaucoma data set, the algorithm can make a decision, which in some research, it can state the stage of glaucoma as well, then lead the result and classification between patients and healthy people [1], [19], [21], [22].

However, the image in Fig. 8, may need further improvement for better resolution. The higher resolution of the image means the higher accuracy of the classification result.

V. CONCLUSION

Glaucoma has effected all around the world, developed countries, developing countries, and under developed countries. Five common tests are used to diagnose glaucoma. In this study, we observe the main problem of glaucoma, people have inadequate knowledge about glaucoma [4], which leads to irreversible blindness. The objective of this study is to solve this problem by creating the prototype which normal people can use it, and classify whether they have glaucoma or not. We decide to use direct ophthalmoscope as the based device. By cutting off some parts, and replace the handle of a direct ophthalmoscope by a grey agricultural PVC pipe. At the exit of a pipe is a position where folding hand loupe lens with X10 magnification. The optic nerve head image from our prototype is illustrated in Fig. 6, which show the brighter section and dimmer section that are optic disc and optic cup respectively. By input our ONH image into an image processing algorithm, classification between healthy people and glaucomatous patients can be achieved.

However, this prototype is needed further improvement since the resolution and quality of the image should be higher. From the direct ophthalmoscope, we may put the concave lens before the halogen lamp to let the light scatter inside the pipe, which may increase the quality of the image. In addition, we believe that accuracy and precision of the classification result are higher with higher quality image and resolution.

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REFERENCES

[1] Chalinee Burana-Anusorn, Waree Kongprawechnon, Toshiaki Kondo, Sunisa Sintuwong, and Konokvate Tungpimolrut "Image Processing Techniques for Glaucoma Detection Using Cup-to-Disc Ratio," *Thammasat International Journal of Science and Technology,* Vol. 18, No.1, pp. 22-34, Jan-Mar, 2013.

[2] Young H. Kwon, John H. Fingert, Markus H. Kuehn, and Wallace L.M. Alward.. "Mechanisms of Disease: Primary Open-Angle Glaucoma," *The New England Journal of Medicine*, Vol. 360, No. 11, pp. 1113-1124, Mar 2009.

[3] Wallace L. M. Alward, Reid A. Longmuir, "Anatomy of Angle," in Color Atlas of Gonioscopy, 2nd ed. San Francisco: American Academy of Ophthalmology, 2008, pp. 1-6.

[4] Suzuki Y, Iwase A, Araie M, et al. "Risk factor for open-angle glaucoma in a Japanese population: the Tajimi Study," Ophthalmology, Vol. 113, No. 9, pp. 1613-17, Sep 2006.

[5] C.E. Ogbonnaya, L.U. Ogbonnaya, O. Okoye, N. Kizor-Akaraiwe, "Glaucoma Awareness and Knowledge, and Attitude to Screening in a Rural Community in Ebonyi State, Nigeria," *Open Journal of Ophthalmology,* Vol. 6, No.2, pp. 119-127, Jan 2016.

[6] Heijl A, Bengtsson B, Hyman L, Leske MC, Early Manifes Glaucoma Trial Group, "Natural history of open-glaucoma," *Ophthalmology*, Vol. 116, No. 12, pp. 2271-2276, Dec 2009.

[7] O. HOFFMAN, "Glaucoma control," Canadian Journal of Public Helath, Vol. 52, No. 1, pp. 23-28, Jan 1691.

[8] Le A, Mukesh BN, McCarty CA, Taylor HR. "Risk factors associated with the incidence of open-angle glaucoma: the visual impairmentproject," *Investigative Ophthamology & Visual Science*, Vol. 44, No. 9, pp. 3783-3789, Sep 2003.

[9] Miglior S, Pfeiffer N, Torri V, Zeyen T, Cunha-Vaz J, Adamsonsl the European Glaucoma Prevention Study (EGPS) Group, "Predictive factors for open-glaucoma among patients with ocular hypertension in the European Glaucoma Prevention Study," Opthalmology, Vol. 114, No, 1 pp. 3-9, Jan 2007.

[10] Rudnicka AR, Mt-Isa S, Owen CG, Cook DG, Ashby D, "Variations in primary open-angle glaucoma prevalence by age, gender, and race: a Bayesian meta-analysis," *Investigative Ophthamology & Visual Science*, Vol. 47, No. 10 pp. 4254-4261, Oct 2006.

[11] Congdon N, Wang F, Tielsch JM, "Issue in the epidemiology and population-based screening of primary angle-closure glaucoma," *Survey of Opthalmology*, Vol.36, No. 6, pp. 411-423, May-Jun 1992.

[12] Cho H-K, Kee C, "Population-based glaucoma prevalence studies in Asians," *Survey of Ophthalmology*, Vol. 59, No. 4, pp. 434-447, Jul-Aug 2014.

[13] Lander J, Goldberg I, Graham SL, "Analysis of risk factors which may be associated with progression from ocular hypertension to primary open-angle glaucoma," *Clinical & Experimental Ophthalmology*, Vol. 30, No. 4, pp. 242-247, Aug 2002.

[14] Kim MJ, Kim JM, Kim HS, Jeoung JW, and Park KH, "Risk factors for open-angle glaucoma with normal baseline intraocular pressure in young population: the Korea National Health and Nutrition Examination Survey," *Clinical & Experimental Ophthalmology*, Vol. 42, No. 9 , pp. 825-832, Dec 2014.

[15] Yamamoto S, Sawaguchi S, Iwase A, et al, "Primary open-angle glaucoma in a population associated with high prevalence of a primary open-angle glaucoma," *Ophthalmology*, Vol. 121, No. 8, pp. 1558-1565, Aug 2014.

[16] Vijaya L, Rashima A, Panday M, et al, "Predictors for incidence of primary open-angle glaucoma in a south Indian population", Ophthalmology, Vol. 121, No. 7, pp. 1370-1376, Jul 2014.

[17] Marcus MW, de Vries MM, Montolio J, Jansonius NM, "Myopia as a risk factor for open-angle glaucoma: a systematic review and meta-analysis," *Ophthalmology*, Vol. 118, No. 10, pp. 1994-1998, Oct 2011.

[18] Nancy C. Sharts-Hopko and Catherine Glynn-Milley, "Primary Open-Angle Glaucoma: Catching and Treating the 'Sneak Thief of Sight'," *The American Journal of Nursing,* Vol. 109, No.2, pp. 40-48, 2009.

[19] M. Roslin, S. Sumathi, " Glaucoma Screening by the Detection of Blood Vessels and Optic Cup to Disc Ratio," in *International Conference on Communication and Signal Processing,* Melmaruvathue, India, April 6-8, 2016, pp. 2210-2214.

[20] Baidaa Al-Bander, Bryan M. Williams, Waleed Al-Nuaimy, Majid A. Al-Taee, Harry Pratt, and Yalin Zheng, "Dense Fully Convolutional Segmentation of the Optic Disc and Cup in Colour Fundus For Glaucoma Diagnosis," in *Symmetry,* Vol. 10, No. 4, April, pp. 1-16, 2018.

[21] Dnyaneshwari D.Patil, and Ramesh R. Manza , "Design New Algorithm for Early Detection of Primary Open Angle Glaucoma using Retinal Optic Cup to Disc Ratio" , in *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT),* Chennai, India, Mar 3-5, 2016, pp. 148-151.

[22] Anum Abdul Salam, M. Usman Akram, Kamran Wazir, Syed Muhammad Anwar, and Muhammad Majid, " Autonomous Glaucoma Detection From Fundus Image Using Cup to Disc Ratio and Hybrid Features," in *IEEE International Symposium on Signal Processing and Information Technology (ISSPIT),* Abu Dhabi, United Arab Emirates, Dec 7-10, 2015, pp. 370-374.