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Cup - Disc Ratio: Agreement between Fundus Biomicroscopic Estimation and Fundus Camera Measurement

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ABSTRACT

Purpose: To compare the accuracy of estimation of cup disc ratio obtained with fundus biomicroscopy with that obtained with fundus camera through undilated pupil.

Methods: 100 patients with disc suspect and /or any asymmetry of disc between two eyes were enrolled for the study at Ruby Hall Clinic, Pune. After signing a written consent form each subject underwent a full ophthalmic examinationwhich included detailed medical and ocular history, visual acuity testing, refraction, slit lamp biomicroscopy, tonometry, perimetry, fundus biomicroscopy using +78D and optic disc photography.Cup disc ratio estimated by fundus biomicroscopy using +78D lenswas then compared with the cup disc ratio obtained by fundus camera measurement to find the accuracy and co relation between the cup disc ratio estimation by using fundus biomicroscopy and fundus camera.

Results: Of the 100 patients recruited 30 were female, with an average age of 35.2 years (range 18 to 65 years). The mean value of cup disc ratio measured with the fundus biomicroscopy for right eye and left eye was 0.58(SD 0.11) and 0.58 (SD 0.1) respectively.The mean value of cup disc ratio measured with the fundus camera for right eye and left eye was 0.63 (SD 0.08) and was 0.64 (SD 0.08) respectively. When the value of CDR estimated with fundus biomicroscopy was compared with that obtained with fundus camera the Pearson correlation was 0.84 for right eye and 0.82 for left eye. The mean value for CDR estimated by fundus biomicroscopy was lesser than that obtained using the fundus camera.

Conclusion: This study has shown that there is a statistically but non clinically significant difference between fundus biomicroscopic estimation and fundus camera measurement.Fundus photograph provides a better documentation of optic nerve head, especially at lower and higher values of CDR.

Keywords: Glaucoma, Optic nerve head, optic disc, cup-disc ratio, fundus biomicroscopy, optic disc photograph, fundus camera.

INTRODUCTION

Glaucoma is now estimated to be the second most prevalent cause of blindness worldwide after cataract, [1,2]causing an irreversible blindness. In a recent publication, about 60 million persons are estimated to be affected by glaucoma.[1,2]Of these, an estimated 11.2 million cases are from the Indian subcontinent, the majority of whom are undiagnosed.[3] The current status of glaucoma care in the world can be summarized as follow: More than half of the glaucoma patients are undiagnosed,[4,5] more than 50% of those undiagnosed would have seen an eye care practitioner in the recent past, more than 50% of the patients treated for glaucoma do not have the disease (over treated),[6] and finally noncompliance with the advised medication varies from 5% to 80%.[7]

Erroneous diagnosis and unnecessary treatment of glaucoma are attributable to the lack of comprehensive evaluation, appropriate clinical skills and proper documentation.[8]

Previous studies have shown that detectable visual field changes in glaucoma become evident after a significant neuronal loss occurs.[9-11] These data suggest that early detection of glaucoma may be only achieved with technology that provides qualitative or quantitative measurements of the axons (nerve fibers) or the bodies of the retinal ganglion cells (RGCs), the main target in glaucomatous optic neuropathy. Quantitative changes in the thickness of the peripapillary retinal nerve fiber layer (RNFL), the morphology of the optic nerve head (ONH), or both can be measured with several instruments. Optic nerve head evaluation is important for the early detection, monitoring, and management of patients suffering from glaucoma and those who are glaucoma suspect.[12] Changes in the structural appearance of the optic disc usually occur before visual field loss[13.] Hence, cautious documentation of optic nerve parameters is essential.

Clinical estimation of the size of the cup remains the simplest and most frequently performed assessment of the optic disc in the diagnosis and follow up of the glaucoma and glaucoma suspect. The cup size is simply the area of the optic nerve that is not occupied by the optic nerve fibers (an empty space). However, with glaucoma, there is progressive loss of optic nerve fibers, and consequent increase in the cup size of the optic nerve. The estimation of the size of the cup is usually made by comparison with the size of the disc, and given as the ratio of the diameter of the cup to the diameter of the disc (cup/disc ratio or CDR) [14-17]. The optic nerve is divided into tenths and the cup is compared to the entire optic nerve (optic disc) to obtain the **cup-to-disc ratio.**

The cup-to-disc ratio in majority (90%) of subjects is typically around 0.2 to 0.4.However, with glaucoma, there is progressive loss of optic nerve fibers, and consequent increase in the cup size of the optic nerve. Precise and reproducible measurements of the optic disc are also critically important for evaluating the progression of the disease. There are several different methods for determining optic disc parameters, including ophthalmoscopy, funduscopy, disc photography, and semi automated methods.[13]Newer binocular ophthalmoscopic examination techniques utilize handheld, high-powered (for example, 78 or 90 D) condensing lenses. The fundus is viewed by placing such a lens between the patient's eye and a slit lamp. The combined ocular, condensing lens and slit lamp optics produce an image that is real and inverted. It is much less susceptible to the effects of ocular media opacity or refractive error than is direct ophthalmoscopy. A stereoscopic view of the fundus can easily be obtained with mydriasis and even without mydriasis in some circumstances. A monoscopic view is possible through smaller pupils. This technique is known as slit lamp binocular indirect ophthalmoscopy or fundus biomicroscopy, and it is the preferred method for clinical ONH examination.[18]

Digital fundus photography is an indispensable component of modern ophthalmological practice worldwide. The capability to document and monitor the appearance of the retina and optic nerve head (ONH) allows the detection and recording of retinal features associated with diseases causing visual loss. The digital fundus camera is increasingly used for all of the applications previously undertaken using conventional 35 mm fundus photography. The decisive advantage is instant image, ensuring a good-quality image at the initial visit. Patient education is also enhanced, as patients can view the image during the consultation. The image is captured using the higher magnification afforded by the 20º field, and allows documentation and follow-up of glaucoma patients and suspects. The images are much more useful than drawings. Documentation and monitoring of qualitative glaucomatous ONH changes, e.g. presence and progression of neuroretinal rim notching, hemorrhages and estimation of the cup-to-disc ratio can be made with, and this approach is clearly superior to simple sketching of the ONH features in the patient's notes. However, the lack of stereopsis excludes any quantitative analysis of changes in depth[19].

Because of the importance of an accurate CDR estimation in the management of the glaucomas, we compared CDR estimation using fundus biomicroscopy with that obtained with the fundus camera.Previous studies have compared different methods, e.g., funduscopy, semi automated methods, or stereoscopic optic nerve photographs (SONP) but a study of this type—a comparison of fundus biomicroscopy, and fundus camera in the same subjects has not, to our knowledge, been carried out before so we decided to do this study.

MATERIALS AND METHODS

A total of 100 patients were recruited from the department of ophthalmology at Ruby Hall Clinic, Pune.The ethical committee of BharatiVidyapeeth Deemed University Medical College School of Optometry has approved the study protocol.The patient to be included for the study was chosen randomly.All patients provided written informed consent form.

Inclusion criteria:

- Age 18 years and above
- Patients with optic disc suspect
- Asymmetry of disc between two eyes

Exclusion criteria:

- Media opacity
- Signs of posterior and/or optic nerve pathology other than those attributed to glaucoma.

All participants underwent a complete ophthalmic examination that included a detailed medical and ocular history, Snellen's visual acuity test, refraction, intraocular pressure (IOP) measurement using Goldmannapplanation tonometer, automated visual field testing, slit lamp biomicroscopy through undilated pupils, and optic disc photography using fundus camera.

This study was conducted in masked fashion. To conduct a non bias study two different examiners clinically assessed the optic nerve head using fundus biomicroscopy and fundus camera to estimate the cup disc ratio.

An experienced clinician has performed the fundus biomicroscopic examination of the optic nerve head (ONH) using Topcon SL 7 F slit lamp with 10 x magnification inconjunction with a Volk 78 D fundus lens (Volk Optical Inc, Mentor, USA).Examinations were carried out without a mydriatic, in dark room.

Protocol for performing fundus biomicroscopy:
Patient was directed to look straight ahead. With a narrowed slit beam, the biomicroscope was focused on the patient's cornea. The condensing lens was placed at a working distance of 8 mm. using the joystick; the biomicroscope was moved back and froth to bring the optic disc image in focus. The extent of cupping was judged on contour and small blood vessel deflection, not on pallor. The CDR obtained with the fundus biomicroscopy was represented with the help of disc drawing and was used for statistical analysis.

A two-dimensional color fundus photograph was then taken, without a mydriatic, using the Kowa VX 10 α fundus camera.It is intended for taking pictures of fundus image with or without mydriatic with two angles of view: 45^{o} and 27^{o}.The cup and disc margins of the optic disc were drawn with a computer mouse using the "area method". [25] The mouse was moved around the cup area and 12 points were clickedto define the edge. Then the mouse was moved around the disc area and again 12 points were clicked to define the edge. The extent of cupping was judged on contour and small blood vessel deflection, not on pallor. The cup margin was drawn from the kinking of blood vessels and not from the area of pallor.[18,26] The CDR was calculated by the specialized software and the ratio was displayed automatically. This cup disc ratio was used for statistical analysis.

The value of the cup disc ratio obtained by fundus biomicroscopy was then compared with that obtained with fundus camera to find the accuracy and co relation between the cup disc ratio estimation by using fundus biomicroscopy and fundus camera.

Results of the measurements and calculations were expressed as mean and SD. The Paired t-test on the observations was used to evaluate the differences in the CDR measurements between fundus biomicroscopy and the fundus camera and to evaluate differences between the right and left eyes. The correlation of the two methods parameters was evaluated in terms of Pearson correlation coefficient. P values of less than 0.05 were considered statistically significant.

RESULTS

From 100 patients in the study 30 were female and 70 were male. The patient's average age was 35.2 years (range 18 to 65 years). These values are shown in Table 1.

Table 1: Patients demographic characteristics

No. of patients	100
Female	30
Male	70
Mean Age (years)	35.2

The mean value of cup disc ratio measured with the fundus biomicroscopy for right eye was 0.58 with standard deviation of 0.11. The minimum CDR observed for right eye was 0.2:1 and the maximum value is 0.9:1. These values are shown in Table 2.

Table 2: Fundus Biomicroscopy measurement of Right Eye:

Mean	0.58
Median	0.6
Standard Deviation	0.11
Range	0.7
Minimum	0.2
Maximum	0.9
N	100

The mean value of cup disc ratio measured with the fundus biomicroscopy for left eye was 0.58 with standard deviation of 0.1. The minimum CDR observed for left eye was 0.2:1 and the maximum value is 0.8:1. These values are shown in Table 3.

Table 3: Fundus Biomicroscopy measurement of Left Eye:

Mean	0.58
Median	0.6
Standard Deviation	0.1
Range	0.6
Minimum	0.2
Maximum	0.8
N	100

The mean value of cup disc ratio measured with the fundus camera for right eye was 0.63 with standard deviation of 0.08. The minimum CDR observed for right eye was 0.41 and the maximum value is 0.86.These values are shown in Table 4.

Table 4: Fundus camera Measurement of Right Eye:

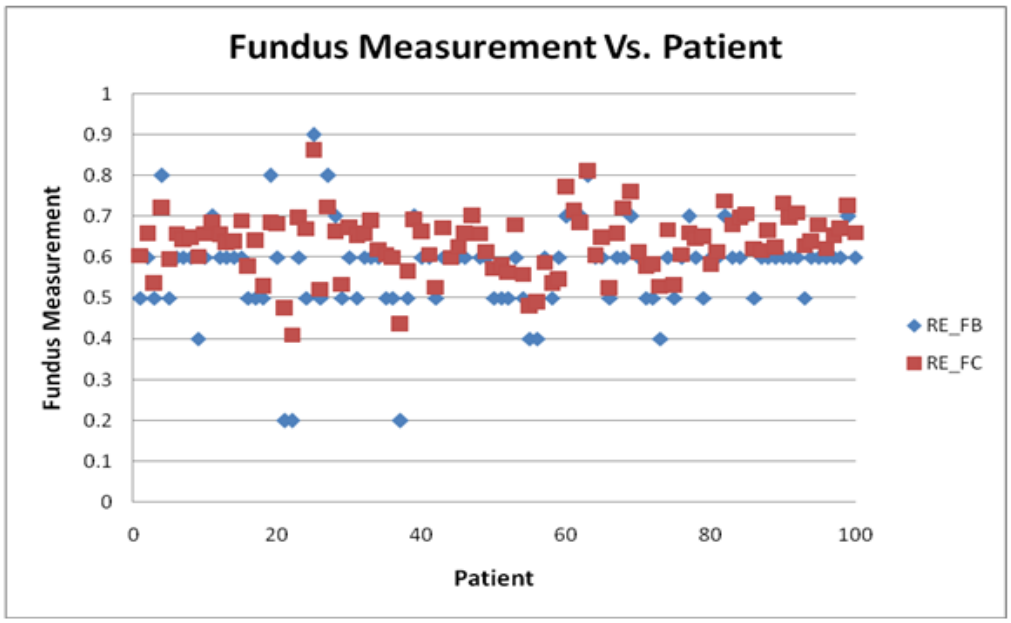
Mean	0.63
Median	0.65
Standard Deviation	0.08
Range	0.45
Minimum	0.41
Maximum	0.86
N	100

The mean value of cup disc ratio measured with the fundus camera for left eye was 0.64 with standard deviation of 0.08. The minimum CDR observed for left eye was 0.33 and the maximum value is 0.78. These values are shown in Table 5.

Table5: Fundus camera Measurement of Left Eye:

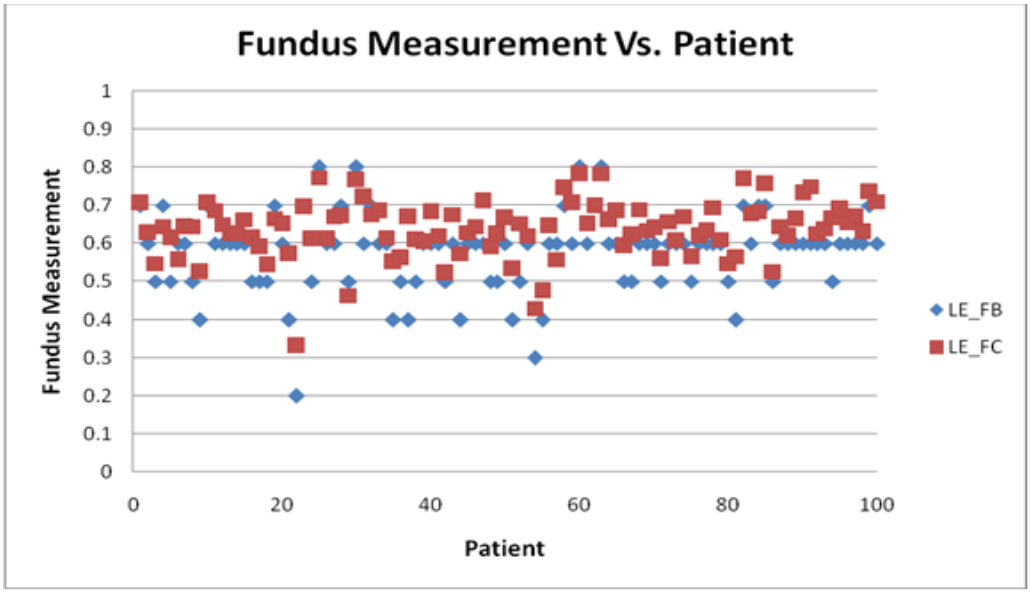
Mean	0.64
Median	0.64
Standard Deviation	0.08
Range	0.45
Minimum	0.33
Maximum	0.78
N	100

Figure 5 and 6 represents the respective graphs of right eye and left eye for fundus biomicroscopic and fundus camera values for estimation of CDR.



RE_FB= Right eye Fundus biomicroscopy, RE_FC=Right eye fundus camera

Figure 5: Graph of Fundus measurement Vs. Patient for Right Eye



LE_FB= left eye Fundus biomicroscopy, LE_FC=left eye fundus camera

Figure 6: Graph of Fundus measurement Vs. Patient for Left Eye

When the value of CDR estimated with fundus biomicroscopy was compared with that obtained with fundus camera the Pearson correlation was 0.84 for right eye and Mean CDR measured with fundus biomicroscopy was smaller than mean measured with fundus camera (Table 6).

Table 6: Comparison for Fundus biomicroscopic Estimation for Right Eye and Fundus camera Measurement for Right Eye:

	RE_FB	RE_FC
Mean	0.58	0.63
Observations	100	100
Pearson Correlation	0.84	
P(T<=t) two-tail	0.0000	

Interpretation: From above table P-value (=0.0000) is less than level of significance (=0.05), so there is strong evidence to reject the null hypothesis. Hence we conclude thatthere is significant difference between Fundus biomicroscopic Estimation for Right Eye and Fundus camera Measurement for Right Eye.

When the value of CDR estimated with fundus biomicroscopy was compared with that obtained with fundus camera the Pearson correlation was 0.82 for left eye and the Mean CDR measured with fundus biomicroscopy was smaller than mean measured with fundus camera (Table 7).

Table 7: Comparison for Fundus biomicroscopic Estimation for Left Eye and Fundus camera Measurement for Left Eye:

	LE_FB	LE_FC
Mean	0.58	0.64
Observations	100	100
Pearson Correlation	0.82	
P(T<=t) two-tail	0.0000	

Interpretation: From above table P-value (=0.0000) is less than level of significance (=0.05), so there is strong evidence to reject the null hypothesis. Hence we conclude that there is significant difference between Fundus biomicroscopic Estimation for Left Eye and Fundus camera Measurement for Left Eye.

In this study when comparing the difference for the CDR between the fundus biomicroscopic estimation and fundus camera measurement we found that for the CDR between0.2 to 0.6 fundus biomicroscopy underestimates the CDR compared with fundus camera. But when the CDR value is greater than 0.6 the fundus biomicroscopy overestimates the CDR as compared with fundus biomicroscopy (figure 5 and 6). As our result has shown*p – value*was less than level of significance so we have concluded that there was significant difference between fundus biomicroscopic estimation and fundus camera measurement (table 6 and 7).

DISCUSSION

In the present study, we found that measurements of optic disc parameters generally differed significantly according to the method of measurement used. Precise evaluation of structural damage to the optic disc is crucial in the early recognition and longitudinal assessment of glaucomatous optic neuropathy.[27] In different clinics, several different methods for evaluating optic disc parameters are currently in use.[13] Measurements of these parameters, in terms of their reproducibility and agreement across the different methods used in making them, are important in the follow-up of patients with glaucoma and those who are glaucoma suspect.

Previous studies have reported significant differences between measurements of optic disc parameters according to the semi automated or traditional methods used. These studies demonstrated that measurements of disc parameters as

determined by different methods are not interchangeable.[28-30] Moreover, three recent studies have indicated that optic disc parameters measured with ophthalmoscopy are smaller than those obtained with other methods. [29-30]

Previous studies have compared other methods of quantitative measurements with qualitative measures. Watkins et al [18] reported that direct ophthalmoscopy and fundus biomicroscopy were biased toward underestimation when compared with Heidelberg Retina Tomography (HRT), although the differences with biomicroscopy were smaller. Our results are consistent with these; we found that measurements of CDR obtained via slit-lamp biomicroscopy and optic disc photograph differed significantly.

This study reflects common, rather than ideal, practice. For instance, it is now recognized that optic disc photographs are preferred for the monitoring of glaucoma patients and glaucoma suspects so that progression can be detected. Furthermore, ONH examination is best performed through a dilated pupil, and this experiment was carried out using undilated pupils. However, although the glaucomatous ONH is best examined after using mydriatic, in practice, mydriatic is not routine—it is used if there is an indication. Asuspicious ONH would be such an indication, but this suspicion would first be raised on examination through an undilated pupil.

Also in this study while measuring the CDR with the fundus camera we have done the mapping of disc and cup margins using computer mouse which can result in false estimation of CDR. However in this study to minimize this same observer has done the mapping for all subjects. This problem can be overcome by using software which will automatically estimate the cup disc ratio.

As we know that glaucoma is the leading cause of irreversible blindness worldwide, and the second most common cause of blindness after cataract.[1,2]More than half of the glaucoma patients are undiagnosed,[4,5] and more than 50% taking medications do not need them (over treated).[6] More than 50% of those undiagnosed would have seen an eye care provider in the recent past. Missed diagnosis in those previously examined by an eye care professional is attributable to the lack of comprehensive evaluation, appropriate clinical skills and proper documentation. The recent advances in the imaging of the optic nerve head seek to achieve an early and “objective” diagnosis of glaucoma.

Clinical implication of this study is that as we know in the large optic disc in the healthy individual tends to have large CDR (e.g. high myopia, ocular hypertension); in this study we found that in such cases the fundus biomicroscopy gives an overestimation of the cup disc ratioespecially when the CDR is greater than 0.6. This may lead to the erroneous diagnosis and unnecessary treatment of glaucoma. But, on the other hand in case of smaller optic disc of 0.2 to 0.6 in this study we have foundthat the fundus biomicroscopy underestimates the CDR and in such cases it is difficult to assess glaucomatous changes which may go unnoticed.

A study done by M. Durmus*et al*[23]has also reported that the mean VCDR measured with funduscopy was smaller than mean measured with either HRT II or SONP in the glaucoma and ocular hypertension groups. Therefore, we should use the best possible clinical examination technique to detect suspicious discs. It could also be argued that as long as a clinician is internally consistent, it does not matter what examination strategy is used as long as change (i.e., progression in the case of Glaucomatous Optic Neuropathy) is detected. On the other hand, if the clinician fails to detect a small optic cup in a small optic disc, an early case of GON may be missed. In this study we have compared the value of the cup disc ratio obtained by fundus biomicroscopy with that obtained with fundus camera. In future the values obtained with the fundus camera can be compared with some other semi automated instruments like HRT or OCT to find the accuracy and co relation of fundus camera measurement.

CONCLUSION

In this study when comparing the difference for the cup – disc ratio (CDR) between the fundus biomicroscopic estimation and fundus camera measurement we found that for the CDR between 0.2 to 0.6 fundus biomicroscopy underestimates the CDR compared with fundus camera. But when the CDR value is greater than 0.6 the fundus biomicroscopy gives an overestimation of measured CDR as compared with fundus biomicroscopy (figure 5 and 6).In this study we also found that the larger optic disc in the healthy individual tends to have large CDR (e.g. high myopia, ocular hypertension) and in such cases the fundus biomicroscopy gives an overestimation of the CDR which may lead to the erroneous diagnosis and unnecessary treatment of glaucoma on the other hand in case of smaller optic disc the fundus biomicroscopy underestimates the CDR and in such cases it is difficult to assess glaucomatous changes which may go unnoticed. This study has shown that there is a statistically but non clinically significant difference between fundus biomicroscopic estimation and fundus camera measurement.

So, we should use the best possible clinical examination technique to detect suspicious disc and this study has shown that Fundus photograph provides a better documentation of optic nerve head, especially at lower and higher values of CDR.

REFERENCES

[1]. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. Br J Ophthalmol2006; 90:262–267.
[2]. ResnikoffS,PascoliniD,Etya'ale D, Kocur I, Pararajasegaram R, PokharelGP,et al. Global data on visual impairment in the year 2002. Bull World Health Organ 2004; 82:844-51.
[3]. George R, Ramesh S Ve, and Vijaya L. Glaucoma in India: Estimated burden of disease.J Glaucoma 2010; 19: 391-7.
[4]. Dandona L, Dandona R, Srinivas M, MandalP,Jhon RK, McCarty CA, et al.Open-angle glaucoma in an urban population in southern India. The Andhra Pradesh Eye Disease Study. Ophthalmology 2000; 107: 1702-9.
[5]. Vijaya L, George R, Arvind Paul PG, Ramesh SV et al. Prevlance of angle closure disease in a rural southern Indian Population. Arch Ophthalmol 2006; 124: 403-9.
[6]. Vanthoranta- Lehtonen H, Tuulonen A, Aronen P etal.Cost effectiveness and cost utility of an organized screening programme for glaucoma. Acta Ophthlmol Scand 2007; 85: 508-18.
[7]. Olthoff CM, Schouten JS, van de Brone BW, Webers CA. Noncompliance with ocular hypotensive treatment in patients with glaucoma or ocular hypertension an evidence-based review. Ophthalmol 2005: 112: 953-61.
[8]. Thomas R, Dogra M. An evaluation of medical college departments of ophthalmology in India and change following provision of modern instrumentation and training. Indian J Ophthalmol 2008; 56: 9-16.
[9]. Sommer A, Katz J, Quigley HA, Millar NR, Robin AL, Richter RC et al. Clinically detectable nerve fiber atrophy precedes the onset of glaucomatous field loss. Arch
[10]. Ophthalmol 1991; 109: 77–83.
[11]. Zeyen TG, Caprioli J. Progression of disc and field damage in early glaucoma. Arch Ophthalmol 1993; 111: 62–65.
[12]. Harweth RS, Carter-Dawson L, Shen F, Smith III EL, Crawford ML. Ganglion cell losses underlying visual field defects from experimental glaucoma. Invest Ophthalmol Vis Sci 1999; 40: 2242–2250.
[13]. Sung VC, Bhan A, Vernon SA. Agreement in assessing optic discs with a digital stereoscopic optic disc camera (Discam) and Heidelberg retina tomograph. Br J Ophthalmol 2002; 86: 196-202.
[14]. Jayasundera T, Danesh-Meyer HV, Donaldson M, Gamble G. Agreement between stereoscopic photographs, clinical assessment, Heidelberg retina tomograph and digital stereoscopic optic disc camera in estimating vertical cup: disc ratio. ClinExpOphthalmol 2005; 33: 259-63.
[15]. Weismann EL, Asiff CF, Phelps CD, et al. Vertical elongation of the optic cup in glaucoma. Trans Am Acad Ophthalmol Otolaryngol 1973;77:157–63.
[16]. Hitchings RA, Spaeth GL. The optic disc in glaucoma. I: Classification. Br J Ophthalmol 1976;60:778–85.
[17]. Tielsch JM, Katz J, Quigley HA, et al. Intraobserver and interobserver agreement in measurement of optic disc characteristics. Ophthalmology 1988;95:350–6.
[18]. Varma R, Steinmann WC, Scott IU. Expert agreement in evaluating the optic disc for glaucoma. Ophthalmology 1992; 99:215–21
[19]. Watkins R, Panchal L, Uddin J, Gunvant P. Vertical cupto-disc ratio: agreement between direct ophthalmoscopic estimation, fundus biomicroscopic estimation, and scanning laser ophthalmoscopic measurement. Optom Vis Sci 2003; 80: 454-9.
[20]. Andrew Mcnaught New imaging techniques. Larry Benjamin Bruce James Ophthalmology Investigation and examination technique. Butterworth Heinemann Elsevier 2007; 17: 223-225
[21]. F Arnalich-Montiel, FJ Mun˜ oz-Negrete, G Rebolleda, M Sales-Sanz and C Cabarga Cup-to-disc ratio: agreement between slit-lamp indirect ophthalmoscopic estimation and
[22]. stratus optical coherence tomography measurement Eye (2007) 21, 1041–1049
[23]. Zangwill L, Shakiba S, Caprioli J, Weinreb. Agreement between clinicians and a confocal scanning laser ophthalmoscope in estimating cup/disk ratios. Am J Ophthalmol 1995; 119: 415– 421
[24]. Correnti AJ, Wollstein G, Price LL, Schuman JSComparison of optic nerve head assessment with a digital stereoscopic camera (discam), scanning laser ophthalmoscopy, and stereo photography.Ophthalmology. 2003 Aug; 110(8):1499-505.
[25]. M. Durmus, R. Karadag, M. Erdumus, Y. Totan, I. Feyzi Hepsen Assessment of cup-to-disc ratio with slit-lamp funduscopy, Heidelberg Retina Tomography II, and stereoscopic photos European Journal of Ophthalmology / Vol. 19 no. 1, 2009 / pp. 55-6024. User's manual Volk lens
[26]. User's guide Kowa VK 2 Digital Imaging System.

[27]. Dr. Medha Prabhudesai Atlas of Optic Nerve Head Evaluation in Glaucoma; First Edition (2006); JAYPEE BROTHERS; ISBN 81-8061-625-5
[28]. Mistlberger A, Liebmann JM, Greenfield DS, et al. Heidelberg retina tomography and optical coherence tomography in normal, ocular-hypertensive, and glaucomatous eyes. Ophthalmology 1999; 106: 2027-32.
[29]. Arthur SN, Aldridge AJ, De León-Ortega J, McGwin G, Xie A, Girkin CA. Agreement in assessing cup-to-disc ratio measurement among stereoscopic optic nerve head photographs, HRT II, and Stratus OCT. J Glaucoma 2006; 15: 183-9.
[30]. Barkana Y, Harizman N, Gerber Y, Liebmann JM, Ritch R. Measurements of optic disk size with HRT II, Stratus OCT, and funduscopy are not interchangeable. Am J Ophthalmol 2006; 142: 375- 80
[31]. Wolfs RC, Ramrattan RS, Hofman A, de Jong PT. Cup to- disc ratio: ophthalmoscopy versus automated measurement in a general population: The Rotterdam Study. Ophthalmology 1999; 106: 1597-601.