
Improved Repeatability Using Automated Disc Centration Post Acquisition of Images from Cirrus™ HD-OCT Spectral Domain Technology

M. DURBIN, S. DASTMALCHI, J. OAKLEY, S. MEYER
Carl Zeiss Meditec, Inc., Dublin, CA USA

ABSTRACT

PURPOSE: To determine the accuracy of an automatic method for identifying the border and center of the optic disc in peripapillary images taken by the Cirrus optical coherence tomography instrument (Carl Zeiss Meditec, Inc., Dublin, CA). Furthermore, to determine the improvement in repeatability achieved using this technique. **METHODS:** Seventeen (17) subjects with no known retinal pathology were imaged in-house. Three OCT volumes (200x200 A-scans) were acquired per eye per session, and a total of three sessions were performed on consecutive days. For each image, the border and center of the optic nerve were identified using an automated graph-based method. This identification determines the center point for a TSNIT analysis and also provides registration between repeat scans. The offset between the two scans was determined by comparing the centers. To evaluate repeatability, the offset was compared to the offset determined from a blood vessel registration

technique. Analysis of variance (ANOVA) was used to determine repeatability standard deviation (SD) of the average RNFL thickness measured in a circle centered on the optic disc. Repeatability SD was compared using no registration and using the optic disc center-based registration. **RESULTS:** Center finding using the graph-based technique was accurate compared to blood vessel registration to within $\pm 200 \mu\text{m}$. Repeatability SD with no registration technique (operator centering only) was $1.6 \mu\text{m}$. Registering scans by lining up the center of their optic disc improved repeatability SD to $1.4 \mu\text{m}$. **CONCLUSIONS:** A graph-based method of determining the boundary of the optic nerve head provides accurate alignment between scans of the optic nerve head. Repeatability of Cirrus HD-OCT RNFLT measurements is excellent, and improves with registration of images.

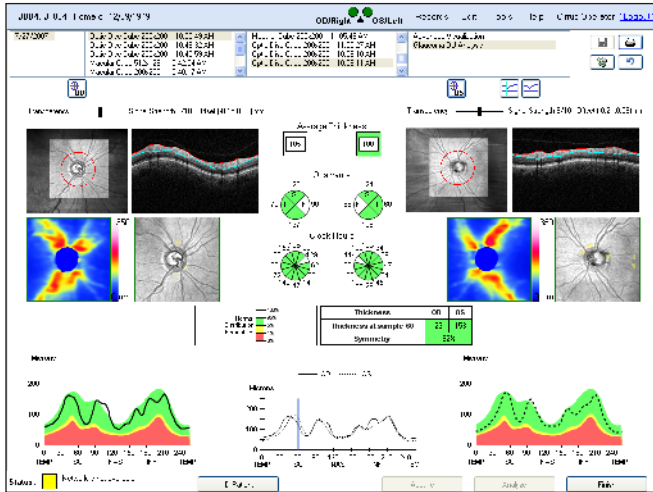
INTRODUCTION

Cirrus HD-OCT (Carl Zeiss Meditec, Inc., Dublin, CA) recently introduced a software package for use in clinical practice to measure retinal nerve fiber layer (RNFL) thickness. The Optic Disc 200x200 scan is used to acquire a cube of side 6mm while the patient is fixated so that the optic disc is near the center of the scan. Cirrus segments the internal limiting membrane (ILM) and the outer boundary of the RNFL. The difference between these is the thickness of the RNFL, presented as a map using a color scale to highlight the inferior and superior nerve fiber bundles. Many studies on Stratus OCT show that the average RNFL thickness measured on a circle with

diameter 3.46mm, as well as parameters such as the inferior and superior quadrants, are powerful diagnostic indicators for the presence or absence of glaucoma^[1-5]. Cirrus provides this information by extracting the thickness values in a circle centered on the optic disc. Cirrus does not depend on the operator correctly placing the scan reproducibly because it includes an automated graph-based algorithm (AutoCenter™) that identifies center and border of the optic disc in peripapillary images. This allows the RNFL thickness to be measured at the same location each time.

The purpose of this study is to determine the accuracy of AutoCenter for identifying the center of the optic disc in peripapillary images taken by Cirrus. Furthermore, we also report the improvement in repeatability achieved using this technique.

Cirrus Glaucoma Analysis Screen



METHODS

Data Collection

An existing dataset acquired to evaluate reproducibility of the RNFL thickness measurements in Cirrus HD-OCT was used. This included seventeen (17) subjects with no known retinal pathology. Three OCT volumes (200x200 A-scans) were acquired per eye per session; three sessions were performed on consecutive days. All subjects provided informed consent and all data collection was performed under IRB.

Image Processing

Three methods were used to identify the center of the peripapillary circle:

- **ScanCenter:** The center of the scan (100,100) was used as the center of the peripapillary circle.
- **AutoCenter:** The center as identified by AutoCenter was used as the center of the peripapillary circle.

- **BVCenter:** The center of the first scan is used as the center of all scans; registration based on blood vessels (which is why this is called BVCenter) is used to ensure that the peripapillary circle based on this center is the same for all scans. This method required three steps:
 - The center of the baseline scan (first scan of first day) was found using the AutoCenter method.
 - The baseline scan was registered to each follow-up scan using a blood vessel technique.
 - The alignment was constrained to rigid translation plus rotation. The translation parameters were used to estimate the shift of each scan from baseline: Xshift, Yshift. The shifts were added to the center of the baseline scan; this sum was used as the center of the peripapillary circle.

Data Analysis — Accuracy

Accuracy of AutoCenter was evaluated by treating BVCenter as a reference standard. Offsets between each scan and baseline using AutoCenter were compared to offsets found using BVCenter. The difference is presumed to be due to inaccuracies in AutoCenter.

Data Analysis - Repeatability

A random effects analysis of variance (ANOVA) was used to determine repeatability standard deviation (SD) of 17 summary parameters based on the average RNFL thickness measured over the peripapillary circle as centered by each method.

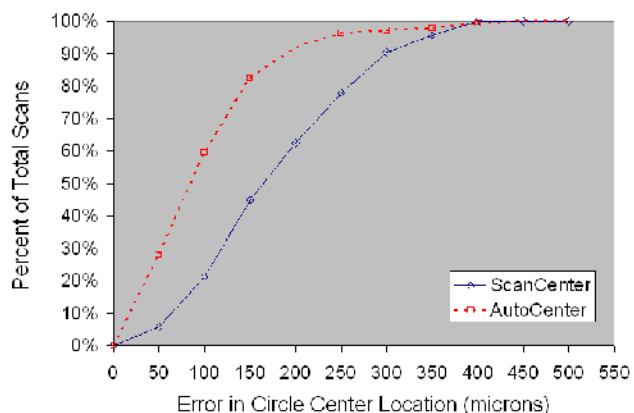
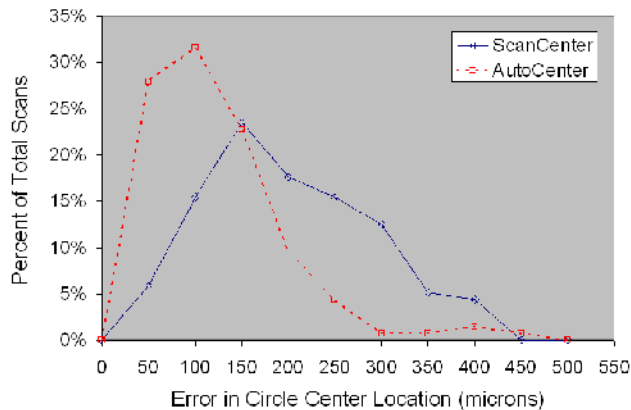
RESULTS

Distribution of Total Radial Offset

The graphs following show the distribution of the error of the center location (as compared to BVCenter) for ScanCenter (blue diamonds) and AutoCenter (red squares). The cumulative distribution is also shown.

- 82% of errors using AutoCenter are less than 150 μm .
- 43% of errors using ScanCenter are less than 150 μm .

- Mean error using AutoCenter is 99 μm , standard deviation is 75 μm .
- Mean error using ScanCenter is 176 μm , standard deviation is 89 μm .



Distribution of Rotations

In general the rotation determined by aligning scan blood vessels to the baseline scan was between -3° and $+3^\circ$, although one subject on the third day had all three scans rotated by $\sim 5^\circ$ from the baseline scan. The rotation information was not used for further analysis.

Analysis of Variance and Repeatability

Using ANOVA, 12 out of 17 summary parameters had significant visit effects when ScanCenter was used to place the peripapillary calculation circle. None of the parameters had a significant visit effect when AutoCenter or BVCenter was used.

Repeatability SD is the square root of the random variance component. This value is shown for each of the three methods below. The repeatability is better for all parameters, but achieves a factor of two improvement for the Temporal and Nasal averages, as well as for clock-hour 6.

	Repeatability SD (microns)		
	ScanCenter	AutoCenter	BVCenter
Average	1.6	1.4	1.5
Temporal	4.6	2.1	2.4
Superior	4.4	3.5	3.7
Nasal	4.6	2.2	2.7
Inferior	5.4	3.2	3.9
ch9	3.5	1.8	1.9
ch10	5.7	3.6	3.6
ch11	6.7	4.9	4.5
ch12	7.6	5.6	5.8
ch1	6.6	4.9	4.9
ch2	6.7	4.1	4.5
ch3	3.8	2.7	3.1
ch4	5.7	3.2	3.7
ch5	6.8	4.4	5.7
ch6	10.7	5.3	6.9
ch7	8.0	4.9	5.6
ch8	6.2	3.2	4.3

CONCLUSION

AutoCenter accurately identifies the center of the optic disc. This improves the repeatability of the RNFL thickness measurement, especially for the parameters that are most affected by scan misplacement (quadrants and clock-hours).

REFERENCES

1. Lin, et al. "Optic Nerve Head and Retinal Nerve Fiber Layer Analysis" *Ophthalmology* 2007; 114:1937–1949.
2. Naithani, et al. "Evaluation of Optical Coherence Tomography and Heidelberg Retinal Tomography Parameters in Detecting Early and Moderate Glaucoma" *Invest Ophthalmol Vis Sci.* 2007; 48:3138–3145.
3. Sihota, et al. "Diagnostic Capability of Optical Coherence Tomography in Evaluating the Degree of Glaucomatous Retinal Nerve Fiber Damage." *Invest Ophthalmol Vis Sci.* 2006; 47:2006–2010.
4. Budenz, et al. "Sensitivity and specificity of the Stratus OCT for perimetric glaucoma." *Ophthalmology* 2005; 112:3–9.
5. Medeiros, et al. "Comparison of the GDx VCC scanning laser polarimeter, HRT II confocal scanning laser ophthalmoscope, and Stratus OCT optical coherence tomograph for the detection of glaucoma." *Arch Ophthalmol* 2004; 122:827–37.
6. Leung, et al. "Evaluation of scanning resolution on retinal nerve fiber layer measurement using optical coherence tomography in normal and glaucomatous eyes." *J Glaucoma* 2004; 13:479–85.

Carl Zeiss Meditec, Inc.
5160 Hacienda Drive
Dublin, CA 94568
USA

Phone: 1 800 342 9821
Fax: 1 925 557 4101
info@meditec.zeiss.com
www.meditec.zeiss.com/us