

1 **Use of a binocular optical coherence tomography system to**  
2 **evaluate strabismus in primary position**

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26 **Running Head:**

27 Automated, quantitative assessment of strabismus using binocular OCT

28 **Keywords:**

29 Binocular

30 Optical coherence tomography

31 Automated

32 Diagnostics

33 Strabismus

34 **Abbreviations:**

35 APCT - Alternating Prism Cover Test

36 OCT – Optical Coherence Tomography

37 LoA – Limits of Agreement

38

39 **Figures:**

40 2

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42 **Tables:**

43 1

## 44 **Key Points**

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46 **Question:** Can a new form of optical coherence tomography (OCT) known as  
47 'binocular OCT' be used to measure the size of strabismus?

48 **Findings:** This study included 15 participants with strabismus and 15 healthy  
49 individuals. Binocular OCT imaging correctly revealed the type and direction of the deviation  
50 in all participants, including both horizontal and vertical deviations. The size of strabismus  
51 measured with binocular OCT had fair agreement with the alternating prism cover test.

52 **Meaning:** Binocular anterior segment OCT imaging can provide clinicians with a  
53 precise measurement of strabismus, which may be useful for diagnosis and monitoring.

## 54 **Abstract**

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56 **Importance:** Current clinical methods for assessing strabismus can be prone to  
57 error. Binocular OCT has the potential to assess and quantify strabismus objectively and in  
58 an automated manner.

59 **Objective:** To evaluate the use of a binocular optical coherence tomography (OCT)  
60 prototype to assess the presence and size of strabismus.

61 **Design, Setting, and Participants:** Fifteen participants with strabismus recruited  
62 from Moorfields Eye Hospital NHS Foundation Trust, London, UK, and fifteen healthy  
63 volunteers underwent automated anterior segment imaging using the binocular OCT  
64 prototype. All participants had an orthoptic assessment including alternating prism cover test  
65 (APCT) prior to imaging. Simultaneously acquired pairs of OCT images, captured with one  
66 eye fixating, were analysed using ImageJ to assess the presence and angle of strabismus.

67 **Main Outcomes and Measures:** The direction and size of strabismus measured  
68 using binocular OCT was compared to that found using APCT.

69 **Results:** The median age for participants with strabismus was 55 years (interquartile  
70 range 33-66.5 years), and 50 years (interquartile range 41-59 years) for healthy group. The  
71 median magnitude of horizontal deviation was 20 $\Delta$  (interquartile range 13-35 $\Delta$ ), and 3 $\Delta$  for  
72 vertical deviation (interquartile range 0-5 $\Delta$ ). Binocular OCT imaging correctly revealed the  
73 type and direction of the deviation in all 15 strabismus participants, including both horizontal  
74 and vertical deviations. APCT and OCT measurements were strongly correlated for both  
75 horizontal (Pearson's  $r = 0.85$ , 95% confidence interval (CI) 0.60-0.95;  $P < 0.001$ ) and  
76 vertical ( $r = 0.89$ , CI 0.69-0.96;  $P < 0.001$ ) deviations. In the healthy cohort, 9 participants  
77 had a latent horizontal deviation on APCT (median magnitude 2 $\Delta$ , range 2-4 $\Delta$ ). Six were  
78 orthophoric. Horizontal deviations were observed on OCT imaging in 12 of the 15  
79 participants, and a vertical deviation was visible in 1 participant.

80           **Conclusions and Relevance:** These findings suggest that binocular anterior  
81 segment OCT imaging can provide clinicians with a precise measurement of strabismus.  
82 The prototype can potentially incorporate several binocular vision tests that will provide  
83 quantitative data for the assessment, diagnosis, and monitoring of ocular misalignments.

## 84 **Introduction**

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86 Strabismus is a common condition that can affect both children and adults.<sup>1,2</sup> Clinical  
87 assessments designed to measure ocular misalignment often require specialist orthoptic  
88 expertise and good patient cooperation. An alternating prism cover test (APCT) is most  
89 commonly used, however, the endpoint of such testing can be subtle or variable, and is  
90 prone to inter- and intra-observer error, particularly in less cooperative children.<sup>3,4</sup> Electronic  
91 instruments that use infrared light to track eye position of both eyes simultaneously such as  
92 video goggles<sup>5</sup> and gaze trackers<sup>6</sup> have been developed to increase the precision of  
93 measurement but are mainly used for research purposes.

94       Optical coherence tomography (OCT) devices are becoming ubiquitous to eye clinics  
95 as they provide objective and quantitative data about ocular structures to aid the diagnosis  
96 and monitoring of eye disease. In this report we demonstrate an application of a prototype  
97 binocular optical coherence tomography system (Envision Diagnostics, El Segundo, CA) that  
98 acquires anterior segment images of both eyes simultaneously, even with one eye fixating,  
99 and in an automated manner. By analyzing simultaneously acquired pairs of anterior  
100 segment images, the presence of strabismus can be identified. We evaluate the use of  
101 anterior segment OCT as a method of assessing strabismus and measuring the angle of  
102 deviation.

## 103 **Methods**

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105 Participants with strabismus were prospectively recruited from clinics at Moorfields Eye  
106 Hospital NHS Foundation Trust, London, UK, as part of the EASE study (ClinicalTrials.gov  
107 Identifier: NCT02822612). Healthy volunteers were recruited from staff members at the  
108 hospital. Written informed consent was obtained from all participants in the study. All  
109 participants were required to have no significant hearing impairment that would affect their  
110 ability to respond to instructions delivered by the device. A conversational level of English  
111 was required for users to understand the instructions, and to be able to communicate with  
112 the device via an English language voice recognition system. No participants were excluded  
113 based on disease status to ensure our cohort consisted of everyday users of eye care  
114 services. All underwent orthoptic assessment prior to binocular OCT examination, including  
115 visual acuity measurement and APCT at distance in primary position, with habitual refractive  
116 error correction if appropriate. Approval for data collection and analysis was obtained from a  
117 UK National Health Service Research Ethics Committee (London-Central). The study  
118 adhered to the tenets of the Declaration of Helsinki.

119

### 120 **Binocular OCT examination**

121 All participants underwent binocular OCT examination as described elsewhere.<sup>7</sup> Briefly, this  
122 is an automated prototype device that acquires OCT images of the anterior and posterior  
123 segments of both eyes simultaneously using a tunable swept-source laser without requiring  
124 an operator. The device uses a Maxwellian view system to simulate distance fixation. The  
125 fixation target was presented to the non-deviating eye in the strabismus group, selected  
126 manually prior to examination. Therefore, the primary deviation was measured on OCT. For  
127 healthy participants, the target was presented to the dominant eye (right eye in all

128 participants). The spherical equivalent of the user's habitual refractive error is corrected  
129 within the device.

130  
131 **Measurement of angle**

132 A volume comprising 128 B-scans of the anterior segment was acquired by the device in the  
133 horizontal and vertical planes. Only a single central anterior segment image was used for  
134 each plane for analyses. The central image can be deduced by the visualization of the  
135 corneal vertex reflection in the fixing eye.<sup>8</sup> This hyperreflective line was used as a surrogate  
136 for the visual axis. The image captured at the same time point was used for the fellow non-  
137 fixing eye. The images were adjusted to 16.5x14.9 aspect ratio as they are acquired at  
138 16.5mm width and 14.9mm depth. ImageJ, a widely use open-source Java image analysis  
139 program was used to measure the difference in angle in degrees between the fixing and  
140 non-fixing eye. A line was drawn between the pupil margins at the posterior epithelium of the  
141 iris for both eyes. These landmarks were chosen as they were visible in both horizontal and  
142 vertical scans. The angle between the lines was calculated as the angle of deviation (Figure  
143 1).

144  
145 **Outcome measures**

- 146 1. The direction of the deviation was determined by the direction of the fellow eye with  
147 respect to the fixating eye in both horizontal and vertical scans. This was compared  
148 to the direction of the misalignment found using APCT for distance fixation.
- 149 2. The size of the misalignment was compared to that found using distance APCT.
- 150 Values in prism diopters ( $\Delta$ ) were converted to degrees using the following formula:<sup>9</sup>

151 
$$\text{degrees} = \tan^{-1}(\Delta/100) \times 180/\pi$$



## 152 **Results**

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154 Twelve participants had concomitant strabismus, one of which had glaucoma and  
155 strabismus. One participant had a decompensated strabismus as a consequence of loss of  
156 vision after a retinal detachment. Two participants had an acquired restrictive incomitant  
157 strabismus related to sphenoid wing meningioma, and thyroid eye disease. These are  
158 described further in Table 1. The median age was 55 years (interquartile range 33-66.5  
159 years). Thirteen subjects were Caucasian, and two subjects were Asian. Seven of the 15  
160 subjects were female. The median magnitude of horizontal deviation was 20 $\Delta$  (interquartile  
161 range 13-35 $\Delta$ ), and 3 $\Delta$  for vertical deviation (interquartile range 0-5 $\Delta$ ). Mean spherical  
162 equivalent was +0.53D  $\pm$ 2.19 (range sphere -2.50 to +5.50DS, range cylinder 0 to -3.50DC).  
163 The cohort of healthy participants had no manifest deviation. Nine healthy participants had a  
164 latent deviation for distance, and 6 were orthophoric. The median age of this group was 50  
165 years (interquartile range 41-59 years). Twelve healthy participants were Caucasian, two  
166 were Asian, and one subject was Black. Eight of the healthy participants were female. Mean  
167 spherical equivalent for this cohort was -0.51D  $\pm$ 1.45 (range sphere -3.50 to +2.75DS, range  
168 cylinder 0 to -2.50DC). All participants understood the examination and were cooperative, as  
169 discussed further in a usability study of the device.<sup>7</sup>

170

### 171 **Direction and size of misalignment**

172 Orthoptic assessment revealed five participants in the strabismus group had a horizontal  
173 deviation only, one participant had a vertical deviation only, and nine participants had both  
174 horizontal and vertical deviations. A torsional element was not detected in any participants.  
175 Binocular OCT imaging correctly identified the direction of misalignment in all 15 strabismus  
176 participants, including both horizontal and vertical deviations. Three out of the five

177 participants assessed as having a horizontal deviation only using APCT were also found to  
178 have an additional vertical deviation on binocular OCT imaging (Table 1).

179         There was a strong correlation between the measurement of strabismus using APCT  
180 and the measurement calculated from the OCT images for both horizontal (Pearson's  
181  $r=0.85$ , 95% confidence interval (CI) 0.60-0.95;  $P<0.001$ ) and vertical ( $r=0.89$ , CI 0.69-0.96;  
182  $P<0.001$ ) deviations. The confidence intervals indicate a strong relationship between the two  
183 methods. Bland-Altman<sup>10</sup> plots show heteroscedasticity where the agreement between the  
184 methods decreases as the size of the deviation increases. There was a mean difference of -  
185  $0.30^\circ$  ( $\sim -0.52\Delta$ ) for horizontal misalignment and  $-2.20^\circ$  ( $\sim -3.84\Delta$ ) for vertical misalignment.  
186 The 95% limits of agreement (LoA) for horizontal misalignment were between  $9.55^\circ$  ( $\sim$   
187  $16.82\Delta$ ) and  $-10.16^\circ$  ( $\sim -17.55\Delta$ ). For vertical misalignment the limits of agreement were  
188 narrower between  $2.66^\circ$  ( $\sim 4.65\Delta$ ) and  $-7.06^\circ$  ( $\sim -12.38\Delta$ ). Regression on the Bland-Altman  
189 plots show no significant proportional bias for horizontal misalignments ( $P=0.957$ ), however  
190 show a significant relationship for vertical misalignments ( $P=0.007$ ).

191         In the healthy cohort, 8 had an exophoria (median magnitude  $2\Delta$ , range  $2-4\Delta$  ( $1.15-$   
192  $2.29^\circ$ ), one participant had an esophoria measuring  $2\Delta$ , and 6 participants were orthophoric,  
193 measured using distance APCT. One participant had a vertical deviation on near APCT. No  
194 other participants in this group had a vertical or torsional component at distance or near. In  
195 the 8 exophoric participants, 6 had a misalignment corresponding to an exo-deviation on  
196 OCT (median magnitude  $5.25^\circ$  ( $\sim 9.19\Delta$ ), interquartile range,  $2.63-6.49^\circ$  ( $\sim 4.59-11.38\Delta$ ),  
197 one had an eso-deviation on OCT measuring  $8.61^\circ$  ( $\sim 15\Delta$ ), and one participant had no  
198 deviation on OCT. From the 6 orthophoric participants, 3 had an exo-deviation on OCT  
199 (range  $2.93-6.38^\circ$ ) and 1 had an eso-deviation ( $4.09^\circ$ ). The single participant with an  
200 esophoria did not have any measured deviation on the binocular OCT. Two participants  
201 measured as orthophoric on APCT was also orthophoric on binocular OCT. A vertical  
202 component corresponding to a left hyper-deviation was identified in 1 healthy participant on  
203 OCT measuring  $2.26^\circ$  ( $\sim 3.95\Delta$ ). This participant did not have a vertical latent deviation on  
204 distance APCT, but did have a left hyperphoria measuring  $5\Delta$  on near APCT. A weak

205 correlation was observed between APCT and OCT measurements for horizontal deviation in  
206 this group (Pearson's  $r=0.06$ ,  $P=0.830$ , CI 0.14-0.85).

207

## 208 Discussion

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210 In this paper we explore OCT-derived quantification and assessment of strabismus angle  
211 using a novel prototype binocular OCT system.

212 The device was able to correctly identify the direction of the deviation in the  
213 strabismus group, including both horizontal and vertical elements. The device also indicated  
214 a vertical deviation ( $<4\Delta$ ) in three participants who were recorded as vertically orthophoric.  
215 Small deviations ( $<2\Delta$ ), particularly vertical deviations, may not be reliably perceived by the  
216 unaided eye on cover testing<sup>11, 12</sup> but may be visible on the OCT. The binocular OCT  
217 identified a horizontal deviation in 12 participants of the healthy cohort. In 9 of these  
218 participants, the direction of the deviation on OCT was the same as the latent deviation  
219 found on APCT. This suggests that the binocular OCT is measuring both manifest and latent  
220 components.

221 In horizontal misalignment, the agreement between the methods tended to decrease  
222 as the size of the deviation increased. A similar heteroscedastic pattern was found for  
223 vertical misalignments however our sample was skewed towards smaller deviations. The  
224 LoA were larger than the inter-examiner variability found by de Jongh et al.<sup>13</sup> for horizontal  
225 deviations ( $10\Delta$ ). This would suggest that our method is not in strong agreement with APCT.  
226 However, a larger sample is required to confirm inferences from Bland-Altman plots.  
227 Differences between the methods may be partly attributable to the limited scale of prism  
228 diopters - as the deviation becomes larger, the difference in degrees between each prism  
229 diopter also increases. In addition, increments between diopters in prism bars increase as  
230 the power increases. For example, between  $1-10\Delta$ , prism power increases in increments of  
231 1 diopter, whereas between  $20-50\Delta$ , power increases by  $5\Delta$  increments, forcing the  
232 orthoptist to choose the closest prism that neutralises the misalignment. Whereas, the  
233 binocular OCT is able to measure strabismus angle more precisely using a scale of degrees  
234 instead of diopters. A longitudinal and repeatability study is required to validate this method

235 and to investigate whether OCT-derived measurements are valuable for monitoring the  
236 change in size of misalignment over time.

237         There are several limitations of the device at present, however it is likely that these  
238 can be overcome in future iterations. A significant limitation of the device includes the  
239 inability to ascertain whether a heterophoria or heterotropia is present. We observed  
240 deviations in both the healthy and strabismus cohorts. It is likely that the device is reliably  
241 identifying manifest vertical and horizontal components in the strabismus group. However, if  
242 the device was used as a screening device for manifest strabismus, it may have a high false  
243 positive rate particularly for horizontal deviations as observed in the healthy cohort. The  
244 unique features of the binocular OCT could potentially be extended to perform a cover test  
245 by switching the fixation between the eyes to differentiate between these entities. In the  
246 present study, all strabismus participants had a constant deviation. Those with intermittent  
247 deviations may not be identified using the current prototype setup. Real-time video OCT with  
248 3D-rendering would also aid measurement of torsional deviations. By bringing the fixation  
249 target closer to the eyes, the device has the capacity to simulate near fixation to measure  
250 deviation at various distances. In addition, the current prototype setup performs ocular  
251 motility testing by displaying the fixation target at different locations of the screen.<sup>7</sup>  
252 Strabismus with varying gaze or motion, in addition to alternating fixation, may help discern  
253 between primary and secondary deviations in incomitant strabismus.

254         The prototype currently corrects a mean spherical equivalent of the user's habitual  
255 correction to aid visualization of the fixation target. Refractive error can affect the size of the  
256 deviation, and the inability to correct cylindrical error may contribute to the differences  
257 observed between the methods. Additionally, although the device simulates distance  
258 fixation, proximal convergence may attribute to differences between APCT and OCT  
259 measurements. In one exophoric participant, a significant eso-deviation was found on OCT.  
260 Monocular viewing conditions has been shown to cause accommodative convergence which  
261 may affect these results.<sup>14</sup> In subsequent devices with binocular viewing conditions this may  
262 be reduced. Some users of the device may naturally fixate closer than distance fixation, and

263 this could explain the larger exo-deviations found on OCT compared to APCT in the healthy  
264 cohort. This may also explain the vertical component found in the one healthy participant  
265 who had a vertical deviation at near.

266 Our method of using the pupil margin as a reference plane for tilt may contribute to  
267 error. An anatomical landmark such as Schwalbe's line may be less variable as this cannot  
268 change dynamically like the iris, but may be less discernible, particularly in vertical scans  
269 due to occlusion of this landmark by the eyelids. Visual axis data could potentially provide  
270 more accurate measurements of strabismus. This could be determined by using retinal OCT  
271 images of the fovea that are also acquired using the device. The device currently does not  
272 measure axial length which prevents mapping the retinal and anterior segment images to  
273 each other to determine the visual axis. However, if axial length data could be obtained, the  
274 visual axis could potentially provide a reliable method of measuring strabismus using OCT,  
275 particularly in strabismus with normal retinal correspondence.

276 In summary, we present a novel application of OCT imaging to detect and measure  
277 ocular misalignment. The advantage of this method is the ability to detect subtle differences  
278 in the size of strabismus that may not be visible to the naked eye. This is encompassed  
279 within a device that can perform several functional tests in addition to whole-eye imaging.  
280 The automated manner of the device means a highly skilled specialist is not required to take  
281 measurements of the deviation, therefore making it ideal for screening purposes. As  
282 discussed, measuring strabismus using prism bars has limitations particularly at larger  
283 angles. The binocular OCT can provide a more precise measurement of this angle using  
284 degrees (with out without converting back to prism diopters). This may be useful for  
285 measuring strabismus over time, before and after surgery, or for patients undergoing  
286 botulinum toxin injections. Although the current setup has many caveats, future iterations of  
287 the binocular OCT may allow quicker and more accurate assessments of strabismus  
288 particularly where orthoptists are limited with huge patient volumes. In addition, the device  
289 can output objective quantitative data for ocular misalignments as well as for other  
290 diagnostic tests,<sup>7</sup> aiding the diagnosis and monitoring of eye disease.

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307 The funders had no role in the design and conduct of the study; collection,  
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### 311 **Author Contributions:**

312 R.C., P.J.M., R.S.A., P.A.K. were involved in the study setup

313 R.C., V.K.T. collected the data for the study

314 R.C. analysed the data

315 R.C., P.J.M., V.K.T., R.S.A., P.A.K. wrote the manuscript

316

### 317 **Access to data:**

318 R.C. had full access to all the data in the study and takes responsibility for the integrity of the  
319 data and the accuracy of the data analysis.



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## Table

**Table 1.** Orthoptic assessment and binocular optical coherence tomography measurements for fifteen participants with strabismus. Vertical deviation measurements obtained using OCT are indicated as hyper- or hypo- with respect to the strabismic eye (i.e. the eye with a horizontal deviation if present).

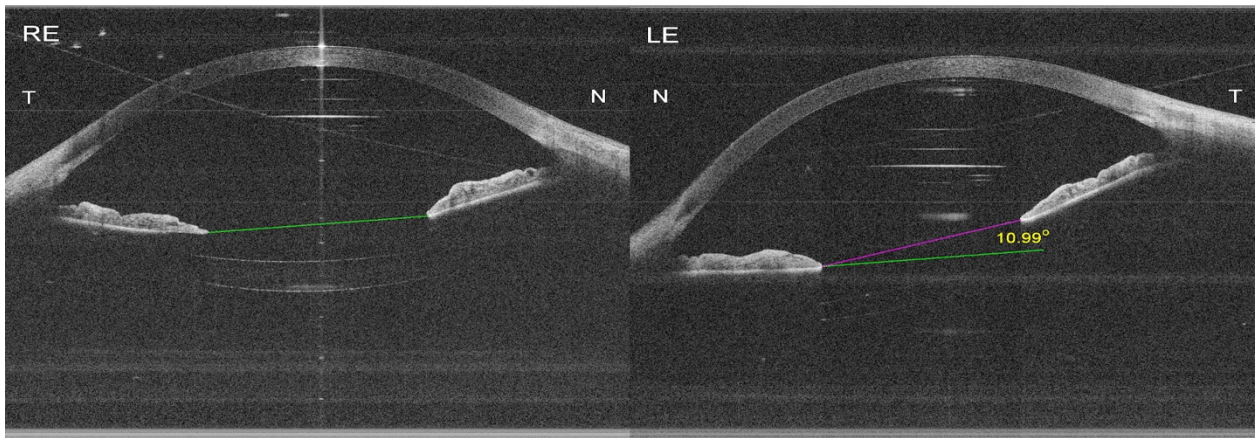
Participant	Clinical diagnosis	Binocular status in primary position	Age	Visual acuity (logMAR)		Mean spherical equivalent (both eyes) (DS)	Distance prism cover test (6 metres)	Prism cover test - equivalent angle in degrees		Angle measured on OCT (degrees)		OCT angle converted to prism (rounded to nearest diopter)
				Right	Left			Horizontal	Vertical	Horizontal	Vertical	
1	RE consecutive exotropia (prior strabismus surgery for childhood esotropia)	No diplopia, RE suppression	35	0.60	0.00	0 (unaided)	12 $\Delta$ BI 5 $\Delta$ BD R/L	6.84	2.86	6.14 (exo)	11.13 (RE hyper)	11 $\Delta$ BI 20 $\Delta$ BD R/L
2	LE/Alternating esotropia (Duane's syndrome)	No diplopia, LE suppression	24	-0.10	-0.10	-0.63	45 $\Delta$ BO	24.23		18.67 (eso)	2.23 (LE hyper)	34 $\Delta$ BO 4 $\Delta$ BD L/R
3	RE fully accommodative esotropia	No diplopia, binocular	23	0.62	0.02	+2.88	6 $\Delta$ BO 4 $\Delta$ BD R/L	3.43	2.29	6.17 (eso)	4.87 (RE hyper)	11 $\Delta$ BO 9 $\Delta$ BD R/L

		single vision										
4	RE consecutive exotropia (prior strabismus surgery for childhood esotropia)	No diplopia, RE suppression	63	0.00	0.16	+5.38	45 $\Delta$ BI 3 $\Delta$ BD R/L	24.23	1.72	29.34 (exo)	2.93 (RE hyper)	56 $\Delta$ BI 5 $\Delta$ R/L
5	RE consecutive exotropia (prior strabismus surgery for childhood esotropia)	No diplopia, RE suppression	50	0.18	-0.02	-0.06	25 $\Delta$ BI	14.04		19.83 (exo)	2.28 (RE hypo)	36 $\Delta$ BI 4 $\Delta$ BD L/R
6	LE childhood esotropia	No diplopia, LE suppression	47	0.16	0.76	-2.44	25 $\Delta$ BO	14.04		11.08 (eso)	0.00	20 $\Delta$ BO
7	LE longstanding distance esotropia	Diplopia	74	0.00	0.00	-1.25	14 $\Delta$ BO 4 $\Delta$ BD L/R	7.97	2.29	12.96 (eso)	2.18 (LE hyper)	23 $\Delta$ BO 4 $\Delta$ BD L/R
8	LE myopic esotropia	Diplopia	74	-0.10	0.00	-0.5	25 $\Delta$ BO 2 $\Delta$ BD R/L	14.04	1.15	23.74 (eso)	3.48 (LE hypo)	44 $\Delta$ BO 6 $\Delta$ BD R/L
9	LE hypertropia (secondary to thyroid eye disease)	Diplopia	62	-0.10	0.00	+1.25	20 $\Delta$ BD L/R		11.31	0.00 (ortho)	18.15 (LE hyper)	33 $\Delta$ BD L/R

10	RE residual esotropia with hypertropia (prior strabismus surgery for childhood esotropia)	No diplopia, RE suppression	31	-0.08	-0.12	+3.13	14 $\Delta$ BO 5 $\Delta$ BD R/L	7.97	2.86	2.07 (eso)	5.89 (RE hyper)	4 $\Delta$ BO 10 $\Delta$ BD R/L
11	RE exotropia with hypertropia (decompensated after loss of vision from a right retinal detachment)	Diplopia	31	0.78	-0.20	0 (unaided)	45 $\Delta$ BI 3 $\Delta$ BD R/L	24.23	2.29	16.97 (exo)	2.02 (RE hyper)	31 $\Delta$ BI 4 $\Delta$ BD R/L
12	LE exotropia with hypotropia (secondary to left sphenoid wing meningioma)	Diplopia	74	-0.04	0.30	+1.25	20 $\Delta$ BI 25 $\Delta$ BD R/L	11.31	14.04	14.75 (exo)	14.26 (LE hypo)	26 $\Delta$ BI 25 $\Delta$ BD R/L
13	LE residual exotropia (prior strabismus surgery for childhood exotropia)	No diplopia, LE suppression	55	0.00	0.48	0 (unaided)	60 $\Delta$ BI 6 $\Delta$ BD R/L	30.96	3.43	26.33 (exo)	6.30 (LE hypo)	49 $\Delta$ BI 11 $\Delta$ BD R/L
14	RE age-related distance esotropia	Diplopia	68	0.16	0.00	-1.50	6 $\Delta$ BO	3.43		1.33 (eso)	0.00	2 $\Delta$ BO
15	LE myopic esotropia (and glaucoma)	Diplopia	61	-0.10	0.10	-0.25	16 $\Delta$ BO	9.09		10.99 (eso)	1.54 (LE hyper)	19 $\Delta$ BO 3 $\Delta$ BD L/R

1 **Figures and Figure Legends**

2



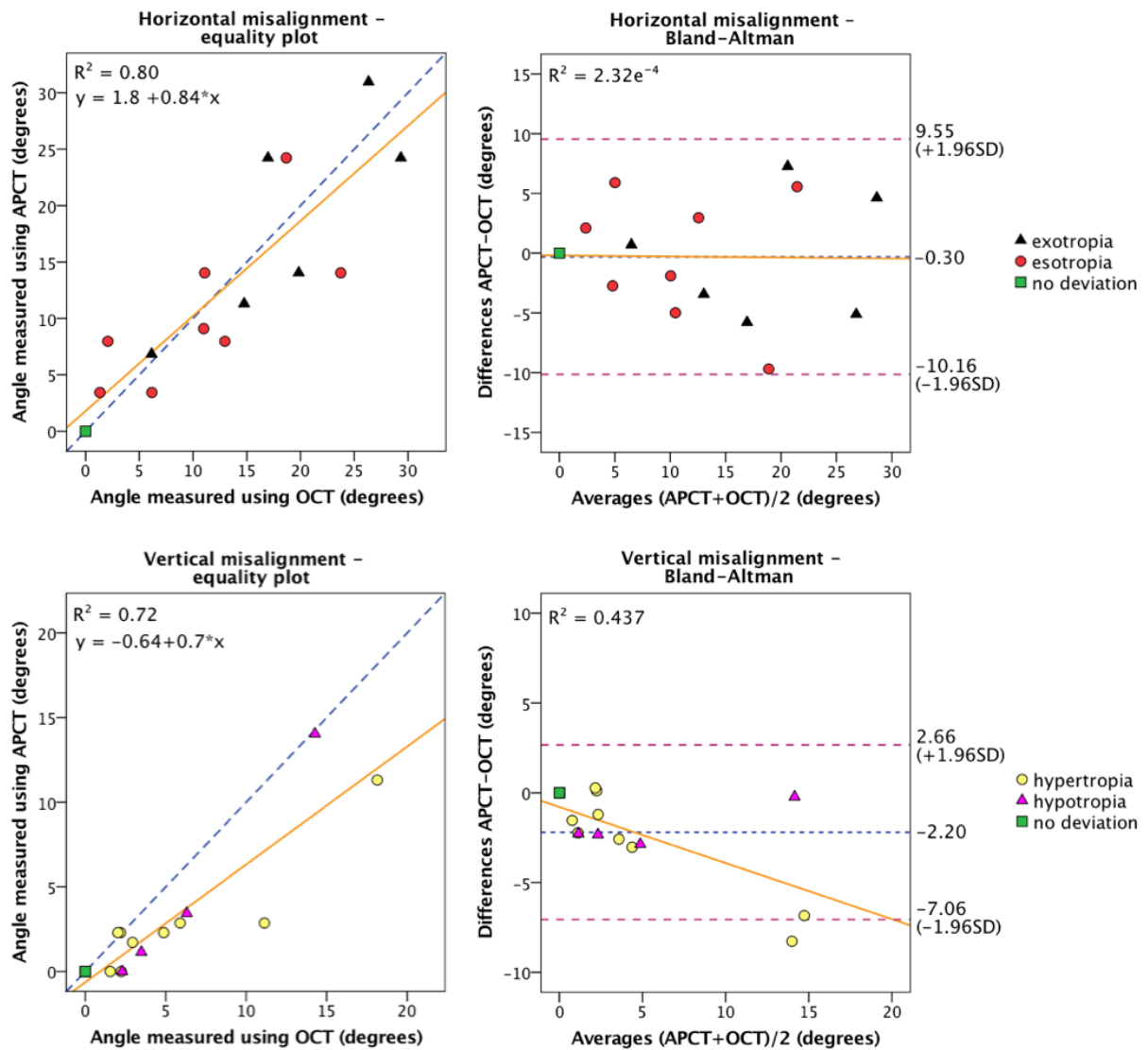
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5 **Figure 1.**

6 **Title:** Simultaneously acquired pair of anterior segment optical coherence tomography  
7 (OCT) images obtained for Participant 15.

8 **Caption:** The right eye is the fixating eye, and the left eye is the strabismic eye. The angle  
9 of the deviation is calculated by measuring the tilt of the eye with respect to the fixating eye.  
10 The pupil margins are used as landmarks to measure tilt. This pair of images indicate a left  
11 esotropia. (N = nasal, T = temporal)

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25 **Figure 2.**

26 **Title:** Equality and Bland-Altman plots comparing agreement of measurements obtained  
 27 using APCT and binocular OCT.

28 **Caption:** Measurements for horizontal misalignments vertical misalignment are presented in  
 29 the top and bottom plots respectively. For vertical deviations, pink triangle markers represent  
 30 a hypo- deviation with respect to the strabismic eye. Green indicates no measured deviation  
 31 with either method. Regression lines are represented in orange. For the equality plots the  
 32 dashed line represents perfect agreement. The reference lines on the Bland-Altman plots  
 33 show the mean and 95% limits of agreement (LoA). The LoA were  $\pm 9.85^\circ$  from the mean for  
 34 horizontal misalignments, and  $\pm 4.86^\circ$  for vertical misalignments.