Original Article

Dynamic distance direct ophthalmoscopy, a novel technique to assess accommodation in children

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Aim: To describe and compare dynamic distance direct ophthalmoscopy (DDDO) with dynamic retinoscopy (DR) in assessment of accommodation in children. **Materials and Methods:** This prospective observational study had four components. Component 1: to understand the characteristic digital images of DDDO. Component 2: to compare DDDO with DR for detection of accommodative defects in children (1–16 years). Component 3: to compare DDDO with DR for the detection of completeness of pharmacologically induced cycloplegia in children (5–16 years) and Component 4: to assess which one of the two techniques was more sensitive to detect onset of cycloplegia after instillation of 1% cyclopentolate eye drops. **Results:** Component 1: image analysis of DDDO on two subjects (7 years and 35 years) demonstrated superior pupillary crescent that progressively disappeared with increasing accommodation. Concurrently an inferior crescent appeared that became bigger in size with increasing accommodation. Component 2: the prevalence of defects in accommodation was 3.3% (33/1000 children). Three had unilateral accommodation failure. Sensitivity of DDDO was 94%, specificity 100%, positive predictive value 100%, negative predictive value 99%, and clinical agreement (kappa) 0.97. Component 3: in the detection of completeness of pharmacologically induced cycloplegia (*n*=30), the sensitivity of DDDO was 94%, specificity 96%, positive predictive value 97%, negative predictive value 93% and kappa 0.9. DR had two false positives. DDDO had one false negative. Component 4: DDDO detected onset of pharmacologically induced cycloplegia 5 min earlier than DR (*n*=5). **Conclusion:** DDDO is a novel, simple, clinical and reliable method to assess accommodation in young children. This test can assess the accommodative response of both eyes simultaneously.

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A reliable, simple, clinical yet objective method is necessary to evaluate children and neurologically impaired patients prone to defects in accommodation. Dynamic retinoscopy (DR) is considered the current *gold standard*.[1,2]

Sophisticated objective tests namely wave front analysis, ultrasonic biomicroscopy and dynamic autorefractometry are useful but difficult for routine clinical examinations.[3,4] Besides, they seriously underestimate the accommodation.

Commonly employed subjective methods to assess accommodation, namely, reading progressively smaller letters at near, accommodative ruler test, assessment of relative positive accommodation using minus lenses and accommodative flipper test using paired +/− lenses are either not feasible or too difficult for young children and neurologically impaired patients. Also, they are not representative of true accommodation due to changing depth of focus related to the pupillary miosis.[5] This makes DR, the most popular method to assess accommodation in these patients.

However, DR requires a patient to hold fixation for some time and suffers from the *subjectiveness* in its interpretation by the examiner. The examiner has to perform the retinoscopy back and forth from one eye to another (for comparison) while the patient wears refractive correction and holds fixation on an accommodative target at a desired distance that is then moved closer or farther to stimulate or relax the accommodation.

In this report, we describe and compare dynamic distance direct ophthalmoscopy (DDDO) that is a novel, simple, clinical, and reliable technique to assess accommodation in children, yet measures accommodation in both eyes simultaneously.

Materials and Methods

This prospective observational study was performed in the department of pediatric ophthalmology of a teaching eye hospital.

Part 1 of the study included two *normal* subjects, whose accommodation on DDDO was video recorded by perfectly aligning the digital camera on the viewing aperture of the direct ophthalmoscope. The images were processed using ImageJ (National institute of health, Bethesda, MD, USA) image processing software to illustrate the characteristics of pupillary reflexes on DDDO.

Part 2 of the study included 1000 consecutive children aged 1 to 16 years who visited us between 1st March 2010 and 30th June, 2010. They presented with a variety of eye-related complaints. Eyes with clear ocular media, well-corrected refractive error and mesopic pupillary diameter between 3 and 7 mm were included. Patients with media opacities, poor fixation, and prior intraocular surgeries were excluded.

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After correcting the refractive error, senior author performed DDDO followed by DR[2] and a complete ophthalmic examination.

Description of the technique [Fig. 1]:

1. After full correction of refractive error, the child was instructed to read the letters from 6 meter Snellen chart.
2. The examiner's refractive error was fully corrected and the lens dial of the ophthalmoscope was set at "0."
3. A direct ophthalmoscope [Heine Beta 200® or Mini 3000 (Optotechnik GmbH, Herrsching, Germany)] was used with full illumination and large spot (aperture diameter) to illuminate both the pupils simultaneously.
4. The direct ophthalmoscope was held at one meter from the patient, at the level of the eyes, close to the line of sight of the patient.
5. The child was then instructed to read the letters from an accommodative target at 40 cm and again read letters on the Snellen chart at 6 m distance. This was repeated a couple of times to assess the latency (onset of accommodation and relaxation of accommodation).
6. The child was then instructed to resolve letters on a hand held target at 40 cm. The target was then moved closer in small steps from 40 cm to 30 cm and then to 20 cm, 10 cm and 8 cm.
7. In patients with squint, DDDO in the deviating eye was performed by occluding the fixating eye. In this situation, simultaneous assessment of accommodation in both the eyes was not possible.

The result of DDDO and DR, when normal (negative test result), was described as "rapid, complete, and steady OU." Examples of abnormal responses (positive test result) included "incomplete," "sluggish," "momentary accommodation only," "accommodative lag," or "asymmetric."[2] Although the *incompleteness* in accommodation is quantifiable with trial lenses, *the sluggishness*, *momentary-ness* or *asymmetricity* was not possible to quantify on DR/DDDO. Hence, for the purpose of analysis, we clubbed all the responses into one of either normal (negative test result) or abnormal (positive test result).

The DDDO and DR were performed at *normal* room illumination. In children < 4 years (n=9), toys with colorful details, lights and sounds were used for the near as well as distance fixation. Only when the examiner was satisfied with the patient's cooperation (able to follow all the instructions and hold the fixation, while resolving the object at desired distance) for a reliable estimation of accommodation, the patient was included in the study.

Part 3 of the study included 30 consecutive children between 5 and 16 years of age with best corrected visual acuity of 20/20 on Snellen chart and N6 at 40 cm on near vision chart in each eye. These children had normal eyes except a refractive error (−1.0 D to −5.0 D myopia/+1.5 D to +3.0 D hyperopia/1.5 D to 3.0 D astigmatism) that was fully corrected with spectacles. They had come for a routine one yearly refraction and fundus examination.

After an oral consent was obtained from the parents, right eye of each child was randomized to dilation with three applications of one drop of 1% cyclopentolate or three applications of one drop of 10% phenylephrine at 5 min interval. Other eye received the *second* drug. Randomization and drug instillation was done by a masked observer using permuted blocks. At end of 45 min, DDDO followed by DR was performed by the senior author who was masked to the randomization process.

To prevent a difference in conjunctival blanching, pupillary dilation and/or lid asymmetry due to phenylelphrine, the eyes randomized to cyclopentolate also received two drops of 10% phenylephrine 15 min prior to DDDO and DR. The results of DDDO and DR were noted as completely relaxed accommodation (test positive) or incompletely relaxed/active accommodation (test negative).

In part 4 of the study, to evaluate which of the two techniques could pick up cycloplegia earlier? DDDO and DR were performed at every 5 min on both the eyes of five consecutive normal subjects aged 12 years, after instillation of 2 drops of 1% cyclopentolate eye drops in both the eyes. This was correlated with the child's near visual acuity, assessed by a masked optometrist.

For part 2 and 3 of the study, 2 × 2 Bayesian tables were made to calculate the sensitivity, specificity and predictive values of DDDO in comparison to DR. Ninety five percent confidence interval and clinical agreement (Cohen's kappa coefficient) between the two techniques were calculated. Sample-size calculation was performed as follows.

We calculated sample size to detect a difference of 1.0 D (effect size) in accommodation (continuous variable) between two techniques (paired variable) namely, DR and DDDO, with 5% significance level ($z_{1-\alpha/2}$) and 80% power of the study ($z_{1-\beta/2}$) and for 2.0 D standard deviation in accommodation.

Using the formula, $n=(Z_{1-\alpha/2} - Z_{1-\beta/2})^2 S^2/d^2$ we needed 32 eyes/patients in our study.[6]

The study was conducted in accordance to the tenets of the declaration of Helsinki.[7]

Results

Part 1: DDDO – image analysis.

Sequential digital images of DDDO in subject 1 (7-year-old girl; Fig. 2, upper panel) and in subject 2 (35-year-old woman; Fig. 2, middle panel), demonstrated a bright superior crescent when fixated for the distance (6 m). After changing the fixation to near and as the target was moved closer, the superior bright crescent progressively reduced in size and disappeared. Concurrently, a bright inferior crescent appeared that became progressively larger in size. These changes could be replicated by introducing convex lenses, of increasing power, in front of the right eye of the subject 2 that was fixated on an accommodative target placed at 6 m (Fig. 2, lower panel).

In contrast to subject 1, DDDO in subject 2 demonstrated a lack of change in the size of the inferior bright crescent when fixation distance was reduced from 20 to 10 cm and further down to 8 cm indicating age-related (physiological) decline in accommodative amplitude.

Pixel intensity gradient plots were obtained from the image processing software. These plots *graphically* demonstrated typical change (decreasing luminosity of pixels from the top of the image and increasing luminosity of pixels from the bottom

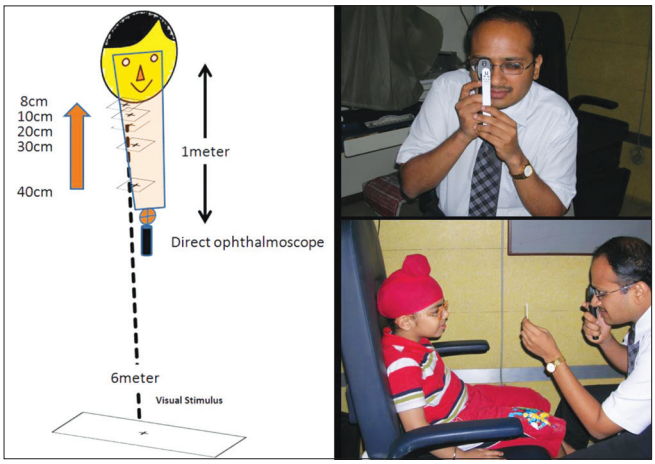

Figure 1: Relative positions of patient, accommodative target and ophthalmoscope/examiner pro DDDO

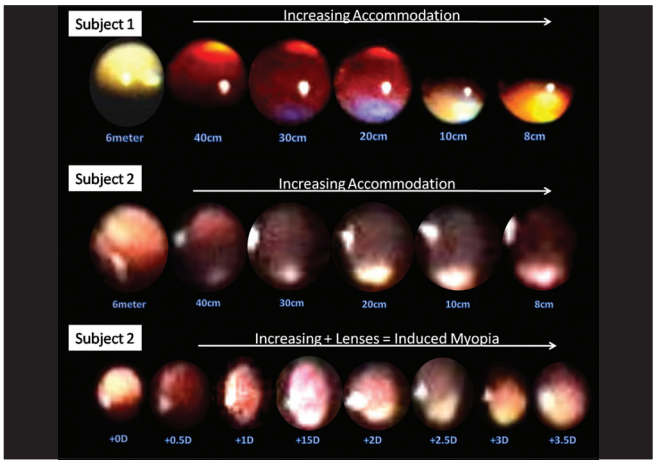

Figure 2: Digital images from the direct ophthalmoscope (DDDO), demonstrating accommodation [left to right] as the fixation target moves from 6 meter (mt) to 40, 30, 20, 10, and 8 cm. DDDO in subject 1 (upper panel). DDDO in subject 2 (middle panel). The lower panel depicts myopia on DDDO induced by placing progressively higher convex lenses (value is mentioned below the image) in front of the emmetropic right eye of subject 2 that is fixated on an accommodative target at 6 m. Bright white spot in the pictures indicate the corneal reflex

of the picture [Fig. 3].) in the pattern of *Pixel intensity gradient* with increasing accommodation and myopia.

Part 2: comparison of DDDO with DR in children with defective accommodation.

The prevalence of defects in accommodation (accommodation failure) was found in 33 (3.3%) out of total 1000 children. Of total 33 patients with defects in accommodation (positive on DR), 19 were males. Mean age was 7 years ± 4.8 (1–16 years).

Three patients had unilateral accommodation failure, of which two had congenital unilateral third nerve palsy and one had transient, post traumatic, accommodation failure associated with traumatic mydriasis (6 mm). Various causes of bilateral accommodation failure were, cortical vision impairment [CVI, (*n*=10)], foveal hypoplasia [*n*=6 (three with albinism, two isolated, and one with aniridia)], Down syndrome (5), idiopathic accommodation failure [*n*=4 (two had myopia of –9.0D with iso-ametropic amblyopia)], ectopia lentis (2), macular degeneration (1), nanophthalmos [*n*=1 with hyperopia of +15.5D)] and near vision palsy (1).

In two patients with CVI, we missed a small (~1.25D) hyperopic astigmatism. In these patients DDDO was negative but DR was positive. There was no patient where DR was negative yet DDDO was positive [Table 1]. The sensitivity, specificity and predictive values of DDDO when compared to DR were excellent [Table 2].

Part 3: Assessment of *completeness* of cycloplegia in pharmacologically dilated pupil.

Of total 30 patients, 15 were males. Mean age was 9.8 years ± 3 (5–15 years). DR identified 32 eyes as completely cyclopleged of which two were negative on DDDO [Table 3]. Both those eyes were dilated with phenylephrine and demonstrated good accommodation on the near vision testing. These findings were suggestive of false positive DR. One eye with complete cycloplegia on DR and near vision testing was missed on DDDO. Sensitivity, specificity and predictive values of DDDO in detection of completeness of cycloplegia were excellent [Table 4].

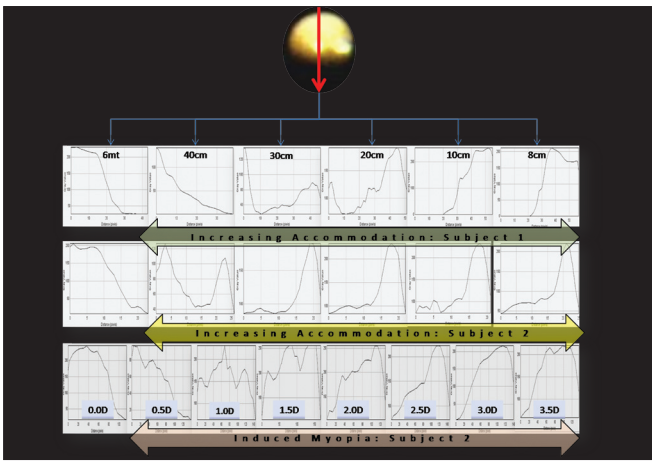

Figure 3: *Pixel intensity gradient* plots. Values on x axis depict the position of a pixel on a central line (red arrow) drawn starting from the top of the DDDO images corresponding to Figure 1. Values on y-axis depict the intensity (luminosity) value of a pixel

Table 1: 2 × 2 bayesian table showing the test results of DDDO and DR in 1000 consecutive patients

	Positive on DR	Negative on DR	Total
Positive on DDDO	31	0	31
Negative on DDDO	2	967	969
	33	967	1000

DDDO: Dynamic distance direct ophthalmoscopy

Part 4: DDDO and DR to assess onset of pharmacological cycloplegia in children.

Table 2: Sensitivity, specificity, and predictive values of dynamic distance direct ophthalmoscopy in 1000 consecutive patients

		95% confidence limits
Sensitivity	94%	(78%–99%)
Specificity	100%	(99%–100%)
Predictive Value of Positive test	100%	(99%–100%)
Predictive Value of Negative test	99%	(86%-100%)
Prevalence of accommodation failure	3.3%	
Cohen's kappa coefficient	0.97	(0.92–1.0)

Table 3: 2 × 2 bayesian table showing the test results of DDDO and DR in 32 pharmacologically cyclopleged eyes

	Positive on DR	Negative on DR	
Positive on DDDO	30	1	31
Negative on DDDO	2	27	29
	32	28	60

DDDO: Dynamic distance direct ophthalmoscopy, DR: Dynamic retinoscopy

Table 4: Sensitivity, specificity, and predictive values of DDDO in 60 pharmacologically dilated eyes

		95% confidence limits
Sensitivity	94%	(78%–99%)
Specificity	96%	(80%–100%)
Predictive Value of Positive test	97%	(81%–100%)
Predictive Value of Negative test	93%	(76%–99%)
Prevalence of complete cycloplegia in pharmacologically dilated eyes	53%	
Cohen's kappa coefficient	0.9	(0.8–1.0)

DDDO: Dynamic distance direct ophthalmoscopy

Of 5 children aged 12 years, 3 were males. In all five patients, after the instillation of cyclopentolate eye drops, at the earliest, the onset of cycloplegia was noticed between 10–15 min and first on DDDO. Cycloplegia on DR was noticed 5 min later.

Discussion

This is an innovative study that describes utility of a direct ophthalmoscope to assess accommodation in young children. The optical principles of DDDO are similar to eccentric photorefraction [erroneously called photoretinoscopy, (Fig. 4)].

From Fig. 4 it would be obvious to the reader that the distribution of pixel luminosity is different in an emmetropic eye vis-à-vis a hyperopic and a myopic eye. When a subject begins to accommodate (Fig. 4, middle panel), the emergent rays become divergent due to induced myopia (pseudo myopia). The light rays reflected from top of the subject's pupil are no more seen by the examiner. Those rays arrive below the viewing aperture (peephole) of the direct ophthalmoscope. Hence the pupillary reflex appears dark at the top while the rays from the lower part of the pupil are reflected back to the viewing aperture of the ophthalmoscope. More the accommodation, higher will be the divergence of the rays and hence more rays reflected from the lower part of the pupil enter the peephole of the direct ophthalmoscope. This results in increasing size of the inferior crescent with rising accommodation [Fig. 1].

With practice, one can easily estimate the size of the crescent and the amount of accommodation being exerted by the subject. However, more objectivity is essential when it comes to accurate measurement of accommodation utilizing the principles of DDDO (photorefraction). This can be easily done by converting the digital images to *Pixel Intensity Gradient* plots [Fig. 3] and assess the characteristics of the resultant curves. These curves can then be utilized for assessment of accommodation objectively.[8-10]

It is reported that as many as 80% children with Down syndrome, more than 50% children with cerebral vision impairment and several children with asthenopia or foveal hypoplasia, albinism, aniridia, ectopia lentis, amblyopia, and internal ophthalmoplegia (postviral illness or congenital supranuclear etiology) suffer from defects in accommodation.[11-15] Accommodative lag and its treatment may also have an important role in the management of progressive myopia.[16] In this study we found excellent clinical agreement (kappa>0.9) and very good sensitivity, specificity and predictive values of DDDO for detection of defects in accommodation in such children.

However, due to excessive *subjectiveness* in assessment of quality of these defects, we refrained from further analyzing the types of the defects in accommodation on these (two) different techniques. We realize that DDDO has a higher chance of going wrong in presence of an uncorrected refractive error, specifically a hyperopia or hyperopic astigmatism. This is simply because, a clinician relying excessively on disappearance of bright crescent from the top of the pupillary area may be foxed by a larger than normal superior crescent to begin with, in patients with hyperopia. However, with experience, false positive test results are likely to decrease provided the examiner learns to take into account the thickness of the superior crescent in hypermetropes before they commence accommodation.

An important and common utility of DR or DDDO would be to assess the completeness of cycloplegia after pharmacological dilatation of pupil in children with ametropia.[1] Under the condition of mydriasis, retinoscopy is known to become less reliable.[17] This can happen due to either interference from the peripheral aberration, especially spherical aberrations, from the crystalline lens that produce two conflicting reflexes, exactly in the opposite direction, one from the center of the lens and another one from the periphery. Or simply the examiner is refracting "off" the visual axis due to mydriasis. Although, both these phenomena can influence the results and interpretation of DDDO, we found DDDO to be more reliable than DR (two false negatives on DR) under the condition of mydriasis.

We believe DDDO is an easier test than DR. Location of bright crescent moving from top to the bottom of the pupil is probably easier to recognize [Fig. 5] than change in the movement of the retinoscopy reflex ("with" movement to the

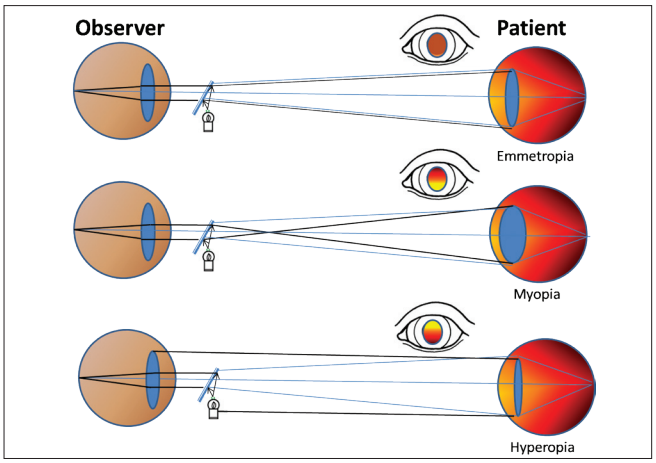

Figure 4: Optics of DDDO. The light from reflecting mirror of the ophthalmoscope is seen in blue. The reflected light (black) from the patient's eye takes a different path in myopia (convergent) and hyperopia (divergent). This results in different pattern of appearance in the pupillary glow

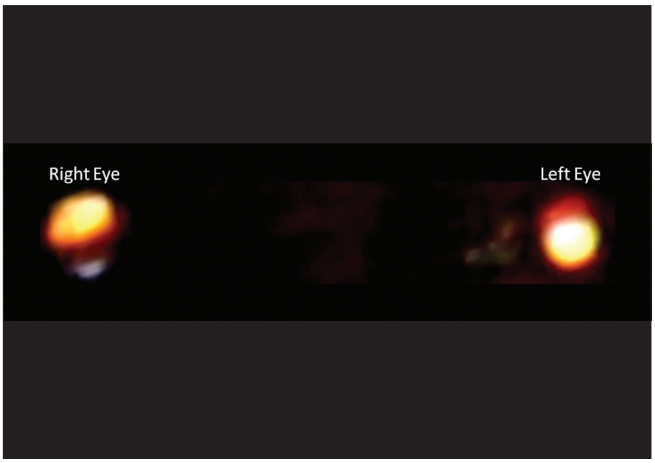

Figure 5: DDDO in a 12-year old, emmetropic child reading N6 print at 8 cm under mydriasis. The light reflex from the right eye shows dilated pupil with minimal or no accommodative response (dilated with 1% cyclopentolate). The light reflex from the left eye shows dilated pupil with excellent accommodative response (dilated with 10% phenylephrine)

"against" movement), more so when the pupils are dilated. This may also be the reason that DDDO could detect the onset of accommodation failure after instillation of cycloplegic a little bit earlier than DR in all the five patients that we examined in the later part of the study.

In this study the same examiner performed DDDO and DR in the same patient at the same time introducing a bias. Future studies should be done with two separate examiners to determine interobserver agreement and sequential examination of the same patient on two different days to assess intraobserver agreement.

An emmetropic eye has "with" movement on retinoscopy and "superior" crescent on DDDO while 1D myopia (due to accommodation) shows "no movement" on retinoscopy and disappearance of superior crescent on DDDO. Although we did not confirm this by performing diopteric calculation with DR and/or DDDO, future studies should address it. We believe, 1D loss of accommodation is clinically significant and produced detectable difference in the reflex on DR and DDDO. Hence, sample size calculation took into account 1 diopter difference in accommodation between the two techniques as significant.

Reflex stimulated by accommodation is certainly more complex and streak retinoscopy clearly has an advantage of additional information on accommodation induced in various direction/meridia. This may have an application in lenticular astigmatism. DR may also be superior when it comes to quantifying the accommodation by using trial lenses. Future studies might need to produce more evidence on the consistency and applicability of the technique.

In summary, DDDO is a novel, clinical, useful, simple and reliable method to assess accommodation in both eyes simultaneously.

Further studies are necessary that compare DDDO and DR with other subjective and objective methods of assessment of accommodation.

References

1. Guyton DL, O'Connor GM. Dynamic retinoscopy. Curr Opin Ophthalmol 1991;2:78-80.
2. Hunter DG. Dynamic retinoscopy: The missing data. Surv Ophthalmol 2001;46:269-74.
3. Win-Hall DM, Glasser A. Objective accommodation measurements in prepresbyopic eyes using an autorefractor and an aberrometer. J Cataract Refract Surg 2008;34:774-84.
4. Marchini G, Pedrotti E, Modesti M, Visentin S, Tosi R. Anterior segment changes during accommodation in eyes with a monofocal intraocular lens: High-frequency ultrasound study. J Cataract Refract Surg 2008;34:949-56.
5. Naduvilath TJ, John RK, Dandona L. Sample size for ophthalmology studies. Indian J Ophthalmol 2000;48:245-50.
6. Rosenfield M, Portello JK, Blustein GH, Jang C. Comparison of clinical techniques to assess the near accommodative response. Optom Vis Sci 1996;73:382-8.
7. Rid A, Schmidt H. The 2008 Declaration of Helsinki - First among equals in research ethics? J Law Med Ethics 2010;38:143-8.
8. Bossong H, Swann M, Glasser A, Das VE. Applicability of infrared photorefraction for measurement of accommodation in awake-behaving normal and strabismic monkeys. Invest Ophthalmol Vis Sci 2009;50:966-73.
9. Gabriel GM, Mutti DO. Evaluation of infant accommodation using retinoscopy and photoretinoscopy. Optom Vis Sci 2009;86:208-15.
10. Jainta S, Jaschinski W, Hoormann J. Measurement of refractive error and accommodation with the photorefractor PowerRef II. Ophthalmic Physiol Opt 2004;24:520-7.
11. Woodhouse JM, Meades JS, Leat SJ, Saunders KJ. Reduced accommodation in children with Down syndrome. Invest Ophthalmol Vis Sci 1993;34:2382-7.
12. McClelland JF, Parkes J, Hill N, Jackson AJ, Saunders KJ. Accommodative dysfunction in children with cerebral palsy: A population-based study. Invest Ophthalmol Vis Sci 2006;47:1824-30.
13. Abdi S, Rydberg A. Asthenopia in schoolchildren, orthoptic and ophthalmological findings and treatment. Doc Ophthalmol 2005;111:65-72.

14. Kothari M, Mody K, Walinjkar J, Madia J, Kaul S. Paralysis of the near-vision triad in a child. J AAPOS 2009;13:202-3.
15. Simons K. Amblyopia characterization, treatment, and prophylaxis. Surv Ophthalmol 2005;50:123-66.
16. Berntsen DA, Sinnott LT, Mutti DO, Zadnik K; The CLEERE Study Group. Accommodative lag and juvenile-onset myopia progression in children wearing refractive correction. Vision Res 2011;51:1039-46.
17. Rabbetts RB. Retinoscopy (skiascopy). In: Rabbetts RB, editor. Bennett and Rabbetts' clinical visual optics. 3rd ed. MD, USA: Butterworth-Heinemann; 2004. p. 343.

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