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Are traditional methods of balancing accommodation still useful in the modern optometry office? A comparison of methods

Przemysław PEMPERA[1], Monika FELTZKE[2*], Bogdan MIŚKOWIAK[2]

[1] Postgraduate Study of Optometry, Department of Optometry and Biology of Visual System, Poznań University of Medical Sciences, Poznań, Poland

[2] Department of Optometry and Biology of Visual System, Poznań University of Medical Sciences, Poznań, Poland

[*] Corresponding author: monikab@ump.edu.pl

The goal of this research is to compare the usefulness of both Turville infinity balance (TIB) and Humphriss immediate contrast (HIC) as methods of balancing accommodation. Statistical analysis of test results and practical application of both tests were taken into account. A group of 50 people between 18 to 72 years of age were examined. Balancing the state of accommodation of each eye by the two aforementioned methods was performed after refractive examination and full correction of refractive errors. The examination was carried out by the use of phoropter and optotypes on the LCD monitor. Bland–Altman plots were used as a method of statistical analysis. Calculations were made by the use of the programs Excel 2000 and MedCalc. Three variables d, T and H were defined as the differences in spherical lens powers, right and left eye respectively, after monocular refraction (d), after the balance of accommodation by the TIB test (T) and after the balance of accommodation by HIC test (H). The mean difference between TIB and HIC methods for the same individuals was +0.05 (95% limits of agreement: from –0.40 to +0.51 D), the mean difference between the refraction monocular (d) and the TIB method (T) was +0.01 D (95% limits of agreement: –0.48 to +0.50 D), the mean difference between monocular refraction (d) and HIC method (H) was 0.07 D (95% limits of agreement: from –0.56 to +0.69 D). Comparison of the selected methods of balancing accommodation shows that for patients, in whom it can be used, the Turville infinity balance test is a superior method to the Humphriss immediate contrast test.

Keywords: binocular balance, Turville infinity balance, Humphriss immediate contrast.

1. Introduction

Balancing accommodation between the two eyes, referred to as a binocular balance, is a necessary step during refraction. The exception would be examinations performed on individuals with monocular vision, or possibly strabismus. The aim of binocular balance is not equal visual acuity between the eyes, but rather to equalize an accommodative effort [1]. Only if the visual acuity with full correction of refractive errors is equal in both eyes is it possible to examine the binocular balance based on the comparison of visual acuity. The balancing of accommodation avoids oscillations of accommodation and provides control of the monocular refractive examination. RABBETTS [2] noted that unbalanced correction of the two eyes could lead to asthenopia resulting from alternating focused images. BORISH and BENJAMIN [3] also noted that unbalanced accommodation can lead to deterioration of stereopsis and reduced convergent ranges of fusion. Their findings suggest that even minimal unequal stimulus may be the etiology of the chief complaint. Therefore, when performing any method of binocular balance in emerging presbyopes, each has to be performed in the near absence of accommodation, otherwise monocular examination quality will not be respected. So, what is the best way to insure binocular accommodative balance in emergent presbyopic eye examinations without creating an undue imbalance of visual acuity?

There are several methods for achieving binocular balance. They can be divided into two groups: the first requires equal visual acuity in each eye while wearing a full correction of refractive status. The second does not require symmetric acuities in each eye. The first group includes, for example, Turville infinity balance (TIB) test, equal loss of acuity with a plus blur or balancing accommodation with the use of polarizing filters. The second group would include Humphriss immediate contrast (HIC) test and the red-green equalization method.

In addition to considering the refractive status and visual acuities, some methods of determining binocular balance require the dissociation of the images between the two eyes. Both RABBETTS [2] and BORISH and BENJAMIN [3], however, prefer the methods where fusion is maintained throughout, arguing better control of accommodation and convergence by retaining the more natural condition of vision. Again, the TIB and HIC tests are examples of non-dissociative methods.

The goal of the present research is to compare the clinical usefulness between the TIB and HIC tests as methods of balancing accommodation (see Section 2 for description of tests). Interest in these particular methods is attributable to not using polarizing filters (polarizing filters within a phoropter may extinguish test objects displayed from an LCD screen) and the fact that HIC and TIB can be used for both binocular balance and binocular refraction [2–8].

2. Modifications of both tests

RABBETTS [2] advocates including the red-green test in the TIB method. We have successfully used this approach in situations where best-corrected visual acuity is not the same in both eyes. The weakness of the TIB test seems to be the lack of a central stimulus for fusion. There is the black frame only for peripheral fusion, therefore patients with significant exophoria have difficulty with the observation of signs on both sides of the septum, causing problems with each eye's image being combined into one. Turville used the letters F and L to detect such situations [1]. If the patient reported is seeing only one letter E, then the examiner would know that the base-in prism is necessary to separate the two letters. An attempt to alleviate the problem was the use of a narrower septum (21 mm) with a visible strip of symbols in the center that created a central stimulus for fusion [2]. SHAPIRO [9] described the modification of the TIB test that he felt created a tool to examine binocular balance, suppression, perceived differences in image size and shape, as well as, heterophoria. In his studies, SHAPIRO noted that this modified test demonstrated how changing one parameter affected the others. The test was created by combining Turville's idea with dissociation using polarizing filters. It is found to be complicated and cumbersome when used in the clinical setting [10]. The HIC method may also incorporate the red-green test similar to the TIB [1].

3. Methods

A group of 50 subjects were examined. All subjects fulfilled the following criteria: age of consent; consent to use the results in research; the lack of observed or previously identified pathology of the visual system; the lack of suppression and binocular vision disorder that would impede the TIB test execution; monocular visual acuity with the best correction equal or better than 0.8. Subjects were from 18 to 72 years old, their mean age was 40 years (standard deviation, 15 years). Spherical equivalent of refractive error ranged from –6.4 D to 5.5 D, with the average being –0.9 D (standard deviation 2.0 D).

Binocular balance was performed in an optometric office and after ocular examination, including an interview, preliminary examination, refraction survey (objective refraction via autorefractometer, monocular subjective refraction of each eye and then balancing the state of accommodation of the two eyes, first by the TIB followed by the HIC). The starting point of binocular balance was determined by the monocular powers obtained during the examination. All tests were carried out using a LCD computer screen and the Reichert Ultramatic RX Master Phoroptor. Bland–Altman plots were used as a method of statistical analysis [11–13]. Calculations were made using Excel 2000 and MedCalc 11.6.1.0 version. Both procedures were performed at a distance of six meters with moderate illumination.

In order to facilitate the comparison of data that represents differences between the values of spherical power of the right and left eye, the following variables have been introduced:

$$d = R_{\mathrm{R\ sph}} - R_{\mathrm{L\ sph}}$$

$$T = \mathrm{TIB}_{\mathrm{R\ sph}} - \mathrm{TIB}_{\mathrm{L\ sph}}$$

$$H = \mathrm{HIC}_{\mathrm{R\ sph}} - \mathrm{HIC}_{\mathrm{L\ sph}}$$

where: $R_{\mathrm{R\ sph}}$ – spherical corrective lens of the right eye after monocular distance subjective refraction, $\mathrm{R}_{\mathrm{L\ sph}}$ – spherical corrective lens of the left eye after monocular distance subjective refraction, $\mathrm{TIB}_{\mathrm{R\ sph}}$ – spherical corrective lens of the right eye after the TIB method, $\mathrm{TIB}_{\mathrm{L\ sph}}$ – spherical corrective lens of the left eye after the TIB method,

$HIC_{R\ sph}$ – spherical corrective lens of the right eye after the HIC method, $HIC_{L\ sph}$ – spherical corrective lens of the left eye after the HIC method.

Turville infinity balance test was performed by using a phoropter, a mirror with a 3 cm white stripe as a septum with the Turville test projected on the LCD screen. The septum was positioned so that the right set of optotypes was viewed only by the right eye, and the left set of optotypes by the left eye. If suppression or horizontal heterophoria prevented the simultaneous observation of optotypes on each side, the research was discontinued. If hyperphoria was observed, the weakest prism that resulted in vertical alignment was used. If the test was administrable, the patients were then asked to choose the optotype that was most clear. They eye with superior visual acuity was overcorrected with +0.50 D. If the visual acuity was equal, the left eye was overcorrected with +0.50 D. Once it was determined which eye was to receive the +0.50 D overcorrection, the second eye was given an amount of plus until an equal blur between the two eyes was reported.

The Humphriss immediate contrast test was accomplished by using the phoropter, optotypes projected on an LCD screen, and loose lenses of +0.25 D and –0.25 D. Letters 0.5 were observed by the subject. A +0.75 D or a +1.00 D lens was placed over the left eye to blur the 0.5 letter optotypes. The subject observed the letters while a +0.25 D mobile lens was placed over the right eye for a few seconds. The +0.25 D was then changed to the –0.25 D mobile lens very quickly and it was kept in place for 1 second before again being replaced by the +0.25 D lens. The subject then identified the lens which provided the clearest vision. If, with the first trial, the patient chose the –0.25 D lens, the power of the lens over that eye was reduced by the same amount. If in the next trial the subject again indicated improved clarity with the –0.25 D lens, an additional –0.25 D was added and the procedure was repeated. However, if the patient chose the +0.25 D lens as more clear, the power of the lens over the examined eye was changed by adding +0.25 D and the testing was complete. If, in the first trial, the subject indicated clearer vision with the +0.25 D lens, then the power of the lens over the examined eye was changed by +0.25 D and repeated until he reported increased clarity with the –0.25 D lens. At this point, –0.25 was added to the examined eye and the procedure was completed. Lastly, if the subject did not appreciate a difference in acuity between each lens, this step was finished. An overcorrection of +0.75 D to +1.00 D was then put over the examined eye to determine if the visual acuity was still on the 0.5 level. The same procedure was carried out for the other eye.

This research is consistent with the tenets of the Declaration of Helsinki and was approved by Poznań University of Medical Sciences Institutional Review Board. Each subject was informed about the nature of this research and gave written consent for his participation.

4. Results

A group of 50 subjects were examined and given the correction for their respective refractive errors. Table 1 illustrates the values of refractive errors and results of spher-

T a b l e 1. Results showing correction of monocular refraction and spherical lenses after TIB and HIC, as well as, visual acuity after monocular refraction.

ID	Age [years]	Spherical monocular refraction				After TIB		After HIC		Visus after monocular refraction	
		OD sph [D]	OD cyl [D]	OS sph [D]	OS cyl [D]	OD sph [D]	OS sph [D]	OD sph [D]	OS sph [D]	OD	OS
1	55	–4.25	–0.75	–3.25	–1.00	–4.00	–2.75	–4.50	–3.25	1.25	1.25
2	18	0.00	0.00	–1.75	0.00	0.50	–1.50	0.00	–1.75	1.25	1.25
3	47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.25	1.25
4	47	–2.00	–0.75	–2.00	–0.25	–1.50	–1.75	–2.00	–2.00	1.00	1.00
5	47	0.25	–0.75	0.00	0.00	1.00	0.50	0.75	0.00	1.60	1.60
6	44	–0.50	–0.75	–0.25	–1.50	–0.25	–0.25	–0.50	–0.25	1.00	1.00
7	37	–3.00	–0.75	–3.50	–0.50	–2.75	–3.00	–2.75	–3.25	1.25	1.25
8	21	–1.25	0.00	–1.25	0.00	–0.75	–1.00	–1.25	–1.75	1.00	1.00
9	32	0.25	–0.50	0.00	0.00	0.25	0.00	0.25	0.25	1.00	1.00
10	45	–0.50	–0.25	–0.50	–0.50	0.00	0.00	–0.25	–0.50	1.25	1.25
11	37	0.00	0.00	0.00	0.00	0.25	0.50	–0.25	0.50	1.00	1.00
12	18	–0.25	0.00	0.25	–0.25	–0.25	0.75	–1.00	0.50	1.25	1.25
13	44	0.00	–0.50	0.50	–0.25	0.50	1.00	0.25	0.50	1.00	1.00
14	40	–2.25	–0.50	–2.50	–0.50	–1.75	–2.25	–2.50	–2.75	1.25	1.25
15	45	–0.25	–0.25	0.00	–0.25	–0.50	–0.25	–1.00	–0.75	1.25	1.25
16	18	–0.25	0.00	–0.50	0.00	0.00	0.00	–0.25	–0.25	1.25	1.25
17	40	–1.25	0.00	–1.50	0.00	–1.00	–1.25	–1.75	–2.00	1.25	1.25
18	22	–0.50	–0.75	0.00	–0.50	0.00	0.25	–0.50	–0.25	1.25	1.25
19	18	–0.50	–0.25	0.25	–0.50	0.00	0.50	–0.25	0.25	1.25	1.25
20	40	–2.00	–0.25	–2.00	0.00	–2.00	–2.00	–2.25	–2.25	1.00	1.25
21	50	0.50	–0.75	0.25	–0.25	0.50	0.50	0.25	0.25	1.25	1.25
22	53	1.50	0.00	1.50	0.00	1.50	1.50	1.25	1.25	1.25	1.25
23	70	–1.50	–1.00	–4.75	–1.25	–1.50	–4.75	–1.75	–4.75	0.80	0.80
24	41	0.50	–0.50	0.50	–0.25	1.00	0.75	–0.25	0.00	1.25	1.25
25	50	–1.25	–0.25	–1.00	–0.75	–1.50	–0.75	–1.25	–1.00	1.25	1.25
26	60	1.00	–1.00	1.25	–1.00	1.50	1.75	1.00	1.25	1.25	1.00
27	50	1.00	–1.25	–0.25	0.00	1.50	1.00	1.00	0.50	1.60	1.60
28	25	–1.75	–0.75	–1.50	0.00	–1.00	–1.00	–1.50	–1.25	1.25	1.25
29	44	0.50	–0.25	0.25	–0.25	0.50	0.50	0.75	0.50	1.60	1.60
30	72	1.75	–1.00	0.25	–1.25	2.00	0.25	1.75	0.25	1.00	1.00
31	20	–4.50	0.00	–3.50	–0.50	–4.25	–3.00	–4.75	–3.75	1.25	1.25
32	39	0.25	–0.25	0.50	–0.50	0.75	0.75	0.75	1.00	1.25	1.00
33	25	1.75	–3.25	1.50	–2.75	2.00	2.00	1.25	1.50	1.25	1.25
34	65	–2.50	–0.50	–2.50	–0.25	–2.25	–2.25	–2.50	–2.50	1.60	1.60
35	55	1.75	–1.50	0.25	–0.25	1.75	0.75	1.50	1.00	1.25	1.25

To be continued on the next page.

T a b l e 1. Continued.

ID	Age [years]	Spherical monocular refraction				After TIB		After HIC		Visus after monocular refraction	
		OD sph [D]	OD cyl [D]	OS sph [D]	OS cyl [D]	OD sph [D]	OS sph [D]	OD sph [D]	OS sph [D]	OD	OS
36	27	–0.50	–1.00	0.00	–1.50	0.00	0.50	–0.50	0.25	1.60	1.60
37	58	1.75	–1.50	2.75	–1.50	2.25	3.50	2.00	3.25	1.25	1.25
38	34	–5.50	0.00	–5.50	0.00	–5.25	–5.25	–5.25	–5.25	1.25	1.25
39	33	–1.00	0.00	–1.00	0.00	–0.50	–0.75	–1.00	–1.00	1.25	1.25
40	18	–4.25	0.00	–4.00	0.00	–3.75	–3.75	–4.25	–4.25	1.25	1.25
41	27	–1.00	–0.75	–1.25	–0.25	–0.50	–0.75	–1.25	–1.50	1.25	1.25
42	65	6.00	–1.00	5.75	–0.75	6.00	5.50	6.00	5.75	1.25	1.00
43	18	–6.00	–0.75	–5.50	–0.25	–5.50	–5.00	–6.00	–5.50	1.25	1.25
44	22	–2.25	–1.00	–2.75	–0.50	–1.75	–2.00	–2.25	–2.75	1.25	1.25
45	55	–1.75	0.00	–1.25	–0.50	–1.75	–1.25	–2.00	–1.25	1.25	1.25
46	50	1.75	–0.25	1.75	–0.50	2.25	2.25	1.50	1.50	1.60	1.60
47	50	3.25	–0.25	3.00	0.00	3.50	2.75	3.25	2.50	1.60	1.25
48	49	–0.25	–0.75	0.25	–2.00	0.25	0.75	0.00	0.25	1.25	1.25
49	24	–0.75	–0.25	–0.75	0.00	–0.25	–0.25	–0.75	–1.00	1.25	1.25
50	50	0.25	–0.50	–0.25	–0.25	0.75	0.25	0.25	–0.25	1.25	1.25

ical lenses, as well as, the visual acuity after monocular refraction once the TIB and HIC were performed. Mean value of the spherical refractive error for the right eye was –0.59 D (±2.13) while the left eye was –0.68 D (±2.09). Mean value of astigmatism was –0.55 D (±0.57) for the right eye and –0.47 D (±0.59) for the left. This demonstrated that in most cases the astigmatism was not higher than 1.0 D in the examined group, with one exception of a subject with 3.0 D of cylinder.

Table 2 shows the difference in spherical powers between the TIB and HIC methods after monocular refractions were completed. The values outside the range of ⟨–0.25, +0.25⟩ are indicated in bold. For the HIC method, 4 results have only a 0.50 D difference in comparison with the monocular refraction, while there was only one case with a similar result when using the TIB. The HIC procedure also shows a difference of more than 0.25 D for the 8 subjects, while there was only 5 when using the TIB.

Figures 1 to 6 illustrate the distribution of differences and the disparity of spherical corrective lenses after monocular distance subjective refraction between the HIC and TIB methods. Figures 1, 3 and 5 confirm that nearly all results are included in the statement of ranges.

5. Discussion

When analyzing the results, the most important question is the magnitude of the error of measurement. This study referred to the question if the measurement error of vari-

T a b l e 2. Values demonstrating the differences between the spherical powers of monocular refractions between TIB and HIC methods.

ID	*d* [D]	*T* [D]	*H* [D]	*d* – *T* [D]	*d* – *H* [D]	*T* – *H* [D]
1	–1.00	–1.25	–1.25	0.25	0.25	0.00
2	1.75	2.00	1.75	–0.25	0.00	0.25
3	0.00	0.00	–0.25	0.00	0.25	0.25
4	0.00	0.25	0.00	–0.25	0.00	0.25
5	0.25	0.50	0.75	–0.25	**–0.50**	–0.25
6	–0.25	0.00	–0.25	–0.25	0.00	0.25
7	0.50	0.25	0.50	0.25	0.00	–0.25
8	0.00	0.25	0.50	–0.25	**–0.50**	–0.25
9	0.25	0.25	0.00	0.00	0.25	0.25
10	0.00	0.00	0.25	0.00	–0.25	–0.25
11	0.00	–0.25	–0.75	0.25	**0.75**	**0.50**
12	–0.50	–1.00	–1.50	**0.50**	**1.00**	**0.50**
13	–0.50	–0.50	–0.25	0.00	–0.25	–0.25
14	0.25	0.50	0.25	–0.25	0.00	0.25
15	–0.25	–0.25	–0.25	0.00	0.00	0.00
16	0.25	0.00	0.00	0.25	0.25	0.00
17	0.25	0.25	0.25	0.00	0.00	0.00
18	–0.50	–0.25	–0.25	–0.25	–0.25	0.00
19	–0.75	–0.50	–0.50	–0.25	–0.25	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.25	0.00	0.00	0.25	0.25	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00
23	3.25	3.25	3.00	0.00	0.25	0.25
24	0.00	0.25	–0.25	–0.25	0.25	**0.50**
25	–0.25	–0.75	–0.25	**0.50**	0.00	**–0.50**
26	–0.25	–0.25	–0.25	0.00	0.00	0.00
27	1.25	0.50	0.50	**0.75**	**0.75**	0.00
28	–0.25	0.00	–0.25	–0.25	0.00	0.25
29	0.25	0.00	0.25	0.25	0.00	–0.25
30	1.50	1.75	1.50	–0.25	0.00	0.25
31	–1.00	–1.25	–1.00	0.25	0.00	–0.25
32	–0.25	0.00	–0.25	–0.25	0.00	0.25
33	0.25	0.00	–0.25	0.25	**0.50**	0.25
34	0.00	0.00	0.00	0.00	0.00	0.00
35	1.50	1.00	0.50	**0.50**	**1.00**	**0.50**
36	–0.50	–0.50	–0.75	0.00	0.25	0.25
37	–1.00	–1.25	–1.25	0.25	0.25	0.00

To be continued on the next page.

Table 2. Continued.

ID	*d* [D]	*T* [D]	*H* [D]	*d* – *T* [D]	*d* – *H* [D]	*T* – *H* [D]
38	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.25	0.00	–0.25	0.00	0.25
40	–0.25	0.00	0.00	–0.25	–0.25	0.00
41	0.25	0.25	0.25	0.00	0.00	0.00
42	0.25	0.50	0.25	–0.25	0.00	0.25
43	–0.50	–0.50	–0.50	0.00	0.00	0.00
44	0.50	0.25	0.50	0.25	0.00	–0.25
45	–0.50	–0.50	–0.75	0.00	0.25	0.25
46	0.00	0.00	0.00	0.00	0.00	0.00
47	0.25	0.75	0.75	**–0.50**	**–0.50**	0.00
48	–0.50	–0.50	–0.25	0.00	–0.25	–0.25
49	0.00	0.00	0.25	0.00	–0.25	–0.25
50	0.50	0.50	0.50	0.00	0.00	0.00

ables *d*, *T* and *H* is the sum of the measurement errors of the monocular refraction. To the variable *d* the answer is yes, the theoretical measurement error is 0.25 D + 0.25 D = = 0.50 D. BORISH and BENJAMIN [3] reported that the measurement error of the correctly carried out examination of refractive condition is ±0.25 D. The worst situation would be the error of one eye to be –0.25 D while the second eye was +0.25 D. In this situation, the measurement error for both eyes is 0.50 D. We therefore expect that the method of verifying the difference does not have an error greater than 0.50 D. But to variables *T* and *H*, the estimation of the measurement error is not as simple when compared to variable *d*. GENTSCH and GOODWIN [1] described the results of research in which several methods of binocular balance were compared. In these studies, the optometer to measure the state of accommodation was used to confirm the results. These studies show that the best method of binocular balance is TIB.

During the TIB procedure we observed that all patients were very sensitive to a change of lens power consisting of only 0.25 D and some had reacted to change of 0.12 D. Based on this clinical observation, we are persuaded that the measurement errors for the TIB method are no greater than 0.25 D. Other publications where similar comparison with the HIC method were made, were not discovered in a literature search.

Figure 1 shows that both methods have the same result (mean difference is +0.05 D), suggesting that the systematic error does not exist or is equal between the two methods.

Figure 1 also shows that the scattering of results neither increase nor decrease with increasing *T* and *H*. It is believed that this indicates no relationship between the differences between the eyes after balancing for both methods. In the same figure, the limits of agreement were defined by dashed lines. If the differences in the range of ±1.96

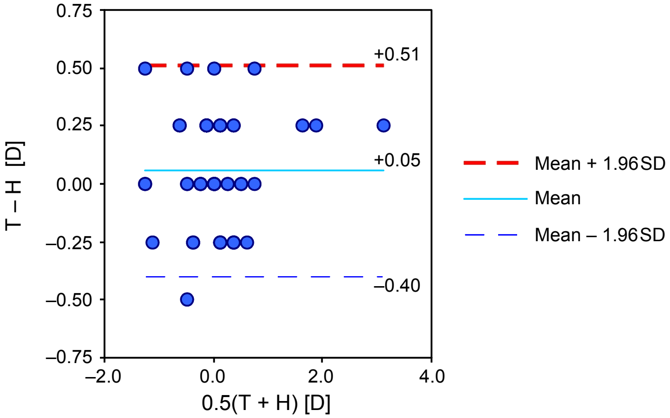

Fig. 1. Differences between the values of *T* and *H* relative to the arithmetic mean of *H* and *T* (Bland –Altman diagram). Standard deviation (*T* – *H*) SD = 0.34 D.

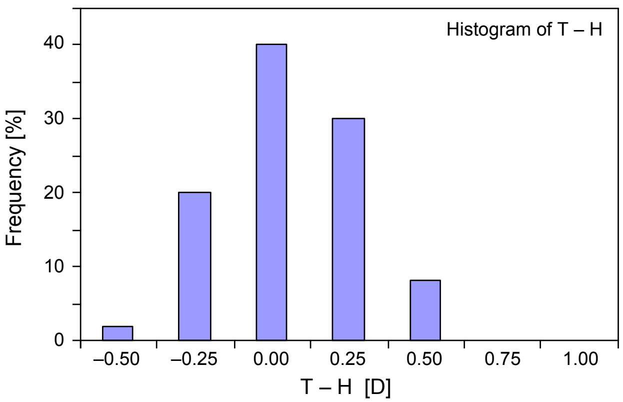

Fig. 2. Frequency distribution of difference cases between HIC and TIB methods.

are not clinically significant, the methods can be used alternatively. For the tested methods –1.96 = –0.40 D and +1.96 = +0.51 D. It follows that with probability 95% the difference between the methods is between –0.40 D and +0.51 D. For the assumed accuracy 0.50 D of balancing accommodation the both methods are equivalent.

To determine which of the two methods is more clinically useful, compatibility between monocular refraction from both methods of balancing accommodation is reviewed. Figure 3 shows the Bland–Altman plot for monocular refraction (variable *d*) and TIB method (variable *T*). As in the Fig. 1, the averages of the both variables are very similar (mean difference is +0.01 D), scattering of results demonstrates neither an increasing nor decreasing trend while increasing the differences between the eyes. But the limits of agreement are not the same in the two figures. In Figure 3

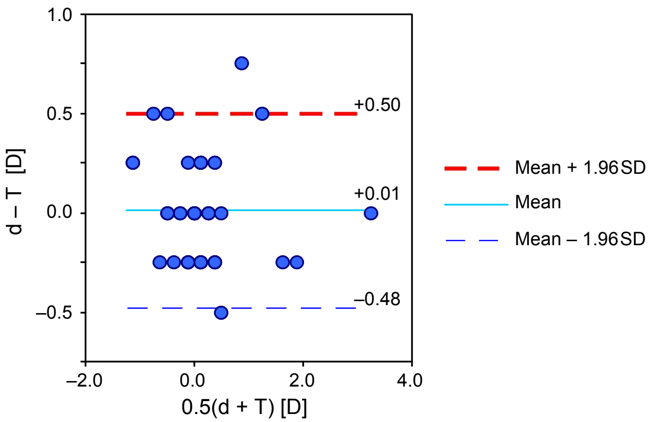

Fig. 3. Differences between the values of *d* and *T* relative to the arithmetic mean of *d* and *T* (Bland–Altman diagram). Standard deviation (*d* – *T*) SD = 0.25 D.

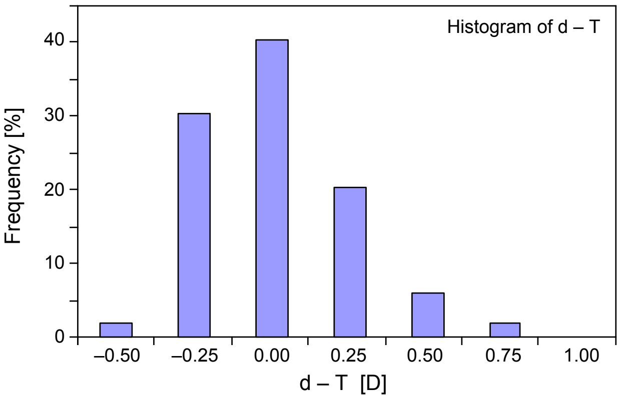

Fig. 4. Frequency distribution of difference cases between monocular refraction and TIB method.

the limits of agreement are between –0.48 D and +0.50 D. It follows that the conformity between the monocular refraction and TIB test is worse than between TIB and HIC methods.

Figure 5 shows the diagram for monocular refraction (variable *d*) and HIC method (variable *H*). Similarly to Figs. 3 and 4, the systematic error does not occur. The mean difference is +0.07 D and the scattering of the results is independent of the difference between the eyes.

The limits of agreement is between –0.56 D and +0.69 D is worse than for monocular refraction and TIB method. The results of the TIB method are more reliable than the results of HIC method.

The scattering of the results in the HIC method is characteristic. Table 2 shows that as many as four results in the HIC method has a 0.50 D difference from the mo-

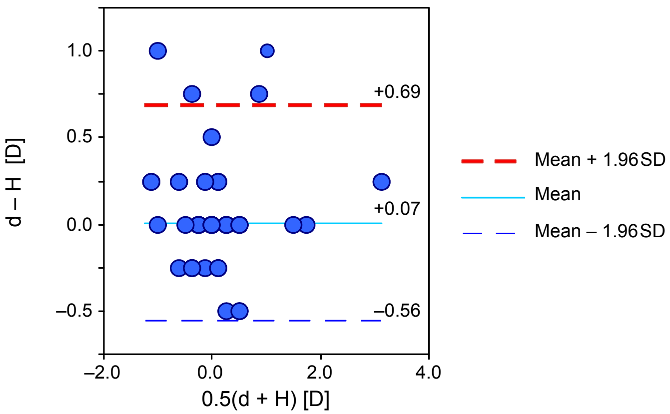

Fig. 5. Differences between the values of *d* and *H* relative to the arithmetic mean of *d* and *H* (Bland –Altman diagram). Standard deviation (*d* – *H*) SD = 0.32 D.

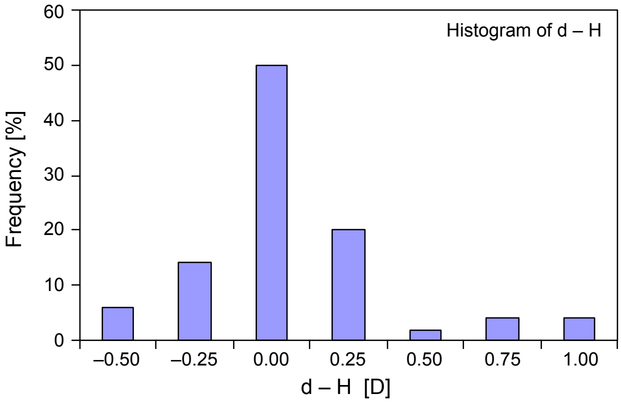

Fig. 6. Frequency distribution of difference cases between monocular refraction and HIC method.

nocular refraction results. For TIB method, only one similar result was appreciated. Additionally, for 8 subjects the results of HIC method differ more than 0.25 D, while for the TIB method only 5 results are different.

Two questions remain: first, why is the measurement error greater in the HIC method? Secondly, why is the scattering of results also greater? We propose several hypotheses. The first one is that patients with small pupil diameters need more than +0.75 D overcorrection to inhibit foveal vision [6]. In the present study, the pupil diameter was not measured so the authors cannot prove or disprove this hypothesis. The second hypothesis suggests that one second of testing duration is not sufficient for the patients to analyze the images in HIC method. Some patients may require additional time for accurate comparison. The third hypothesis is that the phoropter limited the peripheral stimulus for fusion and allowed biocular rather than binocular vision.

And finally, a fourth hypothesis would be that the subjects may have exhibited a strong dominant eye, making it difficult to suppress by the blurring [2].

6. The comparison of practical aspects to use the TIB and HIC methods

In terms of the necessary equipment and its cost, the HIC method is superior to TIB. In practice, the TIB method is difficult to use outside of the phoropter because of the patients side-to-side head movement while wearing trial frames. On the other hand, the HIC method is more comfortable while using the trial frames and manually alternating between the +0.25 D and –0.25 D lenses. In the TIB method, a disadvantage is the need for the mirror. Although MORGAN [7] used this method without the mirror, it is not as comfortable. Both methods are easy to carry out though the TIB method requires the subject's cooperation to place the septum on the mirror. For most of the patients the examination time was very similar, except for those who had very different results at the beginning and the end of the HIC method, where longer testing time was the rule. Lastly, the TIB method cannot be used for every patient because if higher heterophoria exists, the use of prism is required.

Comparison of the selected methods of balancing accommodation shows that the Turville infinity balance test is a superior method to the Humphriss immediate contrast test. The conclusion of this research is similar to that of WEST and SOMERS [14]. WEST and SOMERS concluded that the TIB is the most accurate equalization technique. They went on to suggest that the TIB is not appropriate for patients without normal binocular vision. Therefore in situations where the TIB method cannot be used, it may be replaced by the Humphriss as long as the practitioner is aware of its drawbacks (lower accuracy, longer test time and difficulty in determining the final results in some patients).

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