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GRAU EN ÒPTICA I OPTOMETRIA

TREBALL FINAL DE GRAU

REPEATABILITY OF THE MEASUREMENT OF THE HORIZONTAL PHORIA IN NEAR VISION WITH COVER TEST AND MODIFIED THORINGTON METHOD

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El/s Sr./Srs Jaume Pujol Ramo i Mikel Aldaba Arévalo, com a tutor/s i director/s del treball,

CERTIFICA/CERTIFIQUEN

Que la Sra. Gemma Gervilla Díaz ha realitzat sota la seva supervisió el treball **Repeatability of the measurement of the horizontal phoria in near vision with cover test and modified Thorington method** que es recull en aquesta memòria per optar al títol de grau en Òptica i Optometria.

I per a què consti, signo/em aquest certificat.

Sr/a JAUME PUJOL

Director/a del TFG

Sr/a MIKEL ALDABA

Director/a del TFG

Terrassa, 12 de JUNY de 2017

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REPEATABILITY OF THE MEASUREMENT OF THE HORIZONTAL PHORIA IN NEAR VISION WITH COVER TEST AND MODIFIED THORINGTON METHOD.

RESUM

Objectiu- Estudiar la repetibilitat del cover test alternant i el mètode modificat de Thorington.

Mètode- En aquest estudi han participat 10 persones joves i sanes amb agudesa visual de prop igual o superior a 20/20 amb la seva correcció habitual. El cover test es va realitzar amb un test a 40 cm d'agudesa visual de 20/25 i màxima il·luminació. Thorington es va realitzar a 40 cm amb la vareta Maddox davant de l'ull dret i la targeta corresponent, la il·luminació de la sala era reduïda. Ambdues mesures es van realizar dues vegades pel mateix examinador amb un interval de 24 hores. L'anàlisi estadística es va realitzar amb la versió SPSS 22.0.

Resultats- La mitjana absoluta de les diferències i la desviació estàndard entre les mesures del cover test va ser d'1.000±0.943 i 0.400±0.943 per Thorington (p=0.000). Bland & Altman mostren que hi ha una diferència d'aproximadament 0,5∇ entre les dues proves del cover test i no hi ha diferència apreciable entre les dues mesures amb el mètode de Thorington. S'obté una bona concordança en tots dos mètodes.

Conclusions- El cover test alternant i Thorington modificat van presentar una bona repetibilitat intraexaminador en visió de prop. Tots dos mètodes són precisos per quantificar la fòria en visió propera.

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REPEATABILITY OF THE MEASUREMENT OF THE HORIZONTAL PHORIA IN NEAR VISION WITH COVER TEST AND MODIFIED THORINGTON METHOD.

RESUMEN

Objetivo- Estudiar la repetibilidad del cover test alternante y el método modificado de Thorington.

Método- En este estudio han participado 10 personas jóvenes y sanas con agudeza visual en visión de cerca igual o superior a 20/20 con su corrección habitual. El cover test se realizó con un test a 40 cm de agudeza visual de 20/25 y máxima iluminación. Thorington se realizó a 40 cm con la varilla Maddox delante del ojo derecho y la tarjeta correspondiente, la iluminación de la sala era reducida. Ambas medidas fueron tomadas dos veces por el mismo examinador con un intervalo de 24 horas. El análisis estadístico se realizó con la versión SPSS 22.0.

Resultados- La media absoluta de las diferencias y la desviación estándar entre las medidas del cover test fue de 1.000 ± 0.943 y 0.400 ± 0.943 para Thorington (p = 0.000). Bland & Altman muestra que hay una diferencia de aproximadamente 0,5∇ entre las dos pruebas del cover test y no hay diferencia apreciable entre las dos medidas con el método de Thorington. Se obtiene una buena concordancia en ambos métodos.

Conclusiones- El cover test alternante y el método Thorington modificado presentaron una buena repetibilidad intraexaminador en visión de cerca. Ambos métodos son precisos para cuantificar la foria en visión cercana.

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REPEATABILITY OF THE MEASUREMENT OF THE HORIZONTAL PHORIA IN NEAR VISION WITH COVER TEST AND MODIFIED THORINGTON METHOD.

ABSTRACT

Purpose- Study the repeatability of the alternate cover test and modified Thorington method.

Methods- Ten young and healthy ocular people with visual acuity in near vision equal to or greater than 20/20 while wearing their habitual corrections were recruited to participate in this study. The cover test was performed with a target at 40 cm with a visual acuity 20/25 and maximum lighting. The modified Thorington test was performed at 40cm with the Maddox rod in front of the right eye and the correspondence card, the lighting in the room was reduced. Both measurements were taken twice by the same examiner separated by 24 hours. Statistical analysis was performed using SPSS 22.0 version.

Results- The absolute mean difference and standard deviation between the measurements with the cover test was 1.000±0.943 and 0.400±0.942 for the Thorington (p=0.000). Bland and Altman plots show that there is a difference of approximately 0.5∇ between the two cover tests and there is no appreciable difference between the two measurements with modified Thorington method. Good concordance is obtained in both methods.

Conclusions- The alternate cover test and the modified Thorington method had good intraexaminer repeatability in near vision. Both methods are precise to quantify the phoria in near vision.

1. Introduction

In recent years, people have become more concerned about visual problems. Although the most known visual disorders might be related to refractive error, disorders of the binocular vision are acquiring more importance, especially because of the increasing use of short working distances. Binocular vision happens when the two eyes participate in the perception of images. Binocular vision requires sensory fusion (the unification of two retinal images into a single visual image) and motor fusion (the ability to align the eyes in order for sensory fusion to be maintained) (1).

Primary gaze position is the position of the eyes when a person stays with the head raised, looking at a point in the infinite. In this position, visual axes should be parallel. Proper alignment of the eyes is confirmed with normally functioning sensory and motor fusion mechanisms. However, sometimes visual axes are not properly aligned. All neuromuscular anomalies related with the alignment of the eyes can be classified into two groups: *heterophoria* or *phoria*, if the deviation is latent, and heterotropia or *strabismus* when the deviation is manifested. When one eye is covered, sensory fusion is artificially suspended. Then, one eye is being excluded from vision, motor fusion is frustrated, and a measurable relative deviation of the visual axes will appear in most patients. When the obstacle to sensory fusion is removed, motor fusion in most patients will return the visual axes to their proper relative positions. This relative latent deviation is called *heterophoria*. There is a manifested deviation of one of the visual axes if there is not adequate functioning fusion mechanisms. *Heterotropias* are manifested deviations not kept in check by fusion (1).

Deviations can be classified depending on their direction as *exodeviation* (visual axes diverge), *esodeviation* (visual axes converge), *hyperdeviation* (one visual axis is higher than the other), *hypodeviation* (one visual axis is lower than the other), *incyclodeviation* (rotation to the left) and *excyclodeviation* (rotation to the right) (1). The condition in which the visual axis are well aligned is named *orthodeviation*.

Furthermore, deviations could vary with the position of gaze. When the deviation is similar in all positions of gaze, it is known as *comitant*, whereas in an *incomitant* deviation the angle of deviation changes with gaze position. *Incomitance* may be caused by neural factors (paralytic strabismus) or mechanical-restrictive factors. Another important aspect is the constancy of deviation. A *constant* deviation exists when the deviation is manifested at all times. When the patients are able to maintain the fusion mechanisms adequately to keep the eyes properly aligned in some circumstances but not in all, the deviation is *intermittent*. A person could have a *heterophoria* for one fixation distance and a *heterotropia* deviation for another fixation distance. Patients with a paralyzed muscle may be *heterotropic* in one direction of gaze but *heterophoric* in the opposite direction. The eye that maintains fixation is another important criterion for classifying *heterotropias*. There are two kinds of fixation: *unilateral heterotropias* if the patient uses always the same eye for fixation or *alternating heterotropias* in which the patient fixates with either eye (1).

The cover test is an objective method to evaluate the presence, direction and magnitude of a deviation (2). It is the most commonly used technique for the detection of *heterophoria* and *strabismus* (3). There exist three variants of this test. Firstly, the *unilateral cover test*, in which one eye is briefly covered and then uncovered. It is used principally to reveal the presence of a strabismic deviation. If the uncovered eye does not move when the cover is placed to the other eye, it means that it was fixating with the fovea and, therefore, does not present strabismus. If the uncovered eye moves to recover fixation, it indicates the presence of a *tropia*. Secondly, in the *alternating cover test* the cover is repeatedly switched from one eye to the other. A *phoria* will be diagnosed if the occluded eye moves when it is uncovered. Otherwise, there is orthophoria (2). This variant is the most dissociating technique because binocular vision is not allowed at any time. It is useful to detect the totality of the deviation or the presence of a *latent phoria*. Finally, the *cover-uncover test* is also used to detect and measure *heterophoria* if the eye makes some movement when the cover is removed. This test usually involves covering and uncovering each eye in turn while observing movements and direction of the eyes behind the cover (4). This technique is considerably difficult to perform because in order to see the eye behind the cover, it must be placed at certain distance from the eye and, in turn, the vision is not totally occluded. Actually, the impossibility of observing the covered eye is a limitation of the cover test.

When the eyes maintain fixation without any movement during the cover test, they are well aligned and there is an *orthodeviation*; but if the eyes move from inside to outside when uncovered there is an *esophoria*, or if the eyes move from outside to inside when uncovered there is an *exophoria*. *Hyperphoria* occur when the uncovered eye moves from top to bottom, whereas *hypophoria* is the opposite, which means movement from bottom to top (Figure 1 A, B, C, D). On the other hand, if there is a movement in one or both eyes when they are not covered, there is a *tropia* (Figure 1 E, F, G, H). It would be an *exotropia* if the eyes move to the nose or an *esotropia* if the movement is to outside. Otherwise, there a *hypotropia* if the movement is to the top or *hypertropia* if the movement is to the bottom (5).

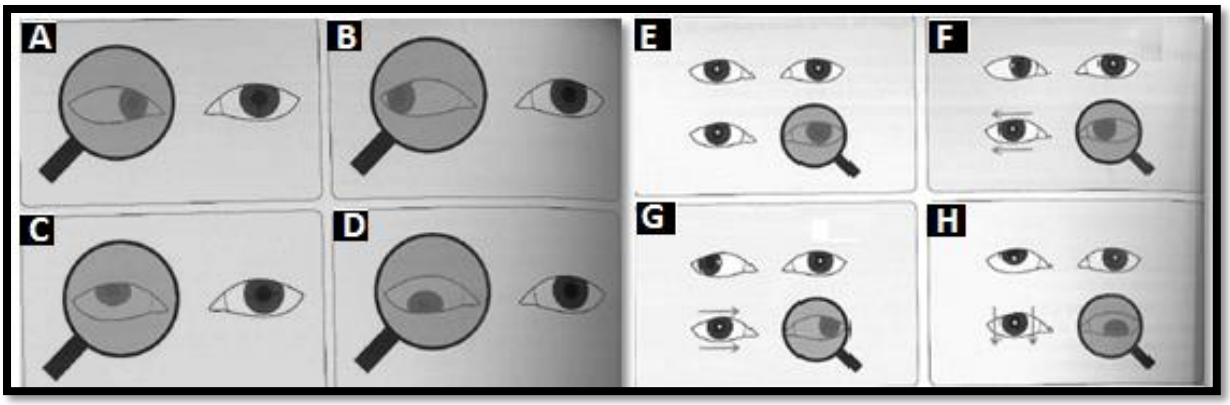

Figure 1. Phoria's and tropia's detection using cover test. A) Esophoria B)Exophoria C) Hyperphoria RE D)Hyperphoria LE E)Orthotropia F)Esotropia RE G) Exotropia RE H)Hypertropia RE (5)

The cover test is performed at both far (6 m) and near (40 cm) distances. The task for the patient is simply to stare at a target. The stimulus must be relatively small and with fine details to control accommodation. The refractive error of the patient at the corresponding distance needs to be corrected.

The deviation is typically measured with a prism bar. It consists of increasing the prism power until the examiner perceives no movement when performing the cover test. *Base-out* prisms are needed to neutralize *esodeviations* and base-in for *exodeviations*. The *hyperdeviations* are neutralized with *base-down* prisms and the *hypodeviations* with *base-up* prisms (6).

The normal values of *phoria* are considered to be 3 ∇ of *exophoria* ±3∇ in near vision and 1 ∇ of *exophoria* ±1∇ in far vision (2). The presence of strabismus is always abnormal.

Unfortunately, the prism value that neutralizes the movements during the cover test is not clear. Normally, the examiner adds prism until no movement is seen (first neutral). But there are a range of prism values in which no additional movement of the eye is seen (neutral range). Adding additional prism beyond the upper limit of this neutral range (high neutral) will result in an opposite movement of the eye (reversal point) and therefore will lead to a different diagnosis. Consequently, there are several possible endpoints: first neutral, high neutral, reversal, and any midpoint value of the three. Most literature suggests using first neutral as the optimum endpoint. However, there is no clear consensus on which endpoint must be the standard. Johns et al. showed that the first neutral and the midpoint of reversal endpoints provided high interexaminer and intraexaminer repeatability (<0.5∇). Although the two prism endpoints differed statistically, they concluded that the differences were not clinically significant (7).

There are other tests to detect and measure misalignments of the visual axis like modified Thorington method (Figure2).

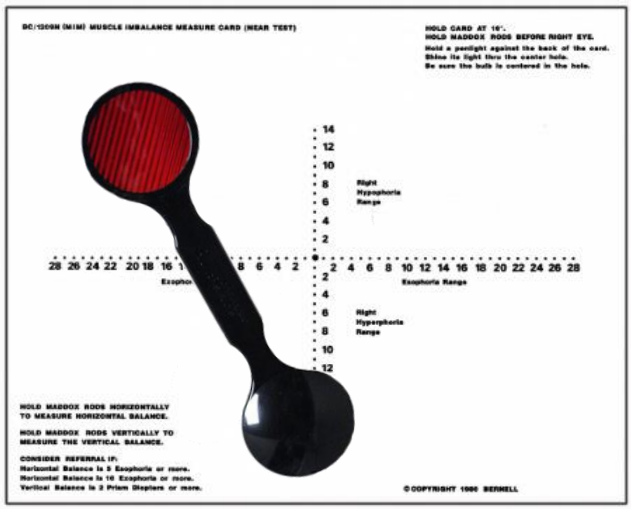

Figure 2. Maddox rod and modified Thorington card

Thorington is a subjective, easy and fast method to detect the magnitude and the direction of a phoria. A penlight, a Maddox rod and the Thorington card are needed to perform the test. The refractive error of the patient at the corresponding distance needs to be corrected. The Maddox rod is held before the right eye of the patient. The striations have to be oriented horizontally (patients see red vertical streak of light) to evaluate horizontal phoria or vertically (patient sees horizontal line) to measure the vertical phoria. The examiner hold the Thorington card at 40 cm with a penlight behind the centre hole of the card. The patient is required to look at the centre of the card and keep the numbers clear all time to control accommodation. The patient is asked to report the number where the line is passing and if it is to the right, left, above or below of the zero (2).

Other techniques are Von Graefe or Maddox the main drawback of these techniques and Thorington method is that they are subjective and need the patient to answer. Although all these tests are designed to measure the same angle, the intrinsic differences between techniques lead to a variability of the results. Among such factors there are the size and degree of complexity of the fixation targets. Daum suggested that there are significant differences in the result depending on the technique that is used to measure the angle of deviation (8).

Antona determined the repeatability of different techniques (cover test, Von Graefe, Maddox rod and Thorington) for measuring ocular deviation. The mean signed differences were less than or equal to 0.7∇ in all techniques studied in both far vision and near vision. The mean absolute differences were all smaller than 3.4∇ and no statistically significant differences were found. All techniques presented better repeatability at far vision than at near. In addition, this study confirmed that the prism cover test is the technique with the best repeatability (9).

Recently, the deviations of visual axes have been quantified using eye-trackers, which are instruments used to measure eye movements. However, its use is mainly in research (3,4). Eye-trackers' accuracy might be up to 0.2º. Therefore, it can detect small deviations (lower than 2∇) which are very difficult to detect with the conventional clinical methods by the examiner (10).

This project is focused on the measurement of the horizontal phoria in near vision using the method of the cover test with prism and the modified Thorington method. The aim of this study is to analyse the repeatability of both methods.

The method, the results, the discussion and the final conclusion of the study are explained in this article.

2. Method

2.1 Subjects

Ten young patients were recruited to participate in this study (8 females and 2 males). The mean age ± SD (standard deviation) was 23.6 ± 2.91 years (range from 21 to 29 years). Healthy ocular people with visual acuity in near vision equal or greater than 20/20 while wearing their habitual corrections were eligible for inclusion. The refractive error of the patients ranged from -4.75 D (diopters) to 0 D (7 patients were emmetropic, 1 wore glasses and 2 wore soft contact lenses). Patients with vertical phoria or heterotropia were excluded.

2.2. Examination Protocol

The horizontal phoria was measured using two different methods. First, the cover test was performed. The patients were asked to fixate an accommodative target at 40 cm with a visual acuity 20/25 and maximum lighting. The patients were required to keep the vision of the letters clear. The eyes were occluded during 4 seconds. When a movement was detected, the prism bar was placed in front of the right eye increasing the power until no movement was seen. Then, the modified Thorington test was performed at 40cm. The lighting in the room was reduced. The patient was required to hold the Maddox rod in front of the right eye and keep the numbers of the target clear. The patient sees a point of light and a vertical red line and has to say in which number and which side of the card the line is in respect to the point of light. Both measurements were taken twice by the same examiner separated by 24 hours.

2.3. Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences software (SPSS) 22.0 version. The Shapiro-Wilk test was used to check the normality of the variables, and the paired t-test and the Bland and Altman plots were used to analyse the repeatability of both methods. Significance was set at $p<0.05$.

3. Results

First, results of cover test and modified Thorington method obtained in the two sessions are shown in a description statistics table (table 1). In addition, the table contains the median and IQR (interquartile range). We work with these statistic parameters because the distribution is skewed. It is discovered by using Shapiro-wilk test (figure 3).

Subject	Cover Test 1	Cover Test 2	Thorington1	Thorington2
1	6	6	8	8
2	-2	-1	-2	0
3	-4	-2	-2	-3
4	-12	-10	-10	-10
5	2	0	2	1
6	-6	-6	-6	-5
7	0	0	1	1
8	4	2	8	6
9	16	16	14	15
10	-1	0	0	0
Median	0,3	0,00	0,50	0,50
IQR	9	6	11	10

Table 1. Statistics results of cover test and modified Thorington method obtained in the two sessions. By convention, exophorias are shown as negative values, and esophorias are shown as positive values.

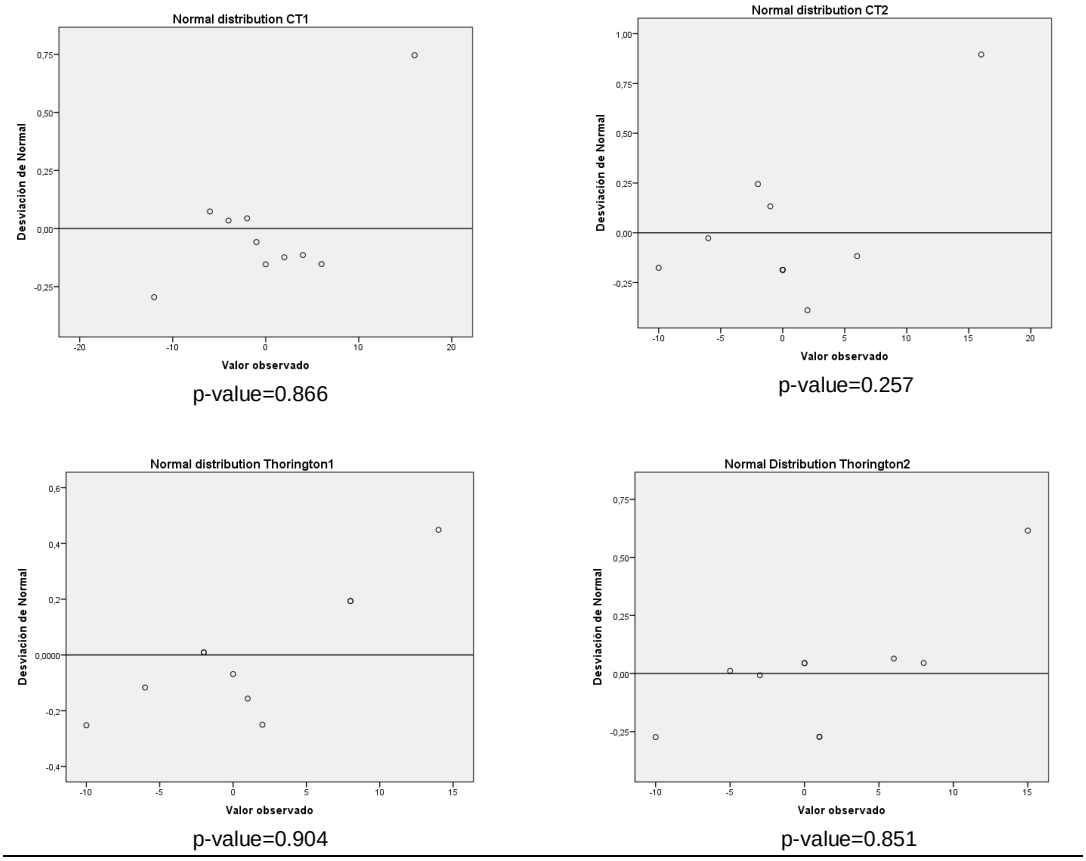

Figure 3. Shapiro-wilk test graphics showing skewed distribution.

Then, by means of the Shapiro-wilk test, we obtained that all data were normally distributed (p>0.05) and consequently, a parametric test (paired t-test) was used to determine whether

there were statistically significant differences between the values of both moments. The paired t-test was applied twice: the first comparing cover test 1(CT1) and cover test 2(CT2) and the second comparing Thorington 1(T1) and Thorington 2(T2). Table 2 shows p-values, the mean, the standard deviation (SD) and the corresponding 95% confidence limits (CL) between measurements from both sessions without regarding the direction.

tests	**p-value**	**Mean**	**SD**	**Min**	**Max**
CT2-CT1	0.000	1.000	0.943	0.325	1.674
T2-T1	0.000	0.400	1.075	-0.369	1.169

Table2. The Paired t-test results of *p*-values, means, SD and the minimum and maximum 95%IC from the comparison of methods.

	DifferencesCT1-CT2	DifferencesT1-T2
	0	0
	1	2
	2	1
	2	0
	2	1
	0	1
	0	0
	2	2
	0	1
	1	0
SDdiff	0,943	0,789
SDws	0,667	0,558

Table3. Differences calculated in absolute value and SDdiff and SDws

Standard deviation intrasubjects (SDws) is calculated with the following formula: 1.96SDdiff=2.77SDws (table3).

Finally, Bland and Altman analysis is done to compare the first with second session of the cover test and another to compare the first with the second session of Thorington. Figure 4 provides the Bland and Altman plots.

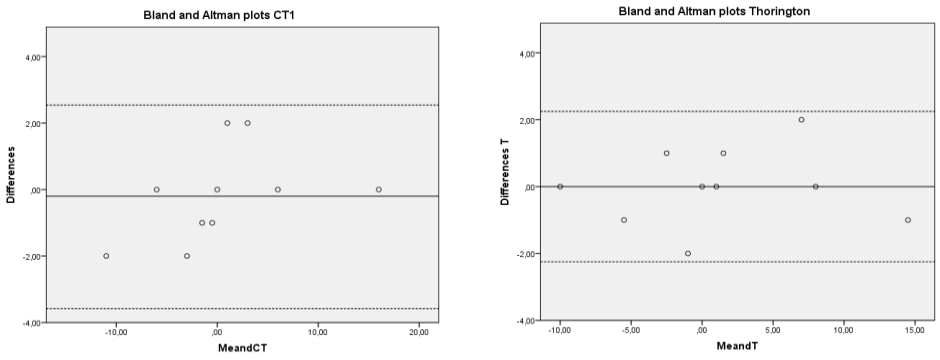

Figure 4. Bland and Altman plots showing the mean of the differences ($mean_d$) and the corresponding 95% confidence limits (CL) between the values of the 2 CT (left) and 2 Thorington(right).

4. Discussion

This study investigated the repeatability of the measurement of the horizontal phoria in near vision with Cover Test and modified Thorington method.

The part of the cover test in this study can be compared with the results found by H. Johns et al. in their study called *The Intraexaminer and Interexaminer Repeatability of the Alternate Cover Test Using Different Prism Neutralization Endpoints* (7). H. Johns et al. found that the averaged signed differences were all <0.5∇, and SD's were <2.6∇. The mean absolute differences were all <1.9∇, and the SD's were <1.8∇. In this study, the result found was a mean difference of -0.20∇ and SD of 1.40∇ with 95% confidence intervals. The results of both studies are similar and show a good repeatability.

The study also includes a comparison on measurements made with the modified Thorington method and found a range of absolute mean differences ± SD from 0.40±1.07 with 95% confidence intervals when comparing two measurements done by the same examiner. These results can be compared with those found in far vision with the same test by JL. Cebrian et al. in their study *Repeatability of the modified Thorington card used to measure far heterophoria*(12). They observe good intraexaminer repeatability for Thorington showed by COR= ±1.51∇.

The discrepancy is high in cover test and Thorington with a P-value<0.001 in both tests which means that there are statistically significant differences between the two measurements CT1 with CT2 and T1 with T2. Otherwise, there are not clinically significant differences.

The mean of CT2-CT1 and T2-T1 should be 0 because the phoria's value of a subject obtained in the same conditions is always the same. The mean in Thoringthon is 0.400 which could be considered a number very close to 0, otherwise the mean obtained in cover test is 1.000 and it is a bit far from 0, it has a positive value and it shows that there is probably going to be esophoria error. On the other hand, as it is expected for a good repeatability, in both cases SD are very close to 1 and it means that the two methods can be considered precise.

Concordance between both measurements are shown by Bland and Altman plots. These graphics show that there is a difference of approximately 0.5∇ between the two cover tests and there is no appreciable difference between the two measurements with modified Thorington method. Good concordance is obtained in both methods because the 95% of results are inside the limits. There is not a tendency in the differences and it could be said that the distribution is random between the limits.

There is a limitation to this study, in the feeling of the patient. The patient may have a different level of visual fatigue at the two measurement moments. This can affect the accommodative effort and with proximal triadic to the convergence, therefore the value of the phoria can vary.

Best repeatability is shown by the Thorington, it is probably because it is not depending on the experience of the examiner, but there are studies that suggest that the mean differences of the

alternate cover test result between experienced examiners and novice examiners compared by the eye tracker, were not clinically meaningful (13). In addition, Thorington could be more precise because the card had the number with a step of 1∇ and in the cover test the prism bar used had steps in 2∇.

5. Conclusion

The aim of this study is to check the repeatability in the cover test and in modified Thorington method measuring the phoria in near vision. The findings of the present study show that the alternate cover test and the modified Thorington method had good intraexaminer repeatability in near vision. Both methods are precise to quantify the phoria in near vision. The results of this study are similar to those found in other publications.

6. Ethical and social commitment

The regulations indicate that, the Final Project must include a section that refers to the ethical and social commitment of the study. This part analyses the work from an ethical point of view and refers to the social and legal implications involved in the study.
First, the aim of this project is to develop a study to improve two techniques for the measurement of the horizontal phoria in near vision: Thorington and cover test. The research and knowledge in the field of health sciences has a direct impact on improving the binocular vision of the population and therefore in their quality of life. In this sense, there is a direct relationship between the main objective of this work and one of the four principles governing bioethics: beneficence.

Two fundamental legal aspects should be treated. First, it was not considered as necessary that the ten patients who have participated in the study signed a document, because all of them were participants in the work. However, the ten people were part of a previous study carried out in the centre and they had signed an informed consent. The second legal aspect which has been considered refers to security measures. All measures have ensured the safety of volunteer patients.

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