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A Comparative Study of the Neuro-Ophtha (NO) Lollipop and Hertel Exophthalmometers in Measuring Anterior-Posterior Globe Position among Patients without Orbital Disease



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ABSTRACT

Background: Exophthalmometer is an instrument used for measuring the degree of forwarding displacement of the eye such as exophthalmos. Exophthalmos is an abnormal protrusion of the eyeball due to many conditions. This study aims to compare the Neuro-Ophtha (NO) Lollipop against the Hertel exophthalmometer, which is a gold standard, in measuring anterior-posterior (A-P) globe position among patients without orbital disease.

Methods: An analytic-experimental study to 423 patients without history of orbital problems at Private Eye-Care Facilities. Subjects with aged 18 years old and above were recruited. Measurements of A-P position of the globe were done using Hertel (Ophthalmologist A) and NO Lollipop (Ophthalmologist B) independently on the same patient, in two separate rooms and the same day.

Results: The A-P globe position measurements were significantly higher using the NO Lollipop as compared to Hertel exophthalmometer. After data log transformation, a mean difference in the A-P globe position was obtained about 0.04977 (log10) or 1.12mm (95% CI 0.12 mm to 2.12mm) between Hertel and NO Lollipop readings on the right eye (OD). In addition, the result was 0.04652 (log10) or 1.11mm (95% CI 0.11mm to 2.11mm) on the left eye (OS). A significant difference in the mean A-P position readings between Hertel and NO Lollipop exophthalmometer were seen in this study on OD ($t=25.2, p=0.000$) and OS ($t=22.5, p=0.00$).

Conclusion: NO Lollipop overestimates the anterior-posterior globe position by as much as 1.11-1.12 mm compared to Hertel exophthalmometer. In clinical setting, NO Lollipop may be used as an alternative instrument when Hertel exophthalmometer is not available.

Keywords: Exophthalmometer, Exophthalmos, Proptosis, Hertel, Neuro-optha Lollipop, Filipinos

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INTRODUCTION

Exophthalmos is an abnormal protrusion of the eyeball. It is characteristic of toxic goiter,¹ an over-activity of the thyroid gland and a disease with a frequency of 2.9 cases per 100,000 population per year in men and 16 cases per 100,000 population per year in women.²

In toxic goiter or Grave's disease, inflammation of the orbital contents, primarily the ocular muscles and retrobulbar fat, causes an increase in the orbital volume pushing the eyeballs forward. This combination of muscles impairment and exophthalmos reduces the ocular motility, causing diplopia and strabismus. In addition, the optic nerves can be affected, reducing vision as well as swelling of the conjunctiva. Finally, the eyes may protrude so far that the palpebra cannot close over them, leading to corneal damage.³

Exophthalmos is obvious when it is advanced enough to cause complications. The upper limit of normal was 21 mm.⁴ When there is doubt in the early stages, a mechanical device called an exophthalmometer can measure the protrusion.³

Exophthalmometer is an instrument used for measuring the degree of forwarding displacement of the eye. The device measures the distance of the corneal apex from the ipsilateral orbital rim.⁵ Exophthalmometers can also be used to identify enophthalmos, a sign of orbital blow-out fracture and certain neoplasms.⁶ An asymmetry of greater than 2 mm between an individual patients' eyes also suggests exophthalmos or enophthalmos.⁷

There are several types of exophthalmometers; Hertel and Luedde measure the distance of the corneal apex from the level of the lateral orbital rim while Naugle measures the relative difference between each eye.⁸ These instruments are accurate and useful in measuring the anterior position of the globe and in detecting exophthalmos. However, they are costly and unavailable in eye clinics. In addition, these instruments are not consistent for measuring exophthalmos in some endocrine exophthalmos cases where tissue edema can cause extensive swelling in the periorbital soft tissues or in all cases where there has been any disease,

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trauma, surgery or congenital anomaly affecting the lateral orbital rims. For example, the Hertel cannot be used postoperatively in the case of a lateral orbitotomy which is used routinely for the removal of orbit tumors and Graves' orbital surgery.⁹

Recently, a new type of exophthalmometer was developed by a consultant at one of a private eye hospital in the Philippines called the Neuro-optha (NO) Lollipop exophthalmometer. The NO Lollipop exophthalmometer was designed as an alternative instrument to commercially available exophthalmometer. However, its accuracy needs to be validated on whether its measurement is comparable to Hertel exophthalmometer, the gold standard in exophthalmometry. This study aims to know the comparison between the anterior globe position on the new NO Lollipop exophthalmometer versus Hertel exophthalmometer in patients without orbital disease.

METHODS

Study Design

An experimental analytic study using repeated measurements within two groups was conducted from March-August 2015. Values of NO Lollipop exophthalmometer was compared to Hertel exophthalmometer in measuring anterior-posterior (A-P) position of the eye. The study was conducted at the Department of Ophthalmology of two private

hospitals. Approval for the study was granted by the Institutional Ethics Review Committee and Review Board. The study adhered to the tenets of the Declaration of Helsinki. Subject's confidentiality was maintained and documents were kept in strict confidence.

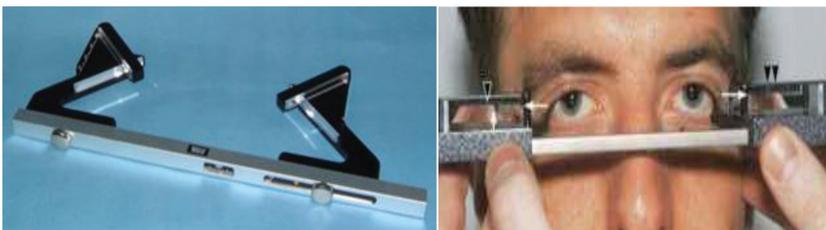
There were 384 patients recruited in this study by consecutive sampling technique. The inclusion criteria were included patients 18-year-old and older, without history of orbital disease, orbital trauma or surgery, and signing an institutional review-board approved informed consent form

Data Collection

Two instruments were used for the examinations: the Hertel exophthalmometer and the NO Lollipop exophthalmometer. The Hertel exophthalmometer (Hertel K-0161, Inami & Co. Ltd. Japan) consisted of a horizontal calibrated bar with mobile carriers at each side. Each carrier includes mirrors inclined at 45 degrees to reflect both the scale reading and the apex of the cornea in profile. Notches on the side carriers were placed on the bony lateral orbital margins of the patient. The patient was then asked to fix on a point on the examiner's nose bridge. The apex of the cornea of each eye was superimposed on the millimeter scale reading by the inclined mirrors. The measurement of each eye was recorded by the examiner, alternately viewing with the right and left eye. The distance along the horizontal bar was also recorded as the bases. (Appendix: [Picture 1](#) and [2](#))

The Neuro-optha (NO) Lollipop exophthalmometer (NO Lollipop, B. Mariano, Philippines) is a plastic ruler with the lollipop-shaped at one end. The lollipop edge of the instrument was placed parallel to the lateral orbital rim with one-hand technique. The patient is asked to look straight at any fixation point. The distance from lateral orbital rim and apex of cornea is the exophthalmometric value. The examiners should position their eye on the ruler perpendicular to corneal tip to minimize the parallax. The small circle is considered as 10 mm. (Appendix: [Picture 1](#) and [2](#)).

Two independent examinations using the Hertel exophthalmometer and NO Lollipop exophthalmometer were done on all subjects by two experienced ophthalmologists who were masked from the measurements taken with the other equipment. Dr. M.B. measured the anterior globe position in both eyes of all subjects using Hertel exophthalmometer while Dr. P.B. did the measurements using NO Lollipop. Conditions were standardized for all measurements; particular attention was paid to illumination and distance fixation. Both examinations



Picture 1 Measuring Anterior-posterior Position of the Globe using Hertel Exophthalmometer



Picture 2 Measuring Anterior-posterior Position of the Globe using Neuro-optha (NO) Lollipop

were done on the same day and conducted in two separate rooms to ensure that both ophthalmologists were blinded on the measurement for each patient.

The bias of measurement was minimized by comparing the measurements of the 2 ophthalmologists on the same patients using both Hertel and NO Lollipop exophthalmometers before the actual data collection. Readings from the 2 ophthalmologists were compared by using inter-rater reliability analysis to get the intraclass correlation coefficient. An intraclass correlation coefficient of 0.7 or more means high inter-rater reliability. Patients included in this reliability analysis were excluded as subjects of the study.

A pre-tested data abstraction tool was developed based on study objectives. Information on subject's age, gender, and measurement of globe anterior-posterior (A-P) position using Hertel and Neuro-ophtha (NO) Lollipop exophthalmometers were gathered using the data abstraction tool.

Data Analysis

Data were encoded in Microsoft Excel and analyzed using Statistical Package for the Social Science (SPSS) version 17. Measurement of central tendency was used to summarize continuous variables including age and exophthalmometry measurements (Hertel and NO Lollipop). Frequency tables and percentage distribution were used to summarize age group and gender of subjects.

Descriptive summary statistics of the globe A-P position measurements were described using box and whiskers plot graph. Shapiro-Wilk test was used to determine normality of data. Data transformation was done using log₁₀ transformation to normalize the data distribution. Paired-related sample t-test was used to compare A-P global position measurements using Hertel and NO Lollipop exophthalmometer. P-value of <0.05 will be considered statistically significant.

RESULTS

Characteristics of Subjects

There were 423 subjects included in the study. Table 1 show ages of subjects ranged from 18 years to 95 years (mean 61.3 ± 15.82 , median 65). Fifty-seven percent (242/423) were females and the remaining 43% were males (181/423).

Descriptive Results of Hertel vs. Neuro-ophtha (NO) Lollipop

Figure 1 shows the descriptive statistics comparing Hertel and NO Lollipop exophthalmometer

using box and whiskers plot on the right eye of subjects. Study revealed that globe position values on the 5 descriptive summary statistics (median, 25th percentile, 75th percentile, minimum and maximum) were consistently higher using the NO Lollipop. Results had shown that median globe position using NO Lollipop was 2 mm higher compared to Hertel (13 mm vs. 11 mm) (Figure 1).

Twenty-five percent of the subjects (25th percentile) had anterior globe position reading of 10 mm and below using Hertel and 11 mm and below using NO Lollipop. Likewise, seventy-five percent (75th percentile) of the subjects had a globe position reading of 13 mm and below using Hertel and 14 mm and below using NO Lollipop (Figure 1).

Results of the study had also shown that minimum anterior globe position reading was 1 mm higher using NO Lollipop compared to Hertel (8mm vs. 7 mm). Likewise, maximum globe position reading was 1 mm higher using NO Lollipop as compared to Hertel (18 mm vs. 17 mm). Extreme globe position values of 18 mm and 19 mm were reported using Hertel while 19 mm and 20 mm were reported using NO Lollipop on the right eye of subjects (Figure 1).

Figure 2 shows the descriptive statistics comparing Hertel and NO Lollipop exophthalmometer using box and whiskers plot on the left eye of subjects. Similar with the measurements made on the right eye, the study revealed that globe positions on the 5 descriptive summary statistics (median, 25th percentile, 75th percentile, minimum and maximum) were consistently higher using the NO Lollipop as compared to Hertel exophthalmometer. Comparison between the 2 exophthalmometers had shown that median globe position using Neuro-ophtha (NO) Lollipop was 1 mm higher compared to Hertel (13 mm vs. 12 mm) (Figure 2).

Twenty-five percent of the subjects (25th percentile) had a globe position reading of 10 mm using Hertel and 12 mm using NO Lollipop. Likewise, seventy-five percent (75th percentile) of the subjects had a globe position reading of 13 mm using Hertel and 15 mm using NO Lollipop (Figure 2).

Data had also shown that minimum globe position reading was 2 mm higher using NO Lollipop compared to Hertel (8mm vs. 6mm). Likewise, maximum globe position reading was 2 mm higher using NO Lollipop as compared to Hertel (19 mm vs. 17 mm). Extreme globe position values of 18 mm and 19 mm were reported using Hertel while 20 mm was reported using NO Lollipop on the left eye of subjects (Figure 2).

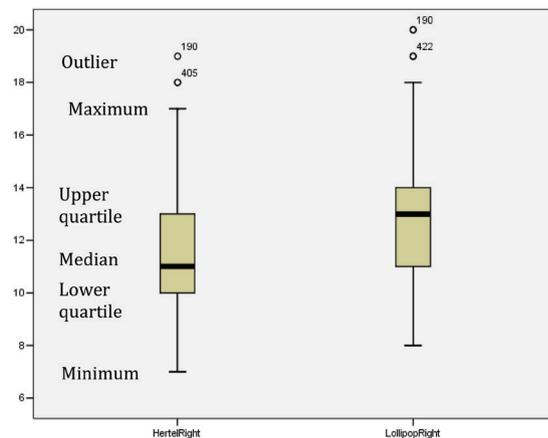
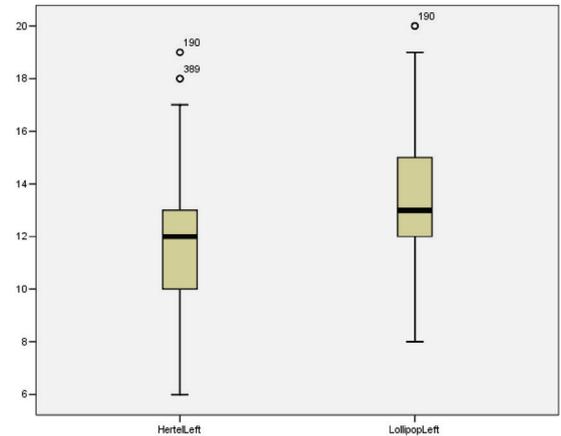
Table 1 Distribution of Subjects by Age group (N=423) at two private eye care institutions from March-August 2015

Age group (year)	Frequency	Percentage
18 to 25	19	4.5
26 to 30	14	3.3
31 to 35	14	3.3
36 to 40	8	1.9
41 to 45	16	3.8
46 to 50	16	3.8
51 to 55	23	5.5
56 to 60	43	10.2
61 to 65	71	16.8
66 to 70	84	19.9
71 to 75	52	12.3
76 to 80	40	9.5
81 to 85	19	4.5
86 to 90	3	.7
91 to 95	1	.2
Total	423	100.0

Table 2 Result of Normality Test on the Mean Difference of Anterior-Posterior Globe Position Measurements using Hertel and NO Lollipop on Both Eyes (N=423) at two private eye care institutions from March-August 2015

Variable	Shapiro-Wilk		
	Statistic	Df	Sig.
OD Mean Difference (Hertel vs NO Lollipop)	.900	423	.000 ^a
OS Difference (Hertel vs NO Lollipop)	.912	423	.000 ^a

^a Lilliefors Significance Correction

**Figure 1** Descriptive Summary Statistics Comparing Hertel and NO Lollipop Exophthalmometer Anterior-Posterior Globe Position Reading on the Right Eye of Subjects (N=423) at two private eye care institutions from March-August 2015**Figure 2** Descriptive Summary Statistics Comparing Hertel and NO Lollipop Exophthalmometer Anterior-Posterior Globe Position Reading on the Left Eye of Subjects (N=423) at two private eye care institutions from March-August 2015

Analytical Statistics of Hertel vs. Neuro-optha (NO) Lollipop

Table 2 shows results of normality test on the mean difference between the 2 exophthalmometers using Shapiro-Wilk Test. It shows a skewed distribution of both eyes and suggests for significant results ($p=0.000$).

Table 3 shows data transformation was carried out using log10 transformation of skewed data in order to comply the assumption of a parametric test (t-test). Using the transformed data, a mean difference results in the globe A-P position of the paired T-test on related samples showed 0.04977 (log10) or 1.12 mm (95% CI 0.12 mm to 2.12 mm) between Hertel and NO Lollipop reading on the right eye. The result on left eye showed 0.04652 (log10) or 1.11 mm (95% CI 0.11 mm to 2.11 mm). Significant difference in the mean globe anterior-posterior (A-P) position reading between Hertel and Neuro-optha (NO) Lollipop exophthalmometer was seen in the study on both right and left eyes ($t=25.2$, $p=0.000$; $t=22.5$, $p=0.00$, respectively) (Table 3).

DISCUSSION

Epstein et al stated that proptosis is a globe that protrudes 18 mm or less and exophthalmos is protrusion of greater than 18 mm.¹⁰ The upper limit of normal was 21 mm. In adult white males, the average distance of globe protrusion is 16.5 mm, with the upper limit of normal at 21.7 mm.¹¹ A separate study reported the average as 18.2 mm, with an upper normal limit of 24.14 mm in males and 22.74 mm in females.¹² According to this data, the quantitative assessment of the position of the

Table 3 Paired Samples Test of Log₁₀ Transformed Data of Anterior-Posterior Globe Position Measurements using Hertel and NO Lollipop Exophthalmometer (N=423) at two private eye care institutions from March 01, 2015 to August 31, 2015

Exophthalmometer	Paired Differences					
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Sig. (2-tailed)
				Lower	Upper	
Lollipop – Hertel Log (Right Eye)	.04977	.04051	.00197	.04589	.05364	.000
Lollipop – Hertel Log (Left Eye)	.04652	.04257	.00207	.04245	.05059	.000

globe in orbit is an important clinical parameter, primarily to detect exophthalmos which commonly related to thyroid disease. Unfortunately, in the ophthalmic practice, exophthalmometry may not often be performed. The reasons for this may include the perceived difficulty of measurement in the clinical setting using the Hertel exophthalmometer and the relative bulk of the instrument.

The value from exophthalmometer is called exophthalmometric value (EV). The comparative EV reflects a change in the amount of protrusion in follow-up examinations, which can document the progression of the condition causing the proptosis.¹³ For exophthalmometric value (EV) measurements using Hertel, the supports are placed against the two temporal orbital walls so that the orbital rim contacts the deepest point of the supports.¹⁴ It is different with The Neuro-ophtha (NO) Lollipop exophthalmometer where millimeter strip of plastic ruler with a round edge at one end designed to fit on the lateral orbital margin. As the readings are carried out from the side, obstructed distance fixation does not pose a problem for this instrument. Thus, NO Lollipop is suitable for relative exophthalmometric value (EV) which is comparing the degree of protrusion between each eye. An asymmetry of greater than 2 mm between each eye suggests an abnormality of the EV. It is beneficial for diagnosing unilateral proptosis.

However, the results shown in this study revealed that measurements taken on subjects to determine the anterior globe position using NO lollipop were higher than measurements taken using Hertel exophthalmometer. Although the paired difference between the 2 exophthalmometers was only 1.11 mm to 1.12 mm, this difference was reported to be statistically different ($P < 0.001$). These findings suggest that some calibration, corrective factor, or change in the design of NO lollipop might be proposed. Moreover, a new reference of absolute exophthalmometric value (EV) for Neuro-Ophtha (NO) lollipop should be suggested by additional of 1-2 mm from normal values obtained from the gold standard, Hertel exophthalmometer. Recently,

this is the first study conducted for measuring globe anterior-posterior position using NO Lollipop.

Any exophthalmometer using the lateral orbital rim as fixation must be used with the head and eyes in the position of straight and steady, the rule must be parallel to the visual line and perpendicular to the frontal plane, and the sighting must be done at right angles to the rule. Compression of the soft tissues over the lateral orbital rim gives rise to an unavoidable error, which can be variable if the amount and duration of pressure are variable.

CONCLUSION

The study found that the measurement findings on anterior globe position using Neuro-Ophtha (NO) Lollipop was statistically significantly higher compared to Hertel exophthalmometer with a mean difference of 1.12 mm on right eye and 1.11 mm on left eye. However, in a clinical setting, NO Lollipop may be used as an alternative when Hertel exophthalmometer is not available since NO Lollipop represents a simple, inexpensive method of performing exophthalmometry, and suitable for relative exophthalmometric-values.

STUDY LIMITATIONS AND RECOMMENDATION

The type of participant included in this study was one of the limitations. Only normal patients were compared, thus paired difference in measurements reported in this study may be generalized only to normal subjects. It is recommended for future studies that this study is also replicated on subjects with abnormal anterior-posterior globe position. Another limitation of the study is that the findings of this study were only based on the experience of 2 institutions, thus a study involving multi-centers can be carried out in the future studies. Besides, interpretation of this study's finding should also take into account degree of precision as presented in the 95% confidence interval of the mean (for example the precision of 1% for the error). It is

recommended that similar study is conducted with more significant number of subjects to make the estimation on the mean difference more precise, thus strengthening further the conclusion made in this study.

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