Correlation between Interpupillary and Inner-Outer Intercanthal Distances in Individuals Younger than 20

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Purpose: To determine the correlation between interpupillary distance (IPD) and inner-outer intercanthal distance (IOICD) and to find a regression equation for calculating IPD based on IOICD measurements.

Methods: The study subjects were randomly selected from individuals aged 3 months to 20 years who were referred to our ophthalmology clinic, health care centers and children attending kindergartens. Participants were divided into 4 age categories: ≤3, 3-5, 5-12.5 and 12.5-20 years. IPD was measured by a PD meter (PD2, Oculus, Germany); other parameters including IOICD, nasal limbus to temporal limbus (NLTL), inner intercanthal distance (IICD) and outer intercanthal distance (OICD) were measured using a translucent plastic ruler.

Results: The study included 254 female (60.6%) and 165 male (39.4%) subjects with mean age of 87.7±73.2 (range 3-240) months. Significant correlation was observed between IOICD and IPD in the 3-5 yr and 12.5-20 yr age groups. In the ≤3 and 5-12.5 year age groups, NLTL had the best correlation with IPD. The regression equations for calculating IPD according to IOICD were as follows. In male subjects, near IPD= 0.941×IOICD (r^2= 0.98, P<0.001) and for female subjects, near IPD= 0.948×IOICD (r^2= 0.98, P<0.001).

Conclusion: IPD and IOICD measurements are strongly and positively correlated; IOICD measurements are simpler to obtain and may be used to calculate IPD readings which are more difficult to measure by usual methods in children.

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INTRODUCTION

Various orbital measurements including interpupillary distance (IPD), inner intercanthal distance (IICD), outer intercanthal distance (OICD), inner-outer intercanthal distance (IOICD) and nasal limbus to temporal limbus (NLTL) are important for several purposes in ophthalmology. These parameters may be altered in craniofacial syndromes and may be useful in the management of post-traumatic cranial and orbitofacial deformities.[1,2] Furthermore, these

values are useful in the manufacture of spectacle frames and lenses.[3] Among these parameters, IPD is the best indicator of the distance between the centers of the two globes.[4]

Accurate IPD measurement is sometimes difficult in children; therefore a simple alternative method providing accurate and reproducible estimations of IPD is very helpful in pediatric ophthalmology.[5] The purpose of this study was to determine the normal values of these parameters in a young Iranian population and to evaluate the correlation between IPD and other interorbital parameters by calculating regression equations.

METHODS

The study included 419 Iranian subjects aged 3 months to 20 years who were randomly selected from the eye clinic at Khatam-Al-Anbia Eye Hospital affiliated to Mashhad Medical University (40% of subjects), and from health care centers and kindergartens distributed over different areas of Mashhad (60% of subjects) from January 2003 to August 2004. Cases with facial or orbital anomalies, eye deviation, history of trauma and facial or orbital fractures were excluded from the study.

Based on the maturation process of facial and orbital structures,[3,6,7] subjects were divided into four age groups as follows: ≤3 years, 3-5 years, 5-12.5 years and 12.5-20 years. Interorbital measurements were repeated until two similar readings were obtained by the same person. A PD-meter (PD-2, Oculus, Germany), a transparent plastic ruler with fixed and sliding cursors, was used for measurement of IPD. Other orbital measurements including IICD, OICD, IOICD and NLTL were measured directly using a non-stretchable transparent plastic ruler as follows (Fig. 1).

- *Near IPD*. With the patient sitting comfortably on a chair (or on the mother's lap in case of small children) in front of the examiner with the head in the same level as the head of examiner; the PD-meter was placed on the nasal bridge on spectacle plane. Closing the non-dominant eye, the examiner focused her dominant eye on the subject`s midline from a distance of 33 cm while she requested the subject to look at her open eye. In children, the child would look at a target placed at the examiner's open eye. The fixed cursor of the PD-meter was placed at the center of the right pupil and the sliding cursor was then placed on the center of the left pupil without moving the instrument; the measured distance between the two cursors was considered as near IPD.
- *Far IPD*. After placing the PD-meter on the nasal bridge of the subject, the examiner closed her right eye and asked the subject to look at her open left eye. The fixed cursor was then placed at the center of subject's right pupil. Thereafter the examiner closed her left eye and asked the subject to look at her right eye. The sliding cursor was placed upon the center of the subject's left pupil. The distance between two cursors was considered as far IPD.
- *IICD, OICD, IOICD*. Distances between two inner canthi, two outer canthi and between the inner canthus of the right eye and the outer canthus of the left eye were measured by a transparent plastic ruler (just at the canthal angles) while the patient was looking straight ahead.
- *NLTL*. The distance between the nasal limbus of the right eye and the temporal limbus of the left eye was measured using a plastic ruler.

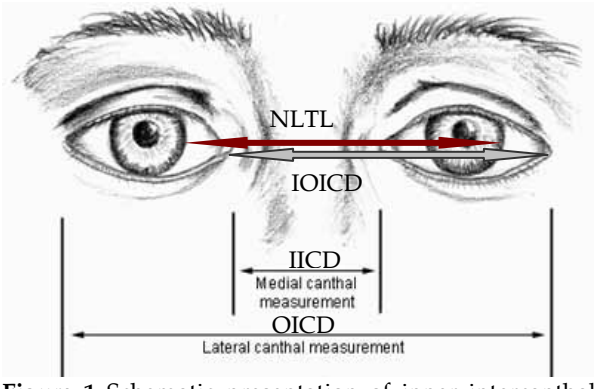

Figure 1 Schematic presentation of inner intercanthal distance (IICD), outer intercanthal distance (OICD), inner-outer intercanthal distance (IOICD), and nasal limbus to temporal limbus (NLTL) measurements.

Mean values of the above-mentioned distances were compared between male and female subjects and among different age groups using *t*-test. The relationship between IPD and other parameters including IICD, OICD, IOICD and NLTL within each age category of either sex was also evaluated and a regression equation was calculated as a means of estimating IPD from these parameters.

RESULTS

Overall, 419 individuals including 254 female (60.6%) and 165 male (39.4%) subjects with mean age of 87.7±73.2 (range 3-240) months were evaluated. Mean values for near IPD, far IPD, IICD, OICD, IOICD, and NLTL are presented in table 1. There was no significant difference between male and female subjects in any of these measurements.

Table 2 summarizes mean measurements based on age groups in either sex. There was a linear correlation between age and near IPD, overall (Fig. 2). Differences between males and females were only significant for OICD, IOICD and NLTL in the 3-5 yr age group and for near IPD and NLTL in the 12.5-20 yr age group.

The transverse measurements including IICD, OICD, IOICD and NLTL were strongly correlated with near and far IPD. Among all parameters, NLTL had the strongest correlation with near and far IPD overall (figures 3, 4, 5). The following equations were determined by regression:

Male: Near IPD= 5.012+0.88×NLTL, r^2=0.85
Female: Near IPD= 3.987+0.904×NLTL, r^2= 0.89
Male: Far IPD= 4.38 + 0.93×NLTL, r^2= 0.83
Female: Far IPD= 4.61 +0.93×NLTL, r^2= 0.81.

Table 1 Mean age and orbital measurements (mean±standard deviation)

	Male	Female	P value	Total (range)
Age (month)	71.7±63.2	98.8±72.2	P< 0.001	87.7±73.2 (3-240)
Near IPD (mm)	51.03±5.69	51.94±6.13	P=0.1	51.59±5.9 (37-66)
Far IPD (mm)	57.32±4.87	57.98±4.78	P=0.3	57.76±4.81(42-69)
IICD (mm)	29.16±3.31	29.2±3.4	P=0.9	29.19±3.36(20.45)
OICD (mm)	78.86±7.7	80.45±9.22	P=0.6	79.82±8.68(60-68)
IOICD (mm)	54.28±4.74	54.55±5.86	P=0.6	54.45±5.44(30-69)
NLTL (mm)	52.27±5.96	53.08±6.4	P=0.1	52.7±6.24(38-68)

IPD, interpupillary distance; IICD, inner intercanthal distance; OICD, outer intercanthal distance; IOICD, inner-outer intercanthal distance; NLTL, nasal limbus to temporal limbus

Table 2 Comparison of interorbital distances in male and female subjects in different age groups

Age/Sex group		Near IPD (mm)	OICD (mm)	IOICD (mm)	NLTL (mm)
≤ 3 yr	Male	45.6 ± 3.5	73.1 ± 4.6	50.4 ± 4.1	46.3 ± 3.7
	Female	44.9 ± 3.5	72.1 ± 4.5	49.3 ± 4.3	45.8 ± 3.6
	P value	0.2	0.3	0.1	0.5
3- 5 yr	Male	50.5 ± 2.3	77.1 ± 3.2	53.6 ± 2.1	52.2 ± 2.4
	Female	49.8 ± 2.1	75.2 ± 3.6	52.4 ± 2.8	50.7 ± 3.5
	P value	0.1	0.01	0.02	0.02
5- 12.5 yr	Male	58.5 ± 2.9	80.2± 5.5	55.7 ± 3.2	53.9 ± 2.9
	Female	52.4 ± 4.3	80.9 ± 7.6	54.5 ± 5.7	53.8 ± 4.5
	P value	0.9	0.5	0.2	0.9
12.5- 20 yr	Male	59.5 ± 3.4	90.5 ± 6.8	60.3 ± 3.4	61.1 ± 4.1
	Female	58.5 ± 2.4	89.8 ± 6.4	60.0 ± 3.1	59.6 ± 2.7
	P value	0.02	0.6	0.6	0.04

IPD, interpupillary distance; OICD, outer intercanthal distance; IOICD, inner-outer intercanthal distance; NLTL, nasal limbus to temporal limbus

Considering different age groups, OICD had the strongest correlation with IPD in the ≤3 year age group and IOICD had the strongest correlation with IPD in the 3-5 year age group. There was also strong correlation between IOICD and IPD in male subjects in the 12.5-20 year age group. The regression equations for each age group are presented in table 3. The equation for calculating far IPD according to near IPD in both 5-12.5 year and 12.5-20 year age groups was as follows: Far IPD= Near IPD×1.04, r^2= 0.99.

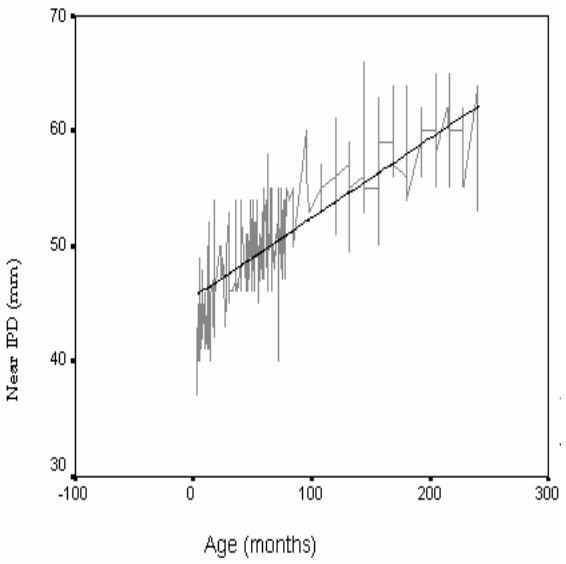

Figure 2 Linear correlation between age and near interpupillary distance (IPD)

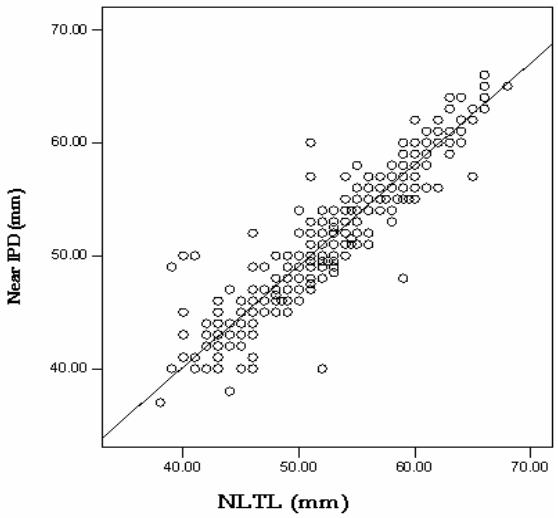

Figure 4 Linear correlation between near interpupillary distance (IPD) and nasal limbus to temporal limbus (NLTL) in all age groups

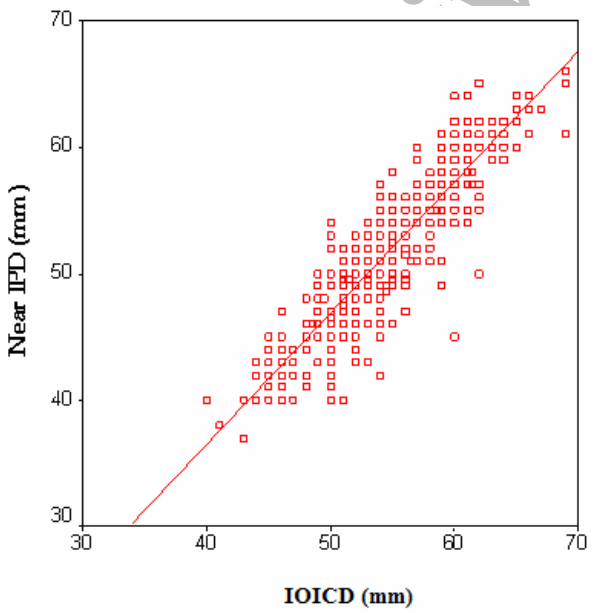

Figure 3 Linear correlation between near interpupillary distance (IPD) and inner-outer intercanthal distance (IOICD) in all age groups

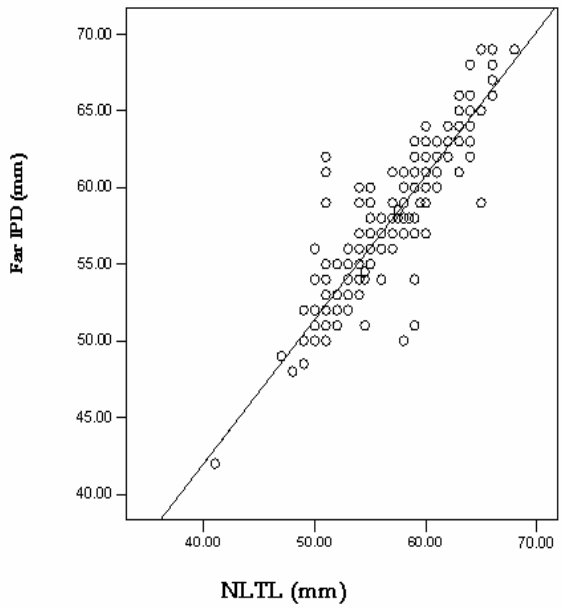

Figure 5 Linear correlation between far interpupillary distance (IPD) and nasal limbus to temporal limbus (NLTL) in all age groups

Table 3 Regression equations between interpupillary and other measured distances

Age group	Sex	Regression equation	r^2
≤3 yr	Male	Near IPD= 0.624×OICD	0.99
	Female	Near IPD= 0.622×OICD	0.99
3-5 yr	Male	Near IPD= 0.941×OICD	0.98
	Female	Near IPD= 0.948×OICD	0.98
5-12.5 yr	Male	Near IPD= 6.179±0.859×NLTL	0.78
		Far IPD= 0.978×NLTL	0.99
	Female	Near IPD= 6.305±0.857×NLTL	0.80
		Far IPD= 0.978×NLTL	0.99
12.5-20 yr	Male	Near IPD= 0.57×IOICD+0.417×NLTL	0.99
		Far IPD= 0.68×IOICD+0.342×NLTL	0.99
	female	Near IPD= 0.26×IOICD+0.7×NLTL	0.99
		Far IPD= 0.31×IOICD+0.7×NLTL	0.99

IPD, interpupillary distance; OICD, outer intercanthal distance; IOICD, inner-outer intercanthal distance; NLTL, nasal limbus to temporal limbus

DISCUSSION

Interorbital distances including interpupillary, inner intercanthal, outer intercanthal, inner-outer intercanthal and nasal limbus to temporal limbus distances are important in the diagnosis and treatment of congenital orbital or craniofacial anomalies and posttraumatic deformities[2] as well as in proper mounting of spectacle lenses to eliminate unwanted prismatic effects.[8] There are several studies on different racial groups in this regard, however no study has been performed in Iran and few studies have reported regression equations for these parameters.[9,10]

IPD is the most important interorbital parameter for measuring the distance between the eyeballs,[4] but measurement may be difficult in childrens,[2,11] uncooperative patients or patients with severe anomalies.[2] Measuring IPD may also be difficult due to ocular instability[4] or lack of contrast between the pupil and darkly pigmented iris.[12] There are several techniques for IPD measurement including use of a ruler,[2,11,13,14] sliding calipers,[2,12] corneal reflection pupillometer[15] and radiologic techniques[7,16] but in some studies, IPD has been estimated from more simple objective measurements such as IICD and OICD.[4,8,9]

For the first time in the current study, we attempted to find an equation to estimate IPD from IOICD. The latter is not affected by lighting conditions, pupil size and contrast between the pupil and iris. Among measured interorbital distances, NLTL had the strongest correlation with IPD overall, but considering different age groups, the strongest correlation with IPD was observed with OICD in the ≤3 yr group and with IOICD in the 3-5 yr group. We determined the equation for estimating IPD from OICD in the former group and from IOICD in the latter group with significant regression coefficients of 0.98 and 0.99, respectively. There also was strong correlation between NLTL and IOICD with IPD in the 12.5-20 yr group. An equation was also calculated for this age group.

In 1969, Pryor[4] reported a simple objective method for indirect estimation of IPD from IICD and OICD. In 1974, Feingold and Bossert[9] reported a different statistical approach based on multiple linear regression for calculating IPD based on IICD and OICD. We evaluated the correlation between IPD and several interorbital measurements including IICD, OICD, NLTL and IOICD and determined regression equations for calculating IPD from these parameters.

IPD values have been compared in subjects of various ethnicities. It has been reported

that IPD values in Chinese subjects are similar to those in Caucasians[15] and that Arab and Caucasian children have the same IPD,[8] however African–American children have wider IPD.[1,12] Pointer[17] evaluated IPD in a Caucasian group and reported an approximately 3% increase in the magnitude of far IPD from mid-teens to later middle ages with a difference between male and female subjects such that this value undergoes a little change beyond early middle ages in males but continues to increase until later middle ages in females. In our study, mean IPD in the 12.5-20 yr group was 59.5±3.4 mm for males and 58.5±2.4 mm for females (P=0.02). Considering the Caucasian racial background for our subjects, our results are to some extent in line with the above-mentioned studies and small differences may be explained by the limited number of enrolled subjects in the 12.5-20 year group and lack of older subjects in our study. Differences between mean IPD of male and female subjects in our study were statistically significant only in the 12.5-20 year group which is in agreement with Maclachlan's study.[10] Gupta[18] reported that mean IPD differed significantly between the two genders in certain age groups. Larger IPDs have also been reported in male subjects in some other studies.[4,9] Murphy[2] and Pivnick[19] reported larger IPD in male subjects in an African population. Osuobeni[8] evaluated gender differences in IPD among Arabs and found that male subjects have mean IPD 2 mm greater than female counterparts in individuals aged 5 to 55 years.

In studies on white subjects and a mixed European population, IICD has been reported from 25.5 to 38.5 mm and from 32 to 34 mm.[20,21] Freihofer[22] reported mean IICD of 31±2.7 mm with no difference between genders. Mean IICD in our study was approximately 32 mm, which falls within the above-reported ranges.

According to accumulated data from different studies,[1,2,11,12,15,18,21] largest values of OICD and IPD in different races in descending order occur in: Africans>Chinese>Caucasians>Arabs >Indians. In our study, mean OICD in the 12.5-20 yr group was 90.5 mm in males and 89.8 mm in females with no statistically significant difference. These values fall between Indians and white populations.

We further evaluated two other interorbital distances including IOICD and NLTL as well as their relationship with IPD. No previous study has addressed this issue other than the study by Gupta[18] on the estimation of IPD based on NLTL. Mean IOICD in the 12.5-20 yr age group was 60.3 mm for male and 60.0 mm for female subjects with no statistically significant difference. Up to a certain point, IOICD values were similar to those of IPD values. This relation also held true for other age groups except the ≤3 yr group, in which the difference between IPD and IOICD was 4.4-4.8 mm. This can be explained by the fact that IPD has two peaks of increase: one in early childhood and the other from 9 to 16 years of age; however, IOICD increases gradually at a lower rate up to 9 years of age and faster thereafter. After adolescence, IPD and IOICD have similar trends with close correlation and it is possible to estimate IPD from IOICD.

Among the four evaluated parameters, NLTL had the best correlation with IPD (except in the 3-5 yr age group); NLTL measurements were similar to IPD measurements in all age groups with only about 0.7-1.7 mm difference. Statistical analysis showed that IPD can be estimated from NLTL measurements with a significant correlation coefficient.

In conclusion, considering the simplicity of IOICD and NLTL measurements and the close correlation between NLTL and IPD in all age groups and between IOICD and IPD in certain age groups, it may be possible to replace the routine method of measuring IPD according to corneal reflex, which is difficult and inaccurate in children and uncooperative patients, by this easy and reproducible method.

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