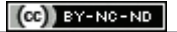


Correlation between Interpupillary Distance, Inner-outer Canthal Distance and Inter Limbal Distance: A Cross-sectional Study

SHEETAL V GIRIMALLANAVAR¹, VITTAL I NAYAK², SAHANA CHETTY³, C VASUNDHARA⁴

ABSTRACT

Introduction: Interpupillary Distance (IPD) is the distance between the centres of two pupils which can be anatomical or physiological. There are various inter orbital distances which are important in studying the orbitofacial configuration and also in prescribing a correct spectacle. Among the various measurements IPD is the most important which is routinely measured using Auto-Refarctometer (AR) machine or Pupil distance meter.

Aim: To find the correlation between IPD and Inner Canthal-Outer Canthal Distance (ICOC) and Right Nasal Limbus to Left Temporal Limbus (RNL-LTL) distance and to derive a regression equation in calculating IPD from measurements like ICOC and RNL-LTL which are easier to measure.

Materials and Methods: In this cross-sectional study with a sample of 100 subjects, participants were randomly selected from individuals attending Outpatient Department at Vydehi Institute of Medical Sciences and Research Centre, Bengaluru, Karnataka, India, between March 2021 to August 2021. The IPD was measured using Auto-Refarctometer/Autorefractor Keratometer (AR/ARK) (Model: UNIQUE-RK:UNICOS URK 800F) and Pupillary Distance Metre (PDM) (Essilor). All the other measurements like Inner Intercanthal Distance (IICD), Outer Intercanthal Distance (OICD), RNL-LTL distance were measured using a transparent plastic ruler. Data was entered in Microsoft Excel and analysed

using Statistical Package for the Social Sciences (SPSS) version 19.0. Categorical variables were presented as frequency and percentage. Multiple Linear regression was performed to find the factors associated with IPD using AR. The p-value <0.05 was considered as statistically significant. Independent sample t-test was performed to compare mean values between males and females.

Results: Of 100 subjects, 60 were males and 40 were females, five subjects were <20 years and 95 subjects were ≥20 years. The analysis of the various distances found positive correlation between IPD measured using AR and PD meter with the other distances ICOC and RNL-LTL measured with transparent ruler, the strongest correlation found between RNL-LTL and IPD. The results were found to be statistically significant (p-value <0.001 for all these comparisons). A regression equation was derived to calculate IPD using ICOC and RNL-LTL distances and also using other inter orbital variables.

Conclusion: Since there was a positive correlation between IPD and ICOC and RNL-LTL distances, these measurements which are easy to perform can be used to calculate IPD in situations where it's difficult to get access to AR machine as in peripheral community based camps or rural settings and in children and uncooperative patients where it is difficult to use AR machine to measure IPD.

Keywords: Autorefractor keratometer, Inner canthus, Limbus of eye, Outer canthus, Pupillary distance meter, Refraction

INTRODUCTION

The Interpupillary Distance (IPD) is the distance between the centre of two pupils and has a function in stereopsis. The IPD can be of two types: anatomical IPD (between two pupils) or physiological (between the two visual axes) of both the eyes [1]. The IPD is known to vary according to age, race and sex [1-3]. The normal distance between the orbits varies during embryogenesis and then after birth with the normal craniofacial development [4,5]. The IPD increases with the growth of the individual. It is also found that the maximum increase in IPD occurs in early years of life and it continues to increase slowly in adulthood [1]. The IPD is also defined as distance between temporal limbus of one eye with nasal limbus of the other eye [4]. Inner Intercanthal Distance (IICD) is the distance between the point where the upper eyelid meets the medial canthus and not the caruncle [6]. Outer Intercanthal Distance (OICD) is the distance between the lateral canthi with the patient looking in primary gaze [4,6]. There are various interorbital distances which are important in studying the orbitofacial configuration and more so in prescribing a correct spectacle and selecting an appropriate spectacle frame. There are various fields like ophthalmology, optometry, oculoplasty, genetics and traumatology where the knowledge of IPD has importance [1]. Amongst the various measurements like IPD, ICOC, Right Nasal Limbus to Left Temporal Limbus Distance (RNL-LTL) distances, IPD is the most important. IPD is ideally measured using AR machine or PD meter.

The present study was done to find a regression equation to calculate IPD from other easily measurable parameters like IICD, OICD, Inner Canthal-Outer Canthal Distance (ICOC), RNL-LTL distances as it can be helpful in situations like working on paediatric age groups, and in settings where availability of AR, which are routinely used to measure IPD, is a challenge.

The present study is the first one to deduce regression equations for all the different variables like IICD, OICD, ICOC, RNL-LTL to calculate IPD whereas previous few studies, have derived only for one or few of the variables. The primary objective of the present study was to correlate the IPD with other easily measurable parameters like IICD, OICD, ICOC, RNL-LTL and the secondary objective was to derive a regression equation to calculate IPD from those parameters.

MATERIALS AND METHODS

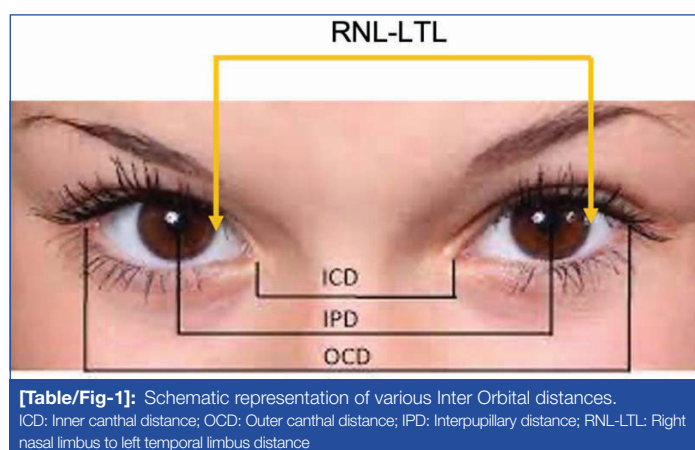
The cross-sectional study was done on 100 patients out of which 40 were females and 60 males who were randomly selected from the patients who visited the Ophthalmology Outpatient Department at Vydehi Institute of Medical Sciences and Research Centre, Bengaluru, Karnataka, India, from March 2021 to August 2021. The study was approved by the Ethical and Research Committee (EC Reg No: ECR/747/Inst/KA/2015/RR). The informed consent was taken from all participants.

Inclusion criteria: Patients of all ages who were healthy (except for refractive errors) were included in the study.

Exclusion criteria: The exclusion criteria considered were craniofacial anomalies, strabismus, trauma to the face and orbit, poor vision with nystagmus, Pupillary abnormalities, corneal abnormalities (dryness, ectasia), iris abnormalities, orbital inflammation, tumors of the orbit or globe and those who did not consent for their participation in the study.

Study Procedure

The patients were divided into age groups <20 years having faster facial and orbital growth and ≥20 years. The IPD was measured using a PD meter having a fixed and sliding cursor [7]. The IPD was also measured using an Auto Ref/Keratometer and Hand Held Scale (HHS). A transparent ruler was used to take the other measurements like IICD, OICD, ICOC, RNL-LTL distance. The IICD was measured from a point where upper lid meets the lower lid and not from any point on the caruncle [4]. The OICD was measured between the two lateral canthi with the patient looking in primary gaze [4]. The RNL-LTL was measured between Nasal Limbus of right eye (3'o clock position) and temporal limbus of the left eye (3'o clock position). The various measurements are schematically represented in the [Table/Fig-1].



[Table/Fig-1]: Schematic representation of various Inter Orbital distances. ICD: Inner canthal distance; OCD: Outer canthal distance; IPD: Interpupillary distance; RNL-LTL: Right nasal limbus to left temporal limbus distance

For far IPD the examiner closed her right eye and asked the patient to look at her open left eye. The fixed cursor was placed at the centre of patient's right pupil. Then the examiner closed her left eye and asked the patient to focus on her right eye. The sliding cursor was now placed at the patients left pupil. The distance between the two cursors was taken as the far IPD. Near IPD values were not taken into consideration in the present study.

All the measurements were taken by the same person to avoid inter observer bias and also they were repeated till two consecutive readings were similar. The measurements were repeated if the patient moved his or her eyes or head. Correlation between IPD and IICD, OICD, ICOC, RNL-LTL distance was studied and a regression equation was derived to calculate IPD using above mentioned variables.

STATISTICAL ANALYSIS

Data was entered in MS Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 19.0. Categorical variables were presented as frequency and percentage. Multiple linear regression was performed to find the factors associated with IPD using AR. The p-value <0.05 was considered as statistically significant. Independent sample t-test was performed to compare mean values of IPD AR, IPD PDM, IPD HHS, IICD, OICD, IC-OC, RNL-LTL between males and females.

RESULTS

The demographic details of the study subjects included were 60 males and 40 females, out of which five subjects were <20 years and 95 subjects were ≥20 years.

The mean difference and Standard Deviation (SD) of IPD (with AR, PD meter and HHS), IICD, OICD, ICOC, RNL-LTL in males and females is shown in [Table/Fig-2]. Statistically significant values were obtained in all the variables among males and females. The values of mean difference between males and females are presented in [Table/Fig-3]. Levene's Test was performed to check for equality of variances between males and females and equal variances were assumed.

Variables	Female		Male		p-value
	Mean (mm)	Standard deviation	Mean (mm)	Standard deviation	
Interpupillary distance					
Auto refractometer	60.0	2.3	64.5	2.7	<0.001
Pupillary distance metre	60.9	2.2	65.1	2.6	<0.001
Hand held scale	60.2	2.3	64.2	2.9	<0.001
Intercanthal distance					
Inner Intercanthal distance	29.3	2.3	31.5	3.0	<0.001
Outer Intercanthal distance	79.8	3.9	82.5	3.4	<0.001
Inner canthal-outer canthal distance	58.4	2.6	62.5	3.0	<0.001
Right nasal limbus to left temporal limbus distance	60.1	2.4	63.6	2.6	<0.001

[Table/Fig-2]: Mean standard deviation of different variables.

Variables	t-test for equality of means						
	T	Degree factor	p-value	Mean difference	Standard error difference	95% Confidence interval of the difference	
						Lower	Upper
Interpupillary distance							
Auto refractometer	8.758	98	<0.001	-4.5	0.5138	-5.5197	-3.4803
Pupillary distance metre	8.394	98	<0.001	-4.2333	0.5043	-5.2341	-3.2325
Hand held scale	7.385	98	<0.001	-3.9917	0.5405	-5.0643	-2.919
Intercanthal distance							
Inner Intercanthal distance	3.989	98	<0.001	-2.2333	0.5599	-3.3444	-1.1222
Outer Intercanthal distance	3.775	98	<0.001	-2.7833	0.7373	-4.2464	-1.3203
Inner canthal-outer canthal distance	7.024	98	<0.001	-4.1083	0.5849	-5.2691	-2.9476
Right nasal limbus to left temporal limbus distance	6.874	98	<0.001	-3.55	0.5164	-4.5748	-2.5252

[Table/Fig-3]: Mean difference of mean values of all the measured variables for males and females.

The various correlation coefficients of the measured variables in the study subjects have been shown in [Table/Fig-4,5]. A positive correlation was noted between the various measured variables like IICD, OICD, ICOC, RNL-LTL and IPD. Strong positive correlation was observed between IPD AR, IPD PDM, IPD HHS and RNL-LTL (r=0.91366, 0.92971 and 0.93036 respectively), with a p-value=0.001.

[Table/Fig-6] shows the regression equations derived for calculating the IPD based on these different variables.

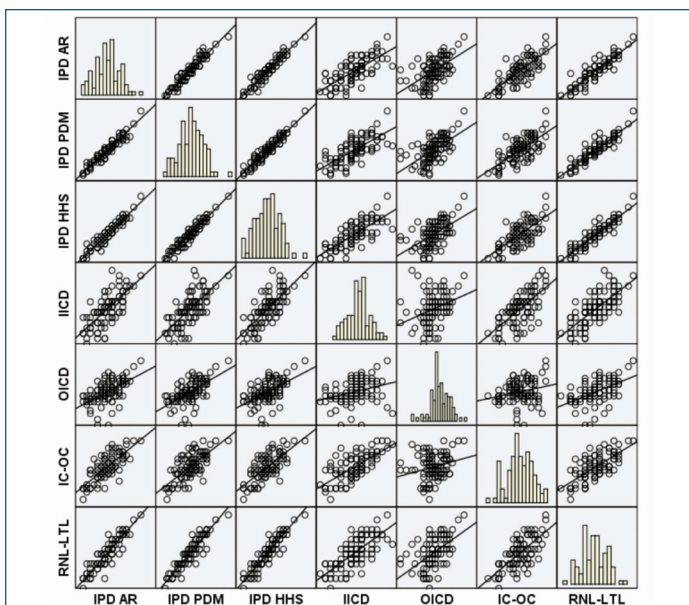
DISCUSSION

The various measurements like IPD, Intercanthal distances (Inner and Outer), Inner Outer Intercanthal distance, Nasal Limbus Temporal Limbus distance are useful in various fields of Ophthalmology like diagnosis and treatment of congenital orbital and craniofacial anomalies and post traumatic deformities [7] and also in mounting of spectacle lenses for avoiding the unwanted prismatic effects [7].

Variables		IPD AR	IPD PDM	IPD HHS	IICD	OICD	ICOC	RNL-LTL
Interpupillary distance								
Auto refractometer	r-value	1.00	0.96043	0.95817	0.71784	0.56754	0.76621	0.91366
	p-value	1.00	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Pupillary distance metre	r-value	0.96043	1.00	0.96243	0.71268	0.60233	0.70587	0.92971
	p-value	<0.0001	1.00	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Hand held scale	r-value	0.95817	0.96243	1.00	0.75967	0.54971	0.72599	0.93036
	p-value	<0.0001	<0.0001	1.00	<0.0001	<0.0001	<0.0001	<0.0001
Intercanthal distance								
Inner Intercanthal distance	r-value	0.71784	0.71268	0.75967	1.00	0.32324	0.68553	0.73746
	p-value	<0.0001	<0.0001	<0.0001	1.00	0.0010	<0.0001	<0.0001
Outer Intercanthal distance	r-value	0.56754	0.60233	0.54971	0.32324	1.00	0.23863	0.52909
	p-value	<0.0001	<0.0001	<0.0001	0.0010	1.00	0.0168	<0.0001
Inner canthal-outer canthal distance	r-value	0.76621	0.70587	0.72599	0.68553	0.23863	1.00	0.70486
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	0.0168	1.00	<0.0001
Right nasal limbus to left temporal limbus distance	r-value	0.91366	0.92971	0.93036	0.73746	0.52909	0.70486	1.00
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	1.00

[Table/Fig-4]: Correlation coefficients of measured variables.

IPD: Interpupillary distance; AR: Auto refractometer; HHS: Hand held scale; PDM: Pupillary distance metre; IICD: Inner Intercanthal distance; OICD: Outer Intercanthal distance; ICOC: Inner canthal-outer canthal distance; RNL-LTL: Right nasal limbus to left temporal limbus distance



[Table/Fig-5]: Scatter Plot Matrix.

Gender	Regression equation	R ²
Male	IPD AR=2.75+0.94 IPD PDM	0.96
Female	IPD AR=2.27+0.94 IPD PDM	
Male	IPD AR=7.34+0.89 IPD HHS	0.96
Female	IPD AR=6.40+0.89 IPD HHS	
Male	IPD AR=44.91+0.62 IICD	0.83
Female	IPD AR=41.80+0.62 IICD	
Male	IPD AR=37.25+0.33 OICD	0.75
Female	IPD AR=33.67+0.33 OICD	
Male	IPD AR=30.06+0.55 IC-OC	0.81
Female	IPD AR=27.83+0.55 IC-OC	
Male	IPD AR=9.34+0.86 RNL-LT	0.93
Female	IPD AR=7.92+0.86 RNL-LT	

[Table/Fig-6]: Regression equations between interpupillary and other measured distances.

The IPD forms one of the most important measurements for calculating interorbital distance or distance between eyeballs, which can be calculated by various ways, but it is difficult to measure in children [8], uncooperative patients and those having severe deformities [8,9]. Lack

of contrast between pupil and darkly pigmented iris and individuals with ocular instability also pose difficulty in measuring IPD [9].

There are various ways in which IPD can be measured like using a ruler [10-12], sliding calipers [13,14], corneal reflection pupillometer [15], and radiological techniques [16], but in some studies it is shown that IPD can also be calculated using more simple objective measurements like IICD, OICD [17,18]. Holland and Siderov used three methods in measuring IPD: Victorin's method, corneal reflection and pupillometer [19]. They have found not much difference in the calculated value of IPD by these techniques hence the results were not clinically significant [19]. However, the gold standard method of measuring IPD is pupillometer [20]. The AR was the fourth method of measuring IPD in a study conducted in Iran [1]. The AR was used in the present study as it helps in measuring IPD and refractive errors simultaneously.

In 1969 Pryor HB, found a simple objective method for derivation of an indirect estimate of IPD from IICD and OICD [9]. Feingold M and Bossert WH, in 1974 reported a different statistical measure by multiple linear regression to calculate IPD using IICD and OICD [18]. The present study is the first one to deduce regression equations for all the different variables like IICD, OICD, ICOC, RNL-LTL to calculate IPD whereas previous few studies have derived only for one or few of the variables.

The IPD values are determined between individuals of various ethnicities [7]. It is found that IPD of Chinese population is similar to Caucasians [14]. It is also found that Chinese and Arab children have similar IPD [17], however African-American children have wider IPD [7]. Pointer JS, found an approximate increase of 3% in the far IPD from mid-teens to late middle age in Caucasian population, but with a difference in sexes suggesting that this value has a little change beyond early middle ages in males but continues to increase till later middle ages in females [21].

In our study, mean IPD by AR in females was 60 with a SD of 2.3 and in males were 64.5 with a SD of 2.7 which was clinically significant. Gupta VP et al., in his study found that there was significant difference in mean IPD between the two genders in certain age groups [22]. It is also shown that males have larger IPDs in certain age groups [18]. Larger IPDs in males were reported in African population by Murphy WK and Laskin DM; and Pivnick EK [8,23]. A study among Arabs by Osuoben EP and Al-ibraheem AM found a difference of 2mm in IPD being greater in males compared to their female counterparts in ages 5 to 55 years [17]. This difference can be attributed to the fact that maturation process occurs faster in females [1].

In few studies, mean IICD was reported to be 25.5 to 38.5 mm in Whites and 32 to 34 mm in mixed European population [24,25]. Freihofer HPM found no difference between the genders and a mean IICD of 31 ± 2.7 mm in his study [26]. Mean IICD in the present study was 29.3 mm in females and 31.5 mm in males. According to data from various studies [22,25], the descending order of OICD and IPD in various races was found to be Africans > Chinese > Caucasians > Arabs > Indian. In the present study, the mean OICD was 79.8 mm in females and 82.5 mm in males, a value between white population and Indians. As per the literature review there is only one study by Gupta VP et al., which has derived a correlation between IPD and NLTL [22]. The present study is the first one to have studied correlation between different interorbital variables and IPD and also to have derived a regression equation in calculating IPD based on the values of the other variables which helps in certain difficult situations like paediatric age group, specially challenged individuals where using AR gets cumbersome, and also in peripheral and community based health checkup camps where availability of AR becomes a concern. In the present study the mean ICOC distance was found to be 58.4 mm in females and 62.5 mm in males. The mean RNL-LTL was found to be 60.1 mm in females and 63.6 mm in males. There was a similarity noted to certain extent between ICOC distance between the two eyes and IPD, which indicates that it is a better variable to approximately conclude regarding IPD measurements when time factor in giving an exact estimate becomes a constraint. However, the present study has also derived regression equations in calculating the IPD based on different inter orbital variables. There was a much stronger correlation noted between RNL-LTL and thus it could be concluded that RNL LNL measurement can be used to deduce IPD with a strong correlation coefficient.

Limitation(s)

Though the present study helps in these difficult times, it still has some limitations like lesser number of subjects less than 20 years, smaller sample size and IPD for near was not considered which gives scope for further research in this regard.

CONCLUSION(S)

The IPD is important in various situations like studying congenital craniofacial anomalies, after orbital trauma and most importantly in optical industry where even a little mistake in the same can cause significant reduction in quality of the image and lead to development of various types of aberrations. Hence, measuring IPD can be aided by regression equations as calculated by the present study, especially in some special situations like paediatric age group, uncooperative patients, especially challenged individuals and in periphery community camps, using other easily measurable inter orbital variables, where the gold standard of using AR becomes a challenge.

Declaration of patient consent: The authors declare of having taken all patients appropriate consent forms. All the patient/s has/have

given his/her/their consent for his/her/their relevant clinical information and images to be included in the journal. They also understand that their names or initials will be concealed and that their identity will be kept confidential, but anonymity cannot be guaranteed.

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