Original Article

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Clinical measurement on eyes and periocular areas: A Khon Kaen University study

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There is still no available dataset on the dimensions of prefabricated ocular prostheses for the Northeastern Thai population. This pilot study aimed to report on pupil positioning, iris and scleral dimensions, and lateral eye curvatures among individuals at the Faculty of Dentistry, Khon Kaen University. It also explored the correlations between these measurements and key demographic variables, including age groups and gender. A total of 276 healthy participants were categorized by gender and further subdivided into three age groups: 20–30, 31–50, and >50 years. Standardized photography was conducted in a well-lit room. A Whibal card with a 10-mm scale was held perpendicularly to the subject. Its inner edge was positioned adjacent to the right nostril, and its top edge was placed 1 cm below the lower eyelid. Measurements included interpupillary distance (IPD), outer canthal distance (OCD), intercanthal distance (ICD), palpebral fissure width (PFW), palpebral fissure height (PFH), iris size, and the angles between the upper and lower eyelids. Group comparisons were conducted using t-tests and one-way ANOVA, with Tukey's post hoc tests ($p = 0.05$). Gender significantly influenced IPD, OCD, PFW, and the upper-lower eyelid angle. Age significantly affected iris size, which was larger in the 20–30 group than in the >50 group. PFH was greater in the 20–30 group than in the >50 group and lower in the >50 group than in the 31–50 group. The upper-lower eyelid angle was more obtuse in the >50 group than in the 20–30 group. Males exhibited age-related differences in IPD, PFW, and eyelid angle, while females showed variations in iris size and PFH. These findings provide baseline periocular measurements which can be utilized to enhance the accuracy of stock ocular prostheses for the Northeastern Thai population.

Keywords: anthropometry, databases, eye prosthesis, iris, pupillary distance

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Introduction

Eyes are a crucial component of the human face, playing a significant role in the perception of facial beauty. Eye defects are commonly acquired through accidents or cancer resection, though they can also result from congenital conditions [1, 2]. To restore aesthetics and maintain socket volume, these patients are treated with ocular prostheses [3]. At the Faculty of Dentistry, Khon Kaen University, which serves as a major medical hub for Northeast Thailand, the demand for this treatment is highly evident, with 89.4% of patients requiring maxillofacial prostheses having experienced eye loss.

Generally, ocular prostheses are categorized as either stock or customized. While custom prostheses conform perfectly to the anophthalmic socket and accurately replicate the companion eye, their fabrication requires multiple clinical visits. Consequently, patients are often required to wear stock prostheses temporarily. However, stock prostheses are produced in standard sizes (small, medium, and large) based on average

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dimensions. Because these standard sizes frequently fail to match the patient's natural companion eye, they can cause complications such as a misaligned iris, socket bed irritation, or lower eyelid laxity [4].

Accurate pupil positioning is important for fabricating realistic prosthetic eyes. Various methods have been employed to estimate the pupil position, including direct measurement on the patient's face, Hirschberg's test, and inscribing a circle [4]. The position of the pupil can also be determined using reference points such as the white flash spot on the pupil in digital photographs or by employing computer-aided design and manufacturing (CAD/CAM) in three-dimensional models to assess both pupil position and prosthetic eye size. Additionally, eye size is also significant for prosthetic eye fabrication. Studies on the determination of eye dimensions have utilized methods such as direct clinical measurements, McCoy facial trisquare, and digital photography [5–9]. However, there is a lack of literature identifying the most accurate method for determining pupil position and eye size.

Research on eye size across various countries in Asia—such as India, China, Korea, and Thailand—has been conducted extensively. In Thailand, studies have focused on eye size in populations from the northern and southern regions [10-11]. Moreover, Khon Kaen University and affiliated hospitals serve as a major medical hub where patients from all regions of Northeast Thailand are treated. Given that modern innovations in CAD-CAM can be utilized to fabricate eye prosthesis in a short period, it is crucial to study eye size for the creation of ocular prosthesis that closely match the patients' eyes across different age groups, genders, and personal characteristics. Therefore, the objective of this research was to conduct anthropometric measurements to determine the average values of various anatomical landmarks—including the size of the iris, pupil, visible sclera, and the lateral contour of the eye—across different age groups and genders in a Northeast Thai population. Ultimately, this dataset aims to facilitate the development of CAD/CAM software for rapid custom fabrication, as well as to improve the proportional accuracy of pre-fabricated ocular prostheses for this specific demographic.

Materials and Methods

For this study, 276 out of 855 individuals who work and study in the Faculty of Dentistry, Khon Kaen University were randomly recruited. This study was approved by the Human Research Ethics Committee of Khon Kaen University (Reference No. HE662161) and was conducted in accordance with the principles of the Declaration of Helsinki and the International Council for Harmo nisation Good Clinical Practice (ICH-GCP) guidelines. Consent forms were provided to participants from the Faculty of Dentistry at Khon Kaen University, who voluntarily agreed to participate in the research. Additionally, participants were required to complete a basic information questionnaire including gender, age, race, medical problems, periocular operations, and surgery as well as visual acuity, before the commencement of the study. The participant group consisted of faculty members, undergraduate and postgraduate dental students from the Faculty of Dentistry at Khon Kaen University during a seven-month period from June to December 2023. Participants included both male and female individuals aged 20-30, 31-50, and >50 years. The calculated sample size was stratified by age proportion. Participants were then randomly recruited from each department, in proportion to the predetermined age strata,

and were then equally divided by gender within each age group. Inclusion criteria for the population were Thai individuals with normal vision in both eyes, without a history of severe ocular trauma, with myopia less than -6.00 diopters, no strabismus, no congenital orbital abnormalities, and no endocrine disorders, such as hyperthyroidism. Exclusion criteria included individuals without a permanent residence in Thailand and those who are unable to remove makeup or makeup devices that obscured landmarks around the eye.

This study involved capturing images in two formats: frontal and lateral views of both the left and right sides. The photographic setup featured a black background positioned 50 centimeters from the subject. A Canon EOS RP camera with a fixed focal length of 100 mm was consistently used, equipped with a MEIKE MK-14EXT iTTL Macro Ring Flash, and was mounted on a tripod 50 centimeters from the subject. Softbox lights on either side of the subject were angled at 45 degrees and positioned 50 centimeters away. The room was lit with fluorescent lighting. The camera settings for photographing the subjects were adjusted as follows: aperture at f/8, shutter speed at 1/125, ISO at 100, and white balance at 5500K. In the frontal view, the subject was seated upright, looking forward and relaxed, with the line of sight aligned with the camera lens. The subject held a Whibal card with a 10 mm scale perpendicular to the floor, positioning the card's inner edge next to the right nostril and the top edge of the card 1 cm below the lower eyelid, ensuring it was close to the face. The resulting photograph captured the area from the eyebrows to the upper lip. For the lateral views, the subject was seated upright, with 90 degrees turn either to the left or right of the camera, while maintaining a relaxed straight gaze. The subject held the Whibal card as previously described and rested it against the left or right cheekbone. The resulting photographs covered the area from the eyebrows to the upper lip (Figure1).

The measurement of various periocular anatomical landmarks, including palpebral fissure width (PFW), defined as the distance between the medial and lateral canthi; palpebral fissure height (PFH), defined as the vertical distance between the upper and lower eyelid margins; interpupillary distance (IPD), defined as the distance between the centers of the two pupils; outercanthal distance (OCD), defined as the distance between the two lateral canthi; innercanthal distance (ICD), defined as the distance between the two medial canthi; iris size, defined as the horizontal diameter of the visible iris; and the angle between the upper and lower eyelids, defined as the angle formed by the upper eyelid, lateral canthus, and lower eyelid at the lateral view, was conducted using Adobe Photoshop 2024 *(Adobe Inc., California,* U.S)

Figure 1 (A)image in frontal view, (B) image in lateral view of right side, (C) image in lateral view of left side

The accuracy of measurements was calibrated using the Whibal card present in the photographs in the software using "Analysis" and "Set measurement". Each image underwent three repeated measurements conducted by the same researcher, distributed across three sessions of ten images each. Measurements were first performed on images 1 through 10, and then repeated on these same images to ensure consistency. The obtained measurements for each parameter were averaged to determine the PFW, PFH, IPD, OCD, ICD, iris size, and the angle between the upper and lower eyelids. This process enabled the determination of the iris size, scleral width, the lateral curvature of the eye, and the pupil's position.

Data analysis was conducted using SPSS Statistics version 20.0 (Armonk, NY: IBM Corp.) with a statistical significance level set at 0.05. Mean values for the PFW, PFH, IPD, OCD, ICD, iris size and the angle between the upper and lower eyelids were calculated. The intra-rater reliability was then assessed using the Intraclass Correlation Coefficient (ICC), which yielded a value of 0.91, indicating excellent reliability. To assess the normality of the data, Kolmogorov-Smirnov tests were utilized. T-tests were conducted to identify significant differences between two gender of participants. To compare differences among three age-range groups, one-way ANOVA was employed. Tukey's post hoc test was applied to compare the measured parameters across different age groups.

Results

In this study, 276 individuals were recruited, with an average age of 31.40±12.10 years, ranging from 20 to 70 years. The sample was equally divided by gender and categorized into three age groups: 20-30 years, 31-50 years, and >50 years. A total of 79.70% of the participants reported their hometown as being located in the northeastern region of Thailand, whereas 20.30% originated from other regions of the country. The racial composition of the study population was 62.30% Thai, 35.10% Thai–Chinese, and 2.50% Thai–Vietnamese. The intra-observer coefficient of reliability (R) demonstrated a high level of measurement consistency, with values ranging from 0.92 to 0.99, indicating excellent reproducibility of the recorded measurements.

Table 1 indicated that gender had a significant effect on IPD (p = 0.01). The male group showed a greater mean IPD (63.08±4.05 mm) than the female group (62.47±3.07 mm). Similarly, the OCD was higher in the male group (87.72±6.57 mm) compared to the female group (86.58±3.81 mm) (p = 0.038). Additionally, the male group had a mean PFW of 26.59±1.69 mm, while the female group had a mean PFW of 26.16±1.38 mm (p = 0.011). Conversely, the male group displayed a lower mean angle between the upper and lower eyelids in lateral view, measuring 52.46°±7.99° compared to 55.78°±6.24° in the female group (p = 0.02).

In **Table 2**, age demonstrated a significant effect on mean IPD, which was lower in the 20-30 years age group compared to the 31-50 years group (62.69±3.46 mm and 63.91±3.99 mm, respectively) (p = 0.049). The mean iris size was greater in the 20-30 years age group than in the >50 years age group (11.59±0.48 mm and 11.32±0.51 mm, respectively) (p = 0.013). Additionally, the mean PFH was higher in the 20-30 years group compared to the >50 years group (9.84±1.17 mm and 8.69±1.35 mm, respectively) (p = 0.001), and it was also lower in the >50 years group compared to the 31-50 years group (9.57±1.18 mm) (p = 0.002). Furthermore, the angle between the upper and lower eyelids in lateral view was more obtuse in the >50 years group compared to the 20-30 years group (57.45°±6.96° and 53.23°±7.08°, respectively) (p = 0.008).

Table 1 The average value (Mean ± SD) of each parameter between gender groups

	Male (n= 138)	Female (n= 138)	p-value
IPD (mm)	63.08 ± 4.05	62.47 ± 3.07	0.001*
ICD (mm)	35.57 ± 3.11	34.88 ± 3.40	0.420
OCD (mm)	87.72 ± 6.57	86.58 ± 3.81	0.038*
Iris (mm)	11.58 ± 0.49	11.51 ± 0.5	0.132
PFH (mm)	9.65 ± 1.23	9.62 ± 1.67	0.414
PFW (mm)	26.59 ± 1.69	26.16 ± 1.38	0.011*
Angle (°)	52.46 ± 7.99	55.78 ± 6.24	<0.001*

Abbreviation: SD: standard deviation, IPD: interpupillary distance, ICD: inner canthal distance, OCD: outer canthal distance, Iris: iris size, PFH: palpebral fissure height, PFW: palpebral fissure width, Angle: the angle between the upper and lower eyelids

* a statistical significance

Table 2 The average value (Mean ± SD) of each parameter among age groups

Parameter	Age (years)			
	20-30 (n = 176)	31-50 (n = 68)	>50 (n = 32)	Total (N = 276)
IPD (mm)	62.69 ± 3.46 ^{A}	63.91 ± 3.99 ^{B}	63.95 ± 3.64 ^{B}	63.14 ± 3.65
ICD (mm)	35.30 ± 3.38 ^{A}	35.23 ± 2.97 ^{A}	34.78 ± 3.31 ^{A}	35.23 ± 3.27
OCD (mm)	86.74 ± 5.62 ^{A}	88.32 ± 4.90 ^{A}	86.91 ± 4.86 ^{A}	87.15 ± 5.39
Iris (mm)	11.59 ± 0.48 ^{A}	11.55 ± 0.51 ^{A,B}	11.32 ± 0.51 ^{B}	11.55 ± 0.50
PFH (mm)	9.84 ± 1.17 ^{A}	9.57 ± 1.18 ^{A}	8.69 ± 1.35 ^{B}	9.6 ± 1.25
PFW (mm)	26.28 ± 1.42 ^{A}	26.76 ± 1.71 ^{A}	26.09 ± 1.81 ^{A}	26.37 ± 1.55
Angle (°)	53.23 ± 7.00 ^{A}	54.85 ± 7.77 ^{A,B}	57.45 ± 6.96 ^{B}	54.12 ± 7.35

* Each parameter was separately analyzed between different age groups.

** The same superscript letter meant there was no significant difference between groups.

According to **Table 3**, in the male group, the mean ICD was 34.21±3.07 mm, 36.34±3.07 mm, and 35.86±3.28 mm in the age groups of 20-30 years, 31-50 years, and >50 years, respectively. The mean iris size was 11.56±0.50 mm, 11.70±0.46 mm, and 11.44±0.46 mm, and the mean PFH was 9.64±1.78 mm, 9.91±1.18 mm, and 9.20±1.50 mm. These parameters showed no significant differences among age groups (p = 0.185, p = 0.184, and p = 0.155, respectively). The mean IPD was 62.82±3.73 mm, 65.60±4.30 mm, and 65.22±3.62 mm in group 20-30 years, 31-50 years, and >50 years, respectively, with a significant difference observed between group 20-30 years and group 31-50 years (p < 0.001). The mean OCD was 86.54±7.02 mm, 90.45±5.28 mm, and 88.45±4.59 mm in group 20-30 years, 31-50 years and >50 years respectively, showing a significant difference between the 20-30 years and 31-50 years groups (p = 0.009). The mean PFW was 26.27±1.53 mm, 27.40±1.92 mm, and 26.60±1.53 mm in group 20-30 years, 31-50 years and >50 years respectively, with a significant

difference found between the 20-30 years and 31-50 years groups (p = 0.003). The mean angle between the upper and lower eyelids in the lateral view was 51.43±7.62 degrees, 53.07±8.25 degrees, and 56.81±8.34 degrees in the group 20-30 years, 31-50 years, and >50 years, respectively, with a significant difference between group 20-30 years and group over-50 years (p = 0.03).

Table 4 exhibited that in the female group, the mean iris size was 11.61±0.46 mm, 11.41±0.53 mm, and 11.19±0.54 mm in group 20-30 years, 31-50 years and over-50 years respectively, with a significant difference between group 20-30 years and over 50 years (p = 0.005). The mean PFH was 10.03±1.14 mm, 9.22±1.10 mm, and 8.18±0.98 mm in group 20-30 years, 31-50 years and over 50 years respectively and had significant difference between group 20-30 years and 31-50 years (p = 0.001) as well as between group 20-30 years and over 50 years (p < 0.001).

Table 3 The average value (Mean ± SD) of each parameter among age groups in male subjects

Parameter	Age (years)			
	20-30 (n = 88)	31-50 (n = 34)	>50 (n = 16)	Total (N = 138)
IPD (mm)	62.82 ± 3.73 ^{A}	65.70 ± 4.28 ^{B}	65.22 ± 3.62 ^{A,B}	63.81 ± 4.05
ICD (mm)	35.21 ± 3.07 ^{A}	36.34 ± 3.07 ^{A}	35.86 ± 3.28 ^{A}	35.57 ± 3.11
OCD (mm)	86.54 ± 7.02 ^{A}	90.45 ± 5.28 ^{B}	88.45 ± 4.59 ^{A,B}	88.73 ± 6.56
Iris (mm)	11.56 ± 0.50 ^{A}	11.70 ± 0.46 ^{A}	11.44 ± 0.46 ^{A}	11.58 ± 0.49
PFH (mm)	9.64 ± 1.18 ^{A}	9.91 ± 1.18 ^{A}	9.20 ± 1.50 ^{A}	9.65 ± 1.23
PFW (mm)	26.27 ± 1.53 ^{A}	27.40 ± 1.92 ^{B}	26.60 ± 1.53 ^{A,B}	26.59 ± 1.69
Angle (°)	51.44 ± 7.62 ^{A}	53.07 ± 8.25 ^{A,B}	56.81 ± 8.36 ^{B}	52.46 ± 7.99

* Each parameter was separately analyzed between different age groups.

** The same superscript letter meant there was no significant difference between groups.

Table 4 The average value (Mean ± SD) of each parameter among age groups in female subjects

Parameter	Age (years)			
	20-30 (n = 88)	31-50 (n = 34)	>50 (n = 16)	Total (N = 138)
IPD (mm)	62.57 ± 3.18 ^{A}	62.13 ± 2.73 ^{A}	62.68 ± 3.30 ^{A}	63.47 ± 3.07
ICD (mm)	35.39 ± 3.69 ^{A}	34.12 ± 2.44 ^{A}	33.71 ± 3.08 ^{A}	34.88 ± 3.4
OCD (mm)	86.95 ± 3.76 ^{A}	86.18 ± 3.39 ^{A}	85.37 ± 4.76 ^{A}	88.58 ± 3.81
Iris (mm)	11.61 ± 0.46 ^{A}	11.41 ± 0.53 ^{A,B}	11.19 ± 0.54 ^{B}	11.51 ± 0.51
PFH (mm)	10.03 ± 1.14 ^{A}	9.22 ± 1.10 ^{B}	8.18 ± 0.98 ^{C}	9.62 ± 1.27
PFW (mm)	26.28 ± 1.30 ^{A}	26.12 ± 1.20 ^{A}	25.57 ± 1.97 ^{A}	26.16 ± 1.38
Angle (°)	55.03 ± 6.02 ^{A}	56.62 ± 6.94 ^{A}	58.10 ± 5.43 ^{A}	55.78 ± 6.24

* Each parameter was separately analyzed between different age groups.

** The same superscript letter meant there was no significant difference between groups.

Out of 276 subjects, the majority were Thai, accounting for 62.30%. The second largest group was Thai-Chinese, comprising 31.10%, while the smallest group was Thai-Vietnamese, representing 2.50%, as shown in **Figure 2**. Additionally, **Figure 3** indicated that 54.30% of male subjects and 70.30% of female subjects identified as Thai. Furthermore, 44.90% of male subjects and 25.40% of female subjects were Thai-Chinese, while 0.70% of male subjects and 4.30% of female subjects were Thai-Vietnamese.

This study observed and categorized iris display into three types: Type I, where the upper and lower border of the iris slightly sinks into the upper and lower eyelids; Type II, where the upper and lower borders of the iris align with the upper and lower eyelids; and Type III, where the lower border of the iris lifts above the level of the lower eyelid. The study found that Type I iris display was the most common, occurring in 80.40% of subjects, while Type II iris display was the least common, found in only 2.50% of subjects as shown **Figure 4** and **Figure 5**.

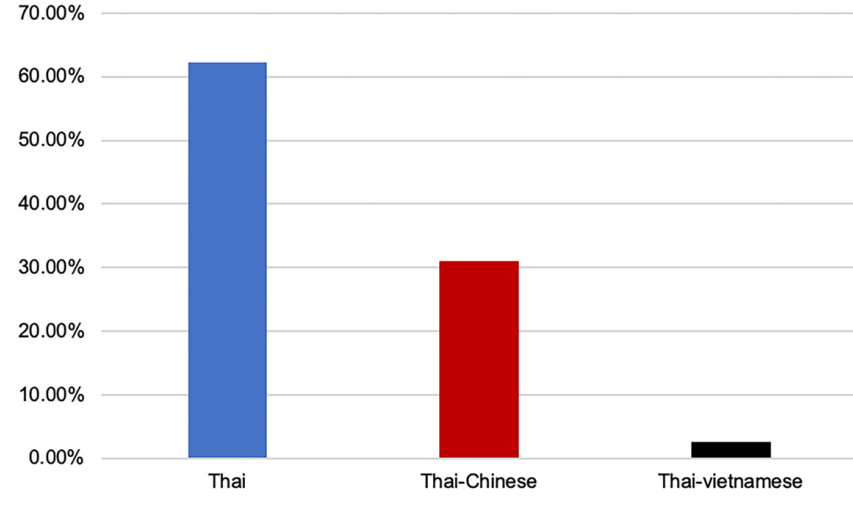

Figure 2 The racial composition of the overall subjects. (n = 276)

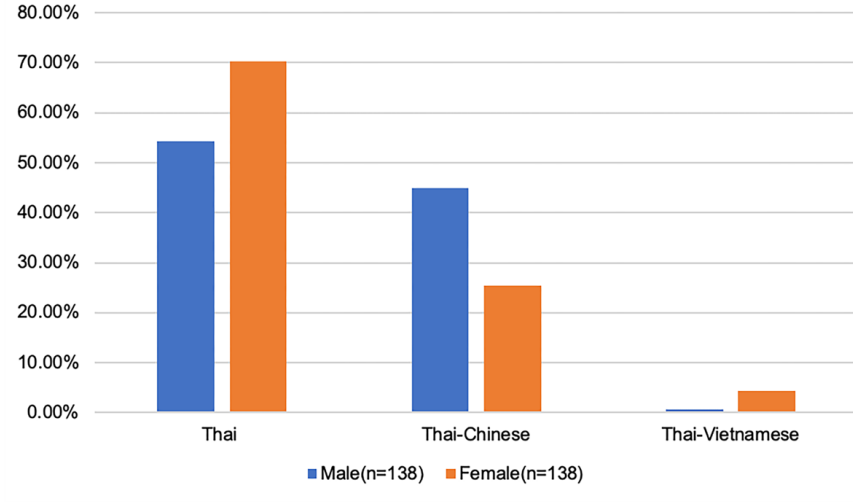

Figure 3 The racial composition of subjects across different gender groups (n = 276)

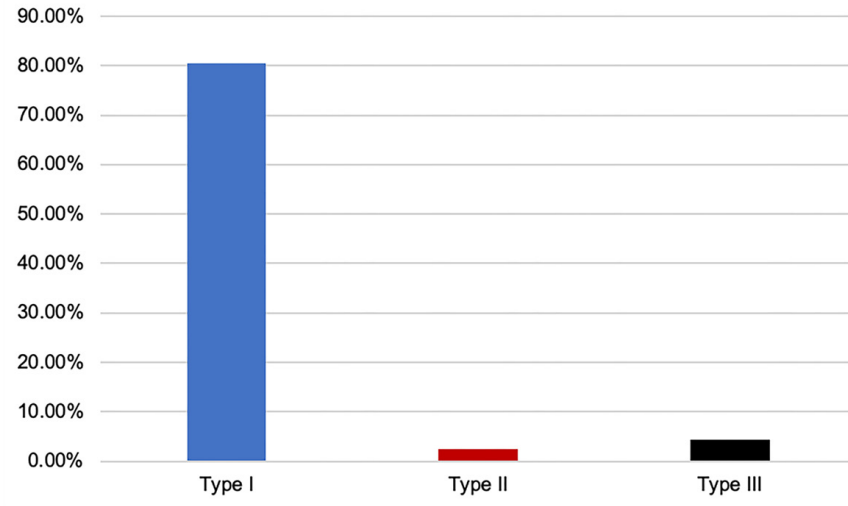

Figure 4 Distribution of type of Iris display.

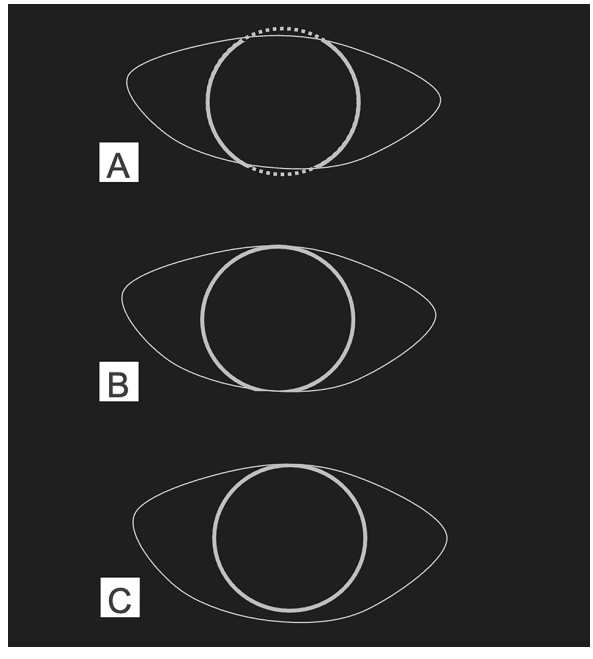

Figure 5 Type of Iris display observed in the study, (5A) Type I, where the upper and lower border of the iris slightly sinks into the upper and lower eyelids; (5B) Type II, where the upper and lower borders of the iris align with the upper and lower eyelids; and (5C) Type III, where the lower border of the iris lifts above the level of the lower eyelid.

Discussion

The replacement of a lost eye with ocular prosthesis is crucial for restoring the quality of life in affected patients. In patients who face difficulties in undergoing multiple visits to obtain a custom ocular prosthesis, restoring the defect with a stock one could be a potential solution. Consequently, studying anthropometric measurements is vital for fabricating a precise stock ocular prostheses.

Although numerous studies have proposed various methods for measuring periocular anatomical landmarks, no definitive research has identified the most accurate technique. Astley and Clarren noted that direct measurement from subjects' faces raises concerns about safety and may lead to less reliable results [6]. Patil *et al.* proposed using digital photography combined with a ruler for measurement [5]. Vasanthakumar *et al.* utilized computer software to measure periocular landmarks, achieving more reliable results [12].

Our study assessed periocular parameters similar to those examined in other research; however, it uniquely included the angle between the upper and lower eyelids in the lateral view and iris size. The angle between the upper and lower eyelids was specifically incorporated to evaluate the curvature of the eyeball displayed in lateral view which is relevant for fabrication stock ocular prostheses. Unlike other studies based on ocular plastic surgery, which often emphasized on periocular soft tissues that can be surgically controlled, our study also considered iris size. The findings revealed that gender significantly influenced IPD, OCD, PFW, and the mean angle between the upper and lower eyelids in lateral view. These results align with Vasanthakumar *et al.'s* study on the Indian population, which found that males had larger IPD, OCD, and PFW values compared to females [12]. Additionally, Kunjur *et al.* reported significant differences in PFW among the Chinese population [13]. In contrast, no significant differences in PFW between males and females in Vietnamese and Asian populations, respectively [9,14]. Despite not differentiating between gender groups, a study by Preechawai *et al.* conducted in southern Thailand reported similar findings to this study [10]. Notably, our study introduced a new parameter—the angle between the upper and lower eyelids in the lateral view which was found to be greater in females than in males. This discrepancy may be attributed to the differential growth of the frontal bone, as the nasofrontal angle was reported to be higher in females, according to Sirimaharaj *et al.* in the Northern region of Thailand [11].

Our study found that age significantly influenced mean IPD, with individuals in the 20-30 year age group exhibiting a lower mean IPD compared to those in the 31-50 year group. This finding aligns with the study by Yildirim *et al.*, which reported an increase in IPD among older adults, with a noted decrease in IPD during their seventies [15]. However, since the maximum age in our study was 70 years, the results indicated that there was no significant difference in IPD between the 31-50 year group and the >50 year group. The observed changes in IPD may be attributed to alterations in orbital tissue and increased laxity of soft tissues with age [16]. Additionally, the mean iris size was greater in the 20-30 year age group compared to individuals >50 years old. Specifically, the mean iris size was 11.60 mm for the 20-30 year age group and 11.30 mm for those >50 years. The reduction in iris size with advancing age may be related to the formation of a gray incomplete ring around the cornea, known as Arcus Senilis [17]. This condition could affect the measurement reference point of the iris, contributing to a diminished appearance of the iris. Although this difference was statistically significant, it may not be clinically significant.

The average iris size was approximately 11.00-11.50 mm, aligning with Spors *et al*., who reported a range of 10.20-13.00 mm in Caucasians [18]. Additionally, the PFH was greater in the 20-30 year age group compared to the >50 year age group. The PFH was also lower in the >50 year group compared to the 31-50 year age group. These results indicate a significant decrease in mean PFH by approximately 1 mm from the 20-30 year age group to those in their fifties. This finding is consistent with Park *et al*., who reported a mean PFH of 8.00 mm and 8.20 mm for Korean men and women, respectively, with a gradual decrease observed from around their fifties [8]. Ma *et al*. noted that signs of aging begin around the early thirties, with PFH and PFW decreasing by approximately 15% with age as a result of increased upper eyelid load and potential loss of tensile strength due to lid retraction by the levator muscles [16]. In contrast, Patil *et al.* reported a mean PFH of 12.30 mm in males and 11.70 mm in females, with no significant age-related differences [5]. Furthermore, the angle between the upper and lower eyelids in the lateral view was more obtuse in the >50 year group compared to the 20-30 year group. This suggests that the angle increases with age, potentially due to changes in periocular tissue, such as ectropion—the outward turning of the eyelid margin—commonly observed in the lower eyelids of individuals over 50 years old [16]. This condition may contribute to a lowering of the reference point. Consequently, when viewed laterally, more of the eye's contour becomes visible, and laxity of the upper eyelid, particularly in the outercanthal area, leads to an increased angle between the upper and lower eyelids in older individuals.

The results indicated that in male subjects, there were no significant differences in the mean ICD, mean iris size, or mean PFH across the age groups of 20-30 years, 31-50 years, and over 50 years. Sirimaharaj *et al.* reported an ICD of 38.25 ± 6.51 mm in male populations aged 16-18 years in the northern region of Thailand.[13] In comparison, this finding suggests that northern populations may have an ICD approximately 3 mm greater than that of the northeastern population. It is important to note, however, that differences between the studies were a younger age group and racial composition in Sirimaharaj's study. Additionally, Preechawai *et al.* reported that the ICD in male Chinese individuals was greater than that in male Thai-Chinese and male Thais aged 20-40 years [14]. A significant difference was observed between the 20-30 years group and the 31-50 years group, indicating that the IPD and OCD increases around age 30 and remains relatively constant thereafter. This finding contrasts with other studies that did not report significant age-related changes in OCD. Furthermore, in comparison to the study by Sirimaharaj *et al*., the OCD in the male population of our study was greater than that reported for the closest age group (16-18 years) (97.60 mm and 86.50 mm, respectively). Additionally, Preechawai *et al.* found that the OCD in male Chinese individuals was greater than that of male Thai-Chinese and Thai males aged 20-40 years in the southern region of Thailand (91.20 mm, 90.40 mm, and 87.70 mm, respectively) [10,11]. For the PFW, Significant differences were found between the 20-30 years and 31-50 years groups. This increase in PFW between these age groups aligns with the increase observed in OCD, while the mean ICD remained stable across age groups. This suggests that in males, lateral growth of the outer canthal area might occur around the age of 31-50 years. Furthermore, according to Sirimaharaj *et al*., the male population exhibited a PFW of 29.70 mm, which was approximately 3 mm higher than the PFW recorded in our study for the closest age group [11]. In this study, The mean angle between

the upper and lower eyelids in the lateral view began to increase significantly in the >50 years group, likely due to the development of ectropion, as previously discussed.

In females, there were no significant differences in the mean values of IPD, ICD, OCD, PFW, and angle between the upper and lower eyelids in the lateral view across all age groups. Sirimaharaj *et al.* reported an ICD of 36 mm in female populations aged 16-18 years in the northern region of Thailand. This finding suggests that northern populations may have an ICD approximately 1 mm greater than that of the northeastern population. Similar to the male group, it is important to note that differences between the studies were a younger age group and vairations in the racial composition [11]. Furthermore, Preechawai *et al*. found that the IPD did not significantly differ among female Chinese, female Thai-Chinese, and female Thai individuals aged 20-40 years [10]. Although the differences were not statistically significant, the results indicated a tendency for increased IPD among the Chinese-related female group. Consequently, this suggests that race may also influence IPD in females. Additionally, Sirimaharaj *et al.* reported a mean OCD 96.10 mm among the female population, which was greater than that observed in our study for the closest age group (16-18 years) [11]. Preechawai *et al.* demonstrated that there were no significant differences in OCD among Chinese, female Thai-Chinese, and female Thai individuals aged 20-40 years in the southern region of Thailand, which is comparable to the age range of 20-30 years in our study [10]. The values reported by Sirimaharaj *et al.* was approximately 4 mm higher than that of our study for the closest age group. The mean iris sizes decreased with age and a significant difference was noted between the 20-30 years group and >50 years group. Similarly there was a decrease in the mean PFH with age and significant differences were observed between the 20-30 years group and the 31-50 years group as well as the 31-50 years group and >50 years groups. These findings suggest that changes in PFH with age may be attributed to the increased laxity of the upper eyelid, as reported by Ma *et al*. [16].

In CAD-CAM systems, average values of specific data are critical for optimizing workflows. The study revealed that Type I iris display was the most prevalent, whereas Type II iris display was the least common. This information can utilized for the fabrication of stock ocular prostheses by highlighting common characteristics among populations, in conjunction with the mean PFH, which assists in the design process (Figure 5).

The data from this study could facilitate the creation of a pilot 3D virtual clinical model of periocular tissues. Key factors influencing the iris position include the mean values for IPD, ICD, OCD, and PFH. The medio-lateral width of the prosthesis is primarily determined by the mean PFW, while the mean angle between the upper and lower eyelids in the lateral view affects the lateral curvature of the ocular prosthesis. Additionally, the PFH is relevant for soft tissue data used to simulate the average clinical appearance of the iris. In females, the mean iris size demonstrated statistical significance across age groups, as did the mean PFH. Consequently, the prosthesis can be designed in 3D CAD software to account for variations in iris display and size. For males, significant variations were observed in the PFW, IPD, and angle between the upper and lower eyelids across age groups. Thus, the prosthesis needs to account for variations in medio-lateral width, iris positioning, and prosthesis contour. Current commercial stock ocular prostheses at Khon Kaen University are available in three standard sizes—small (20 mm), medium (22 mm and 24 mm) or large (26 mm and 28 mm) in width,

with a 12-mm iris size. Compared to these commercial sizes, the prostheses designed from this study's dataset would likely approximate the large size. The study's limitations include the absence of data on the depth of both the upper and lower fornices. However, Kadir proposed a technique for contracted socket reconstruction that emphasizes the lower fornix, reporting the normal depths of 14 mm for the upper fornix and 10 mm for the lower fornix. The depth of the lower fornix is particularly critical, as it bears more weight and must be sufficiently deep to support the ocular prosthesis [19]. Amornvit *et al.* indicated that a depth of 3 mm is adequate to maintain the ocular prosthesis [20]. According to Hoang *et al.*, the mean vertical dimension of custom ocular prostheses were approximately 23 mm, with a prosthesis thickness ranging from 8 to 9 mm, depending on the surgical techniques employed [21]. Given that the mean PFH in our study was about 9.60 mm, it can be estimated that the prosthesis may extend about 5 mm inferiorly into the lower fornix and approximately 8.40 mm superiorly from the iris display (Figures 6,7). Nowadays, the fabrication of digital custom ocular prostheses requires a three-dimensional (3D) scan of both the defective ocular socket and the intact side. Measurements obtained from the normal side are used as reference values to create a prosthesis with symmetrical dimensions corresponding to the healthy eye [22]. In contrast, the fabrication of stock ocular prostheses relies on normative values reported in previous studies and the present study, which serve as a reference library rather than measurements from the patient's intact eye. In such cases, the relationship between the two sides of the eye can be estimated using the IPD value. As mentioned above, this represents only one example of how such information, including the results of the present study, may be applied. However, these reference values may vary depending on the factors emphasized by CAD–CAM users, such as age-related differences, gender-related differences, or a combination of both.

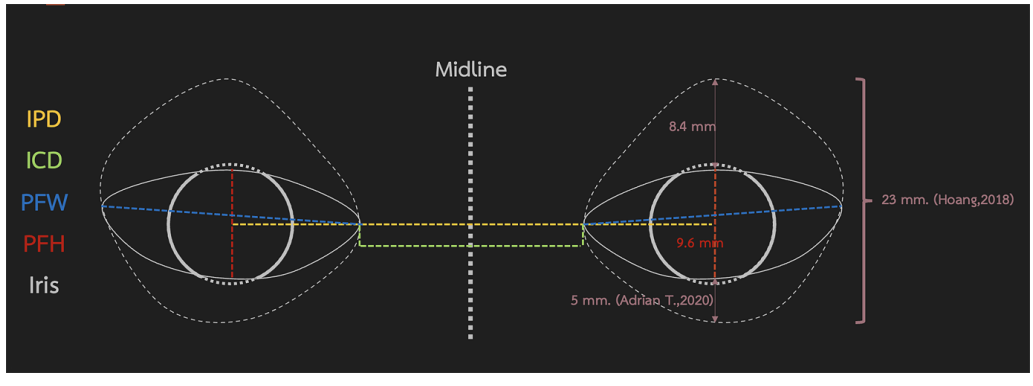

Figure 6 A simulated model of a stock ocular prosthesis in frontal view incorporates IPD (yellow line), mean ICD (green line), and mean PFH (red line) and PFW (blue line). Type I iris display was integrated along with thickness data from Hoang and lower fornix depth data from Adrian T.'s study.

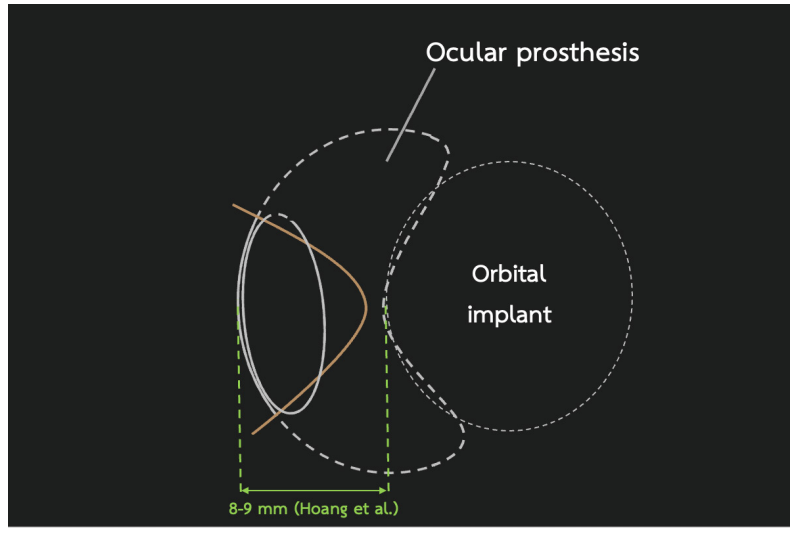

Figure 7 A simulated model of a stock ocular prosthesis in the lateral view using the lateral curvature of the eye obtained from the mean angle between the upper and lower eyelids data from this study, combined with thickness data from Hoang's study.

This preliminary study provides insights into the mean size of periocular tissues, not only for the Faculty of Dentistry, Khon Kaen University, but also for a portion of the Thai population. However, it is important to note that the majority of participants were from northeastern Thailand. Additionally, future studies should consider focusing on the racial composition of the population, as our results indicated that some values were similar to those reported by Preechawai *et al*., which included participants of Chinese descent. This observation is consistent with the presence of participants of Chinese ethnicity within the study sample, which may have influenced the overall findings. Future research should aim to include a more representative sample of the Thai population to enhance the generalizability of the data on periocular tissue sizes. Moreover, in addition to measuring healthy tissue, data on upper and lower fornix depths and the thickness of the protheses in anophthalmic patients are essential data for fabricating better-fitting 3D prostheses. Additionally, current commercial stock ocular prostheses offer only two iris colors: brown and black. Future developments should consider incorporating a broader range of iris and sclera colors and characteristics to create more realistic stock ocular prostheses, thereby improving the quality of life for patients.

Conclusions

In certain age groups, variations were observed in the IPD, PFW, and the angle between the upper and lower eyelids among males. For females, differences were noted in iris size and PFH across various age groups. This study provides preliminary data on the mean dimensions of periocular landmarks, which can be used as a reference database to enhance the precision of stock ocular prosthesis fabricated for the northeastern Thai population.

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