Original Article

Racial and sexual differences of eyebrow and eyelid morphology: three-dimensional analysis in young Caucasian and Chinese populations

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Background: With globalization, oculoplastic surgeons must understand the intricate morphological nuances of the periocular region across ethnicities to ensure precise treatment and avoid facial disharmony or dysfunction. Direct comparisons in two-dimensional (2D)-based periocular morphology between studies can be challenging due to the limited number of parameters and complicated variations in equipment, environments, measurement personnel, and methods. Therefore, it is imperative to explore the detailed

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three-dimensional (3D) periocular morphological disparities between young Caucasian and Chinese populations. This study aimed to establish gender- and ethnicity-specific 3D anthropometric data in periocular soft tissue for young Caucasian and Chinese adults and to determine the inter-racial and inter-gender differences.

Methods: This descriptive, cross-sectional study enrolled 46 Asians and 101 Caucasians aged 18 to 30 years. 3D models were analyzed with 32 landmarks, yielding 21 linear distances, three curvatures, six angles, and three proportions. Comparisons were made across left and right eyes, ethnic groups, and sexes to assess ethnic disparities and sexual dimorphism.

Results: Twenty-nine measurements were compared between the left and right sides revealing significant differences (P<0.002) in two measurements for Caucasian and Chinese females, respectively. However, these differences were submillimeter levels and potentially inconsequential in practical settings with left-right differences of −0.58 and −0.57 mm (P<0.001) for double-eyelid fold-palpebral margin distance (medial) (FPDm) and double-eyelid fold-palpebral margin distance (medial limbus) (FLmD) in Chinese females and −0.38 and −0.52 mm (P<0.001) for palpebral fissure width (PFW) and lower palpebral margin length (LPML) in Caucasian females. Caucasian males displayed significantly larger palpebral fissure height (PFH), iris diameter (ID), LPML, lateral canthal angle (LCA), canthal tilt (CT), palpebral fissure index (PFI), and canthal angular index (CAI), as well as smaller inner intercanthal distance (EnD), outer intercanthal distance (ExD), and canthal index (CI) than Chinese males (P<0.05). In contrast, Caucasian females showed significantly larger PFW, ID, LPML, LCA, CT, and CAI, as well as smaller EnD, ExD, CI, and medial canthal angle (MCA) than Chinese females (P<0.05). Furthermore, Caucasians showed more prominent double-eyelid folds, except at the pupil center in females. In eyebrow measurements, Caucasian males exhibited non-significant differences with Chinese males, while Caucasian females had significantly larger measurements at lateral positions but smaller ones at the endocanthion than Chinese females (P<0.05).

Conclusions: This study established sex- and ethnicity-specific 3D anthropometric data for the periocular region of young Caucasian and Chinese adults. These findings must be considered for periocular disease diagnosis, surgical planning, and outcome evaluation across diverse sexual and ethnic populations.

Keywords: Eyelid; eyebrow; ethnicity; gender; three-dimensional (3D)

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Introduction

The periocular region is one of the most eye-catching three-dimensional (3D) facial features. Its complex surface morphology is formed by various anatomical subunits comprising the palpebral fissure, eyelids, endocanthion, exocanthion, and eyebrow (1). These periocular subunits in different sizes and proportions aggregate harmoniously as the central aesthetic feature of the face. Hence, even a minor lesion caused by injury or illness may lead to significant facial incongruence and dysfunction (2). Furthermore, periocular abnormalities are corrected skillfully by a plastic surgeon or ophthalmologist according to the published norms concerning genders and ages in specific races (3). The surgeon can encounter challenges when an ethnically diverse patient presents for periocular surgeries (3,4). As a result, it may lead to disharmony in facial aesthetics when traditional Caucasian-based norms are applied to patients from diverse ethnic backgrounds (5). With the development of globalization, many countries now have multi-ethnic populations, especially in Europe and the United States. Therefore, there is a need to investigate the anthropometric differences in detailed 3D periocular morphology between young Caucasian and Asian populations.

Classical facial anthropometry, including direct anthropometry, two-dimensional (2D) photogrammetry, and cephalometry, has been used to identify craniofacial differences among age, sex, or ethnicity (6). In recent decades, 3D surface imaging, particularly stereophotogrammetry, has become preferred due to its unprecedented precision and reliability, easy acquisition, noninvasiveness, and detailed quantification (7-9). Previous studies reported anthropometric data on Caucasians (10-12) and Asians from India (13), Korea (6), China (14,15), Japan (16), Turkey (17), and Malaysia (4). However, they are 2D-based or less detailed, mainly focusing on a limited number of parameters, e.g., palpebral fissure width (PFW), palpebral fissure height (PFH), double-eyelid fold-palpebral margin distance (FPD), inner intercanthal distance (EnD), and outer intercanthal distance (ExD). While 2D photogrammetry has been used to investigate Chinese populations' periorbital morphology (18-20), Jayaratne *et al.* were the first to use 3D stereophotogrammetry for Hong Kong Chinese in 2013 (21). Chong *et al.* reported 3D anthropometric values for northern Chinese women (14). We have proposed detailed and standardized protocols to depict 3D features in the periocular region and validated their accuracy (1,7,8,22-27). However, there is a paucity of 3D anthropometric evidence comparing ethnic differences in periocular morphologies between Chinese and Caucasian populations. Direct comparisons between studies can be challenging due to variations in equipment, environments, measurement personnel, and methods. Therefore, a comprehensive 3D comparison of periocular morphological characteristics between Chinese and Caucasian populations remains needed.

Therefore, this study aimed to establish gender- and ethnicity-specific 3D anthropometric data in periocular soft tissue for young Caucasian and Chinese adults and to determine the inter-racial and inter-gender differences, which may help diagnose periocular diseases, plan rejuvenation surgeries, and assess surgical effects in different sexual and ethnic populations. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1113/rc).

Methods

Patients

One hundred and forty-seven young volunteers with normal craniofacial appearance were recruited at the Department of Ophthalmology, University of Cologne, Germany. Exclusion criteria included histories of craniofacial difference, severe craniofacial asymmetry, or histories of previous cosmetic and orbital or eyelid surgeries that affect the orbit and its surrounding soft tissue. This study was conducted in accordance with the principles of the Declaration of Helsinki (as revised in 2013). This descriptive and cross-sectional study was approved by the institutional ethics board of the University of Cologne (No. 17-199). Written informed consent was obtained from all subjects before study enrollment.

3D stereophotogrammetry

The imaging system used in this study was the VECTRA M3 3D Imaging System (Canfield Scientific, Inc., Parsippany, NJ, USA). A single experienced operator performed 3D image acquisition and measurement in conformity with the procedures described in our previous study (1,22,23,28). Subsequently, the VECTRA Analysis Module (VAM) software version 2.8.2 (Canfield) was used to measure, analyze, and manipulate the 3D surface topography.

Landmarks

In previous studies (6,14,29), the most applied landmarks assessing 3D periocular soft tissues have been the exocanthion, endocanthion, palpebrale superius, palpebrale inferius, and upper lid crease superius. However, they are insufficient for accurately evaluating the intricate soft tissue morphology in the periocular region. Therefore, we introduced some novel landmarks to ensure a standardized and accurate description of the periocular surface, which increased a series of periocular metrical measurements, including linear distances, curvatures, and angles. Briefly, the operator identified five prime landmarks on each 3D model, i.e., endocanthion (En), exocanthion (Ex), pupillary center (Pc), as well as medial and lateral corneoscleral limbus (Lm and Ll, horizontal to the pupillary center). Then, to standardize and simplify the protocol, other landmarks were placed vertically to one of them with the aid of the coordinate axes in the VAM (22,23,28). Thirty-two periocular anthropometric landmarks are shown in *Figure 1*.

Periocular parameters

Based on our previous studies and the literature (1,22,23,30), the 32 landmarks generated 21 linear distances, three curvatures, six angles, and three proportions in the periocular region automatically by the software. Several examples of the parameters are shown in *Figure 1*. These parameters were divided into three categories as follows.

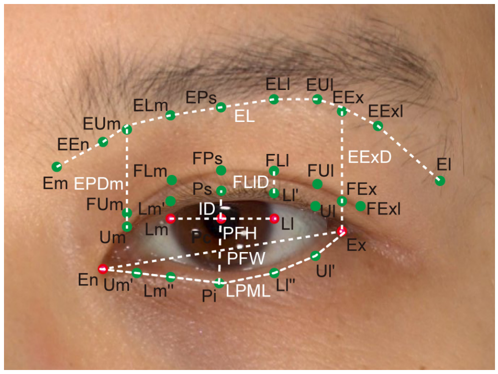

Figure 1 Thirty-two periocular anthropometric landmarks and several examples of parameters. Landmarks: En, endocanthion, inner commissure of the palpebral fissure; Ex, exocanthion, outer commissure of the lower and upper eyelash roots of the palpebral fissure; Pc, pupillary center; Lm, medial corneoscleral limbus horizontal to pupillary center; Ll, lateral corneoscleral limbus horizontal to pupillary center; Lm', upper palpebral margin point vertical to Lm; Um, upper palpebral margin point in the middle of En and Lm'; Ps, upper palpebral margin point vertical to Pc; Ll', upper palpebral margin point vertical to Ll; Ul, upper palpebral margin point in the middle of Ex and Ll'; Lm'', lower palpebral margin point vertical to Lm; Um', lower palpebral margin point in the middle of En and Lm''; Pi, lower palpebral margin point vertical to Pc; Ll'', lower palpebral margin point vertical to Ll; Ul', lower palpebral margin point in the middle of Ex and Ll''; FUm, double-eyelid fold point vertical to Um; FLm, double-eyelid fold point vertical to Lm; FPs, double-eyelid fold point vertical to Pc; FLl, double-eyelid fold point vertical to Ll; FUl, double-eyelid fold point vertical to Ul; FEx, double-eyelid fold point vertical to Ex; FExl, double-eyelid fold point vertical to Ex in lateral view; EEn, lower margin of eyebrow vertical to En; EUm, lower margin of eyebrow vertical to Um; ELm, lower margin of eyebrow vertical to Lm; EPs, lower margin of eyebrow vertical to Pc; ELl, lower margin of eyebrow vertical to Ll; EUl, lower margin of eyebrow vertical to Ul; EEx, Lower margin of eyebrow vertical to Ex; EExl, lower margin of eyebrow vertical to Ex in lateral view; Em, Lower margin of the medial eyebrow end; EI, Lower margin of the lateral eyebrow end. Parameters: EPDm, lower margin of eyebrow-palpebral margin distance (medial), i.e., the distance between eyebrow's margin EUm and palpebral margin Um; ID, iris diameter, i.e., the distance between medial limbus Lm and lateral limbus Ll; PFH, palpebral fissure height, i.e., the distance between superior palpebral margin Ps and inferior palpebral margin Pi; PFW, palpebral fissure width, i.e., the distance between endocanthion En and exocanthion Ex. LPML, lower palpebral margin length, i.e., the curving distance between inferior palpebral margin landmarks En-Um'-Lm''-Pi-Ll''-Ul'-Ex; EExD, lower margin of eyebrow-exocanthion distance, i.e., the distance between eyebrow's margin EEx and palpebral margin Ex; EL, lower eyebrow length; FLlD, double-eyelid fold-palpebral margin distance (lateral limbus).

(I) Palpebral fissure measurements: PFW (En-Ex); PFH (Ps-Pi); upper palpebral margin length (UPML, En-Um-Lm'-Ps-Ll'-Ul-Ex); lower palpebral margin length (LPML, En-Um'-Lm"-Pi-Ll"-Ul'-Ex); medial canthal angle (MCA, Ps-En-Pi); lateral canthal angle (LCA, Ps-Ex-Pi); canthal tilt [CT, Ex (left)-En (left)-En (right), or Ex (right)-En (right)-En (left)]; MCA in 2D (MCA_2D, Ps-En-Pi in 2D); LCA in 2D (LCA_2D, Ps-Ex-Pi in 2D); CT in 2D (CT_2D, Ex (left)-En (left)-En (right), or Ex (right)-En (right)-En (left) in 2D); Iris diameter (ID, Lm-Ll); Inter-pupillary distance (PD, Pc (left)-Pc (right)); EnD [En (left)-En (right)]; ExD [Ex (left)-Ex (right)]; palpebral fissure index (PFI, PFH/PFW); canthal angular index (CAI, LCA/MCA); canthal index [CI, En (l)-En (r)/Ex (l)-Ex (r)].

(II) Double-eyelid fold measurements: FPD (medial) (FPDm, FUm-Um); FPD (medial limbus) (FLmD, FLm-Lm'); FPD (FPs-Ps); FPD (lateral limbus) (FLlD, FLl-Ll'); FPD (lateral) (FPDl, FUl-Ul); double-eyelid fold-exocanthion distance (FExD, FEx-Ex); FExD (lateral) (FExDl, FExl-Ex). Among them, "F" is the abbreviation of "fold".

(III) Eyebrow measurements: lower margin of eyebrow-endocanthion distance (EEnD, EEn-En); Lower margin of eyebrow-palpebral margin distance (medial) (EPDm, EUm-Um); lower margin of eyebrow-palpebral margin distance (medial limbus) (ELmD, ELm-Lm'); lower margin of eyebrow-palpebral margin (Ps) distance (EPD, Ps-EPs); lower margin of eyebrow-palpebral margin distance

Table 1 Summary of demographic features for the volunteers

Characteristics	Chinese male	Chinese female	Caucasian male	Caucasian female
Numbers	19 (38 eyes)	27 (54 eyes)	42 (84 eyes)	59 (118 eyes)
Age (years)				
Mean ± SD	25.61±2.91	24.71±3.20	25.31±3.04	24.43±3.01
Range	20.73–30.42	20.40–30.03	18.09–30.35	18.20–29.94

SD, standard deviation.

(lateral limbus) (ELlD, ELl-Ll'); lower margin of eyebrow-palpebral margin distance (lateral) (EPDl, EUl-Ul); lower margin of eyebrow-exocanthion distance (EExD, EEx-Ex); lower margin of eyebrow-exocanthion distance (lateral) (EExDl, EExl-Ex); lower eyebrow length (EL, Em-EEn-EUm-ELm-EPs-ELl-EUl-EEx-EExl-El). Among them, "E" is the abbreviation of "eyebrow".

Statistical analysis

Data was entered into Excel (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA) and analyzed using IBM SPSS Statistics for Mac (Version 27.0. IBM Corp., Armonk, NY, USA). Each eye was pseudonymized with a code. Shapiro-Wilk test assessed data normality. Normal distribution variables were shown as mean ± standard deviation (SD), 95% confidence interval (95% CI), and non-normal distribution variables were presented as median. Pearson χ^2 test compared gender composition between Caucasians and Chinese. One-way analysis of variance (ANOVA) compared age differences among Caucasian males, Caucasian females, Chinese males, and Chinese females. Matched-pair *t*-test with Bonferroni correction (P<0.002) compared left and right eye differences in 29 measurements obtained from the landmarks. Multivariate ANOVA with Bonferroni adjustment compared differences among four groups and determined significance. Mean differences were statistically significant at P<0.05.

Results

The study recruited 294 eyes from 147 healthy volunteers. *Table 1* summarizes the demographic features of the volunteers. *Table 2* presents 3D periocular measurements and their statistical differences among young Chinese and Caucasian populations. *Figures 2-4*, respectively, show the palpebral fissure measurements, double-eyelid fold measurements, as well as eyebrow measurements and their statistical differences in 3D images of young Chinese and Caucasians. No statistically significant gender differences were found between Caucasians and Chinese (χ^2=0.001, P=0.975), and age was similar across all four groups (F=1.098; P=0.352).

Comparisons between left and right eyes

A comparison of 29 measurements obtained from the landmarks revealed significant differences (P<0.002) between the left and right sides in two measurements for Caucasian and Chinese females, respectively. However, these differences were minimal, approaching submillimeter levels, potentially rendering them negligible in practical applications. Specifically, Chinese females exhibited left-right differences of −0.58 mm (P<0.001) for FPDm (mean ± SD, 2.68±0.66 mm) and −0.57 mm (P<0.001) for FLmD (2.89±0.87 mm). Similarly, Caucasian females showed differences of −0.38 mm (P<0.001) for PFW (29.69±1.63 mm) and −0.52 mm (P<0.001) for LPML (33.16±2.08 mm). Furthermore, although differences in periocular shapes between the left and right eyes occur in real-world scenarios, our study excluded individuals with noticeable asymmetry or deformities. Therefore, we did not exclude these variables in further analysis.

Comparisons between ethnic groups

Palpebral fissure measurements

In males, Caucasians exhibited significant larger measurements than Chinese for most parameters, i.e., PFH, ID, LPML, LCA, CT, LCA_2D, CT_2D, PFI, and CAI, with a difference and P value of 0.8837 mm and P<0.001, 0.5556 mm and P<0.001, 1.6397 mm and P=0.002, 3.9997° and P<0.001, 12.7718° and P<0.001, 5.5423° and P<0.001, 4.1049° and P<0.001, 0.0187 and P=0.024, as well as 0.1010 and P<0.001, respectively. Caucasians showed significantly

Table 2 Three-dimensional periocular measurements in young Chinese and Caucasian populations

Parameters	Chinese male	Chinese female	Caucasian male	Caucasian female	P value					
					CM *vs.* CF	CM *vs.* CaM	CM *vs.* CaF	CF *vs.* CaM	CF *vs.* CaF	CaM *vs.* CaF
PFH	10.73±1.17, 10.39–11.07	11.52±1.08, 11.24–11.81	11.61±1.02, 11.39–11.84	11.63±1.04, 11.44–11.83	0.003**	<0.001***	<0.001***	>0.99	>0.99	>0.99
PFW	30.24±1.96 (30.25[#]), 29.66–30.82	28.63±1.87, 28.15–29.12	31.15 (31.26[#])±1.96, 30.76–31.54	29.69±1.63, 29.36–30.02	<0.001***	0.069	0.615	<0.001***	0.003**	<0.001***
PFI, PFH/PFW	0.36±0.03, 0.34–0.37	0.40±0.03, 0.39–0.41	0.37±0.03, 0.37–0.38	0.39±0.03, 0.39–0.40	<0.001***	0.024*	<0.001***	<0.001***	0.295	0.001**
UPML	39.96±2.78, 39.10–40.83	38.65 (38.19[#])±2.86, 37.93–39.38	41.04 (40.58[#])±2.69, 40.45–41.62	39.36±2.66, 38.87–39.86	0.142	0.265	>0.99	<0.001***	0.678	<0.001***
LPML	33.23 (33.27[#])±2.43, 32.50–33.96	31.63 (31.17[#])±2.48, 31.02–32.25	34.87±2.38, 34.37–35.36	33.16±2.08, 32.75–33.58	0.007**	0.002**	>0.99	<0.001***	<0.001***	<0.001***
LCA	32.21±2.79, 31.18–33.24	36.24±3.28, 35.38–37.11	36.21±3.45, 35.51–36.90	38.16±3.19, 37.57–38.74	<0.001***	<0.001***	<0.001***	>0.99	0.002**	<0.001***
MCA	39.10±4.70, 37.86–40.34	44.21±4.37, 43.18–45.25	39.11 (39.63[#])±3.80, 38.28–39.94	40.80±3.39, 40.10–41.51	<0.001***	>0.99	0.114	<0.001***	<0.001***	0.014*
CAI, LCA/MCA	0.83±0.08, 0.80–0.86	0.82±0.09, 0.80–0.85	0.93±0.10, 0.91–0.95	0.94±0.08, 0.92–0.96	>0.99	<0.001***	<0.001***	<0.001***	<0.001***	>0.99
CT	165.65 (164.90[#])±5.25, 162.13–169.17	164.27±2.87, 161.31–167.22	178.42 (169.80[#])±14.73, 176.05–180.79	171.53 (167.01[#])±11.63, 169.53–173.53	>0.99	<0.001***	0.027*	<0.001***	<0.001***	<0.001***
LCA_2D	36.92±3.27, 35.72–38.12	41.31±3.88, 40.30–42.31	42.46±4.14, 41.65–43.27	44.55±3.55, 43.87–45.23	<0.001***	<0.001***	<0.001***	0.477	<0.001***	0.001**
MCA_2D	37.55±4.71, 36.30–38.80	42.56±4.46, 41.51–43.61	38.17±3.83, 37.33–39.02	40.08±3.42, 39.37–40.79	<0.001***	>0.99	0.004**	<0.001***	0.001**	0.005**
CT_2D	175.11±3.03, 174.23–175.99	173.99±2.93, 173.25–174.73	179.22±2.75, 178.63–179.81	177.60±2.57, 177.10–178.09	0.334	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
EnD	37.28±2.69, 36.10–38.46	36.06±3.02, 35.07–37.05	32.12±2.54, 31.33–32.91	30.35±2.39, 29.69–31.02	0.710	<0.001***	<0.001***	<0.001***	<0.001***	0.006**
ExD	95.67±4.52, 93.87–97.48	91.13±4.14, 89.62–92.65	92.55±4.18, 91.33–93.76	87.90±3.55, 86.88–88.93	0.001**	0.031*	<0.001***	0.912	0.004**	<0.001***
CI, EnD/ExD	0.39±0.03, 0.38–0.40	0.40±0.03, 0.39–0.41	0.35±0.02, 0.34–0.35	0.35±0.02, 0.34–0.35	>0.99	<0.001***	<0.001***	<0.001***	<0.001***	>0.99
ID	11.55±0.48, 11.41–11.70	11.44±0.58, 11.32–11.56	12.11±0.41, 12.01–12.20	11.83±0.39, 11.75–11.91	>0.99	<0.001***	0.007**	<0.001***	<0.001***	<0.001***
PD	65.34±3.42, 63.93–66.76	62.03±3.27, 60.84–63.22	63.93±3.25, 62.97–64.88	60.36±2.86, 59.56–61.16	0.003**	0.620	<0.001***	0.091	0.136	<0.001***
FPDm	1.55 (1.52[#])±0.30, 1.21–1.89	2.68 (2.74[#])±0.66, 2.39–2.96	4.64±1.27, 4.41–4.86	4.37±1.18, 4.18–4.56	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.455
FLmD	1.61 (1.54[#])±0.40, 1.24–1.98	2.89±0.87, 2.58–3.20	4.16±1.37, 3.91–4.41	4.10±1.26, 3.89–4.30	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	>0.99
FPD	1.54 (1.35[#])±0.43, 1.20–1.89	2.97 (3.01[#])±0.86, 2.68–3.26	3.35 (3.20[#])±1.23, 3.11–3.58	3.39± (3.21[#])1.22, 3.19–3.59	<0.001***	<0.001***	<0.001***	0.285	0.116	>0.99
FLID	2.19 (2.09[#])±0.54, 1.83–2.56	2.85±1.20, 2.54–3.15	3.72 (3.56[#])±1.31, 3.48–3.96	3.77 (3.58[#])±1.12, 3.57–3.98	0.042*	<0.001***	<0.001***	<0.001***	<0.001***	>0.99
FPDl	3.14±1.03, 2.79–3.49	4.12±1.27, 3.83–4.41	4.93±1.20, 4.69–5.16	4.74 (4.64)±0.93, 4.55–4.94	<0.001***	<0.001***	<0.001***	<0.001***	0.003**	>0.99
FExD	5.08±1.48, 4.64–5.52	6.23 (5.98[#])±1.89, 5.86–6.60	7.75±1.32, 7.45–8.04	7.25 (7.06[#])±1.09, 7.00–7.50	0.001**	<0.001***	<0.001***	<0.001***	<0.001***	0.077
FExDl	3.84±0.94, 3.47–4.21	4.14±1.11, 3.83–4.44	5.28 (5.05[#])±1.26, 5.03–5.53	4.87 (4.74[#])±1.14, 4.66–5.08	>0.99	<0.001***	<0.001***	<0.001***	0.001**	0.076
EEnD	18.55±2.68, 17.81–19.28	19.42±2.43, 18.81–20.04	17.36±1.99, 16.86–17.85	17.52 (17.40[#])±2.32, 17.10–17.94	0.434	0.051	0.104	<0.001***	<0.001***	>0.99
EPDm	14.66±2.21, 13.97–15.36	15.10±2.16, 14.52–15.69	15.00±2.14, 14.54–15.47	14.76±2.22, 14.36–15.15	>0.99	>0.99	>0.99	>0.99	>0.99	>0.99
ELmD	11.04±2.76, 10.31–11.77	11.61±2.56, 11.00–12.23	11.03±2.06, 10.54–11.53	11.64±2.16, 11.22–12.05	>0.99	>0.99	0.965	0.886	>0.99	0.394
EPD	10.45 (9.82[#])±2.72, 9.70–11.20	10.86±2.29, 10.23–11.49	9.48±2.22, 8.98–9.99	10.93±2.32, 10.50–11.35	>0.99	0.213	>0.99	0.005**	>0.99	<0.001***
ELID	10.01±2.59, 9.16–10.86	10.64±2.98, 9.92–11.35	9.73±2.75, 9.16–10.30	12.04 (11.87[#])±2.46, 11.56–12.52	>0.99	>0.99	<0.001***	0.313	0.009**	<0.001***
EPDl	10.55±2.72, 9.70–11.41	11.48 (11.22[#])±3.12, 10.77–12.20	11.91±2.59, 11.33–12.48	14.23±2.49, 13.75–14.72	0.612	0.060	<0.001***	>0.99	<0.001***	<0.001***
EExD	13.55±2.31, 12.61–14.49	15.21 (14.41[#])±3.54, 14.42–16.00	15.92±2.89, 15.29–16.55	18.53±2.86, 18.00–19.07	0.049*	<0.001***	<0.001***	>0.99	<0.001***	<0.001***
EExDl	12.21±2.14, 11.41–13.01	13.61±3.11, 12.94–14.28	13.50±2.15, 12.96–14.04	15.12±2.55, 14.66–15.57	0.052	0.052	<0.001***	>0.99	0.002**	<0.001***
EL	68.54±7.02, 66.60–70.49	61.99±5.84, 60.36–63.63	69.54±5.79, 68.23–70.85	61.37 (60.3[#])±6.10, 60.27–62.48	<0.001***	>0.99	<0.001***	<0.001***	>0.99	<0.001***

Data are presented as mean (median for non-normal distribution variables) ± standard deviation, 95% confidence interval. The unit of projective linear and curve dimensions is shown in millimeters, and the unit of angles is shown in degrees. *, P<0.05; **, P<0.01; ***, P<0.001. [#], Shapiro-Wilk test P<0.05 (median for non-normal distribution variables). CM, Chinese male; CF, Chinese female; CaM, Caucasian male; CaF, Caucasian female; PFH, palpebral fissure height; PFW, palpebral fissure width; PFI, palpebral fissure index, i.e., PFH/PFW; UPML, upper palpebral margin length; LPML, lower palpebral margin length; LCA, lateral canthal angle; MCA, medial canthal angle; CAI, canthal angular index, i.e., LCA/MCA; CT, canthal tilt; LCA_2D, lateral canthal angle in 2D; MCA_2D, medial canthal angle in 2D; CT_2D, canthal tilt in 2D; EnD, inner intercanthal distance; ExD, outer intercanthal distance; CI, canthal index, EnD/ExD; ID, iris diameter; PD, inter-pupillary distance; FPDm, double-eyelid fold-palpebral margin distance (medial); FLmD, double-eyelid fold-palpebral margin distance (medial limbus); FPD, double-eyelid fold-palpebral margin distance; FLID, double-eyelid fold-palpebral margin distance (lateral limbus); FPDl, double-eyelid fold-palpebral margin distance (lateral); FExD, double-eyelid fold-exocanthion distance; FExDl, double-eyelid fold-exocanthion distance (lateral); EEnD, lower margin of eyebrow-endocanthion distance; EPDm, lower margin of eyebrow-palpebral margin distance (medial); ELmD, lower margin of eyebrow-palpebral margin distance (medial limbus); EPD, lower margin of eyebrow-palpebral margin (Ps) distance; ELID, lower margin of eyebrow-palpebral margin distance (lateral limbus); EPDl, lower margin of eyebrow-palpebral margin distance (lateral); EExD, lower margin of eyebrow-exocanthion distance; EExDl, lower margin of eyebrow-exocanthion distance (lateral); EL, Lower eyebrow length.

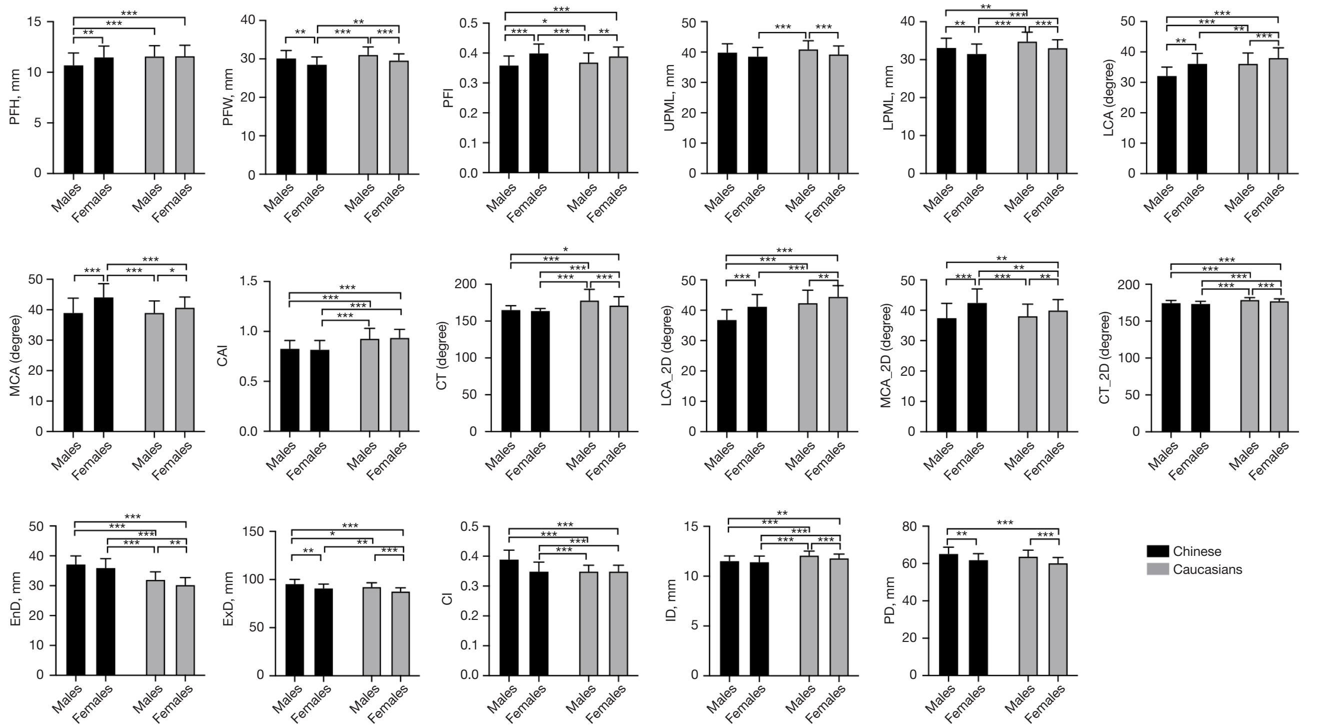

Figure 2 Palpebral fissure measurements and statistical differences on three-dimensional images of young Chinese and Caucasians. *, P<0.05; **, P<0.01; ***, P<0.001. PFH, palpebral fissure height; PFW, palpebral fissure width; PFI, palpebral fissure index, i.e., PFH/PFW; UPML, upper palpebral margin length; LPML, lower palpebral margin length; LCA, lateral canthal angle; MCA, medial canthal angle; CAI, canthal angular index, i.e., LCA/MCA; CT, canthal tilt; LCA_2D, lateral canthal angle in 2D; MCA_2D, medial canthal angle in 2D; CT_2D, canthal tilt in 2D; EnD, inner intercanthal distance; ExD, outer intercanthal distance; CI, canthal index, EnD/ExD; ID, iris diameter; PD, inter-pupillary distance.

smaller EnD, ExD, and CI, with a difference and P value of −5.158 mm and P<0.001, −3.127 mm and P=0.031, as well as −0.043 and P<0.001, respectively. Furthermore, Caucasian males presented non-significant differences with Chinese counterparts in PFW, UPML, PD, MCA, and MCA_2D (0.9034 mm and P=0.069, 1.0739 mm and P=0.265, −1.416 mm and P=0.620, 0.0109° and P>0.99, as well as 0.6264° and P>0.99, respectively).

In females, Caucasians showed significantly larger PFW, ID, LPML, LCA, CT, LCA_2D, CT_2D, and CAI than their Chinese counterparts, with a difference and P value of 1.0541 mm and P=0.003, 0.3875 mm and P<0.001, 1.5290 mm and P<0.001, 1.9156 and P=0.002, 7.2634°and P<0.001, 3.2417°and P<0.001, 3.6050°and P<0.001, as well as 0.1142 and P<0.001, respectively. In contrast, Chinese females demonstrated significantly larger EnD, ExD, CI, MCA, and MCA_2D, with a difference and P value of 5.704 mm and P<0.001, 3.229 mm and P=0.004, 0.050 and P<0.001, 3.4102° and P<0.001, 2.4858° and P=0.001, respectively. Additionally, Caucasian females presented non-significant differences with Chinese females in PFH, UPML, PD, and PFI (0.1119 mm and P>0.99, 0.7101 mm and P=0.678, −1.673 mm and P=0.136, as well as −0.0107 and P=0.295, respectively).

Double-eyelid fold measurements

In males, Caucasians exhibited a statistically significantly more prominent double-eyelid fold in all measured positions, including FPDm, FLmD, FPD, FLlD, FPDl, FExD, and FExDl, with a difference of 3.0876, 2.5543, 1.8025, 1.5263, 1.7868, 2.6665, and 1.4402 mm, respectively (P<0.001).

Similarly, in females, the double-eyelid fold was more prominent in Caucasians, with significant differences observed in all positions except for FPD (FPDm: 1.6921 mm, P<0.001; FLmD: 1.2060 mm, P<0.001; FPD: 0.4214, P=0.116; FLlD: 0.9260 mm, P<0.001; FPDl: 0.6257 mm, P=0.003; FExD: 1.0279 mm, P<0.001; FExDl: 0.7316, P=0.001).

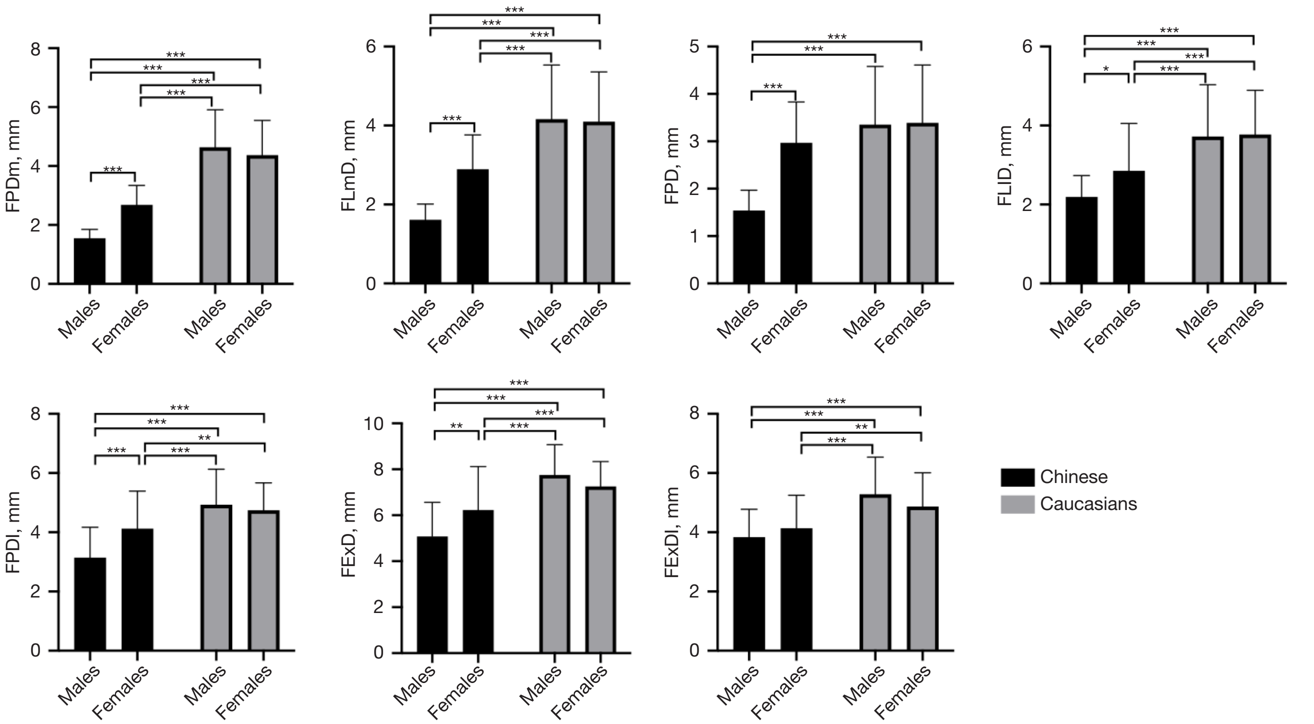

Figure 3 Double-eyelid fold measurements and statistical differences on three-dimensional images of young Chinese and Caucasians. *, P<0.05; **, P<0.01; ***, P<0.001. FPDm, double-eyelid fold-palpebral margin distance (medial); FLmD, double-eyelid fold-palpebral margin distance (medial limbus); FPD, double-eyelid fold-palpebral margin distance; FLlD, double-eyelid fold-palpebral margin distance (lateral limbus); FPDl, double-eyelid fold-palpebral margin distance (lateral); FExD, double-eyelid fold-exocanthion distance; FExDl, double-eyelid fold-exocanthion distance (lateral).

Eyebrow measurements

In males, there were no statistically significant differences between Caucasian and Chinese subjects for most measurements, except for EExD (2.3698 mm, P<0.001). Specifically, Caucasian males exhibited non-significantly larger EPDm, EPDl, EExDl, and EL than Chinese males, with a difference and P value of 0.3402 mm and P>0.99, 1.3536 mm and P=0.060, 1.2957 mm and P=0.052, as well as 0.9992 mm and P>0.99, respectively; but non-significantly smaller EEnD, ELmD, EPD, and ELlD, with a difference and P value of −1.1908 mm and P=0.051, −0.0037 mm and P>0.99, −0.9686 mm and P=0.213, as well as −0.2812 mm and P>0.99, respectively.

In females, Caucasians had significantly larger ELlD, EPDl, EExD, and EExDl but smaller EEnD compared to Chinese females, with a difference and P value of 1.4024 mm and P=0.009, 2.7525 mm and P<0.001, 3.3217 mm and P<0.001, 1.5039 mm and P=0.002, as well as −1.9050 mm and P<0.001, respectively. Caucasian females were also non-significantly larger in ELmD and EPD but smaller in EPDm and EL than their Chinese counterparts, with a difference of 0.0243, 0.0686, −0.3447, and −0.6219 mm, respectively (P>0.99).

Comparisons between sexes

Palpebral fissure measurements

In Chinese, females exhibited significantly larger PFH, MCA, LCA, MCA_2D, LCA_2D, and PFI than males, with a difference and P value of 0.7918 mm and P=0.003, 5.1172° and P<0.001, 4.0340° and P<0.001, 5.0156° and P<0.001, 4.3890° and P<0.001, as well as 0.0479 and P<0.001, respectively. Conversely, males had significantly larger PFW, LPML, PD, and ExD, with a difference and P value of 1.6095 mm and P<0.001, 1.5930 mm and P=0.007, 3.311 mm and P=0.003, as well as 4.540 mm and P=0.001, respectively. Additionally, males presented non-significantly larger ID, UPML, EnD, CT, CT_2D, and CAI, as well as smaller CI, with a difference and P value of 0.1118 mm and P>0.99, 1.3093 mm and P=0.142,

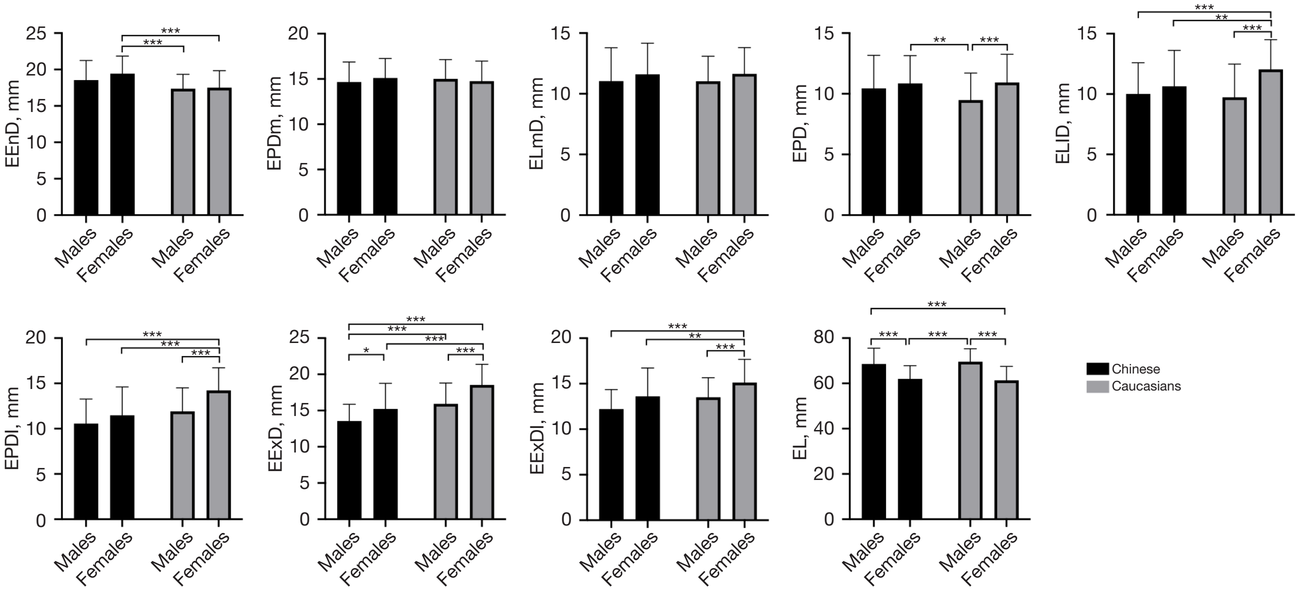

Figure 4 Eyebrow measurements and statistical differences on three-dimensional images of young Chinese and Caucasians. *, P<0.05; **, P<0.01; ***, P<0.001. EEnD, lower margin of eyebrow-endocanthion distance; EPDm, lower margin of eyebrow-palpebral margin distance (medial); ELmD, lower margin of eyebrow-palpebral margin distance (medial limbus); EPD, lower margin of eyebrow-palpebral margin (Ps) distance; ELlD, lower margin of eyebrow-palpebral margin distance (lateral limbus); EPDl, lower margin of eyebrow-palpebral margin distance (lateral); EExD, lower margin of eyebrow-exocanthion distance; EExDl, lower margin of eyebrow-exocanthion distance (lateral); EL, lower eyebrow length.

1.222 mm and P=0.710, 1.3795° and P>0.99, 1.1198° and P=0.334, 0.0055 and P>0.99, as well as −0.006 and P>0.99, respectively.

As for Caucasians, males showed significantly larger PFW, ID, UPML, LPML, EnD, PD, ExD, CT, and CT_2D than females, with a difference and P value of 1.4588 mm and P<0.001, 0.2799 mm and P<0.001, 1.6732 mm and P<0.001, 1.7037 mm and P<0.001, 1.768 mm and P=0.006, 3.568 mm and P<0.001, 4.641 mm and P<0.001, 6.8879° and P<0.001, as well as 1.6197° and P<0.001, respectively. In contrast, females presented significantly larger MCA, LCA, MCA_2D, LCA_2D, and PFI, with a difference and P value of 1.6961° and P=0.014, 1.9499° and P<0.001, 1.9033° and P=0.005, 2.0884° and P=0.001, as well as 0.0184 and P=0.001, respectively. Additionally, males also had marginally smaller PFH and CAI but larger CI, but these differences were not statistically significant (−0.1119 mm, −0.0077, 0.002, respectively, P>0.99).

Compared to Caucasian females, Chinese males had non-significantly smaller MCA and significantly smaller PFH, ID, LCA, CT, MCA_2D, LCA_2D, CT_2D, PFI, and CAI, with a difference and P value of −1.7070° and P=0.114, −0.9037 mm and P<0.001, −0.2757 mm and P=0.007, −5.9495° and P<0.001, −5.8838° and P=0.027, −2.5298° and P=0.004, −7.6307° and P<0.001, −2.4852° and P<0.001, −0.0371 and P<0.001, as well as −0.1088 and P<0.001, respectively. In contrast, Chinese males exhibited significantly larger EnD, PD, ExD, and CI than Caucasian females, with a difference of 6.926 mm, 4.984 mm, 7.768 mm, and 0.045 (P<0.001), and non-significantly larger PFW, UPML, and LPML, with a difference and P value of 0.5554 mm and P=0.615, 0.5992 mm and P>0.99, as well as 0.0640 mm and P>0.99, respectively.

Compared to Caucasian males, Chinese females had significantly smaller PFW, ID, UPML, LPML, CT, CT_2D, and CAI, with a difference of −2.5129 mm, −0.6673 mm, −2.3832 mm, −3.2327 mm, −14.1513°, −5.2247°, and −0.1065, respectively (P<0.001). In contrast, Chinese females presented significantly larger EnD, MCA, MCA_2D, PFI, and CI, with a difference of 3.936 mm, 5.1062°, 4.3892°, 0.0291, and 0.049 (P<0.001). Additionally, Chinese females had statistically non-significantly smaller PFH, PD, ExD, and LCA_2D but larger LCA, with a difference and P value of −0.0919 mm and P>0.99, −1.895 mm and P=0.091, −1.412 mm and P=0.912, −1.1533° and P=0.477, as well as 0.0343° and P>0.99, respectively.

Double-eyelid fold measurements

In Chinese, male double-eyelid fold measurements were non-significantly smaller in FExDl and significantly smaller than females in FPDm, FLmD, FPD, FLlD, FPDl, and FExD, with a difference and P value of −0.2975 mm and P>0.99, −1.1269 mm and P<0.001, −1.2829 mm and P<0.001, −1.4240 mm and P<0.001, −0.6546 mm and P=0.042, −0.9772 mm and P<0.001, as well as −1.1450 mm and P=0.001, respectively.

In contrast, among Caucasians, no statistically significant differences were observed in double-eyelid fold measurements. Specifically, males exhibited non-significantly larger FPDm, FLmD, FPDl, FExD, and FExDl than females, with a difference and P value of 0.2686 mm and P=0.455, 0.0655 mm and P>0.99, 0.1840 mm and P>0.99, 0.4935 mm and P=0.077, as well as 0.4112 mm and P=0.076, respectively; while non-significantly smaller in FPD and FLlD than females, with a difference of −0.04306 mm and −0.05436 mm (P>0.99).

Compared to Caucasian females, Chinese males exhibited significantly smaller double-eyelid fold measurements in FPDm, FLmD, FPD, FLlD, FPDl, FExD, and FExDl, with a difference of −2.8191, −2.4889, −1.8454, −1.5806, −1.6029, −2.1729, and −1.0290 mm, respectively (P<0.001).

Similarly, Chinese females had significantly smaller measurements across the board than Caucasian males, except for a non-significant difference in FPD. Specifically, the differences were −1.9607, −1.2715, −0.8717, −0.8097, −1.5215, and −1.1428 mm (P<0.001) in FPDm, FLmD, FLlD, FPDl, FExD, and FExDl, respectively; and −0.3785 mm (P=0.285) in FPD.

Eyebrow measurements

In Chinese, males exhibited statistically significantly larger EL and smaller EExD than females, with a difference and P value of 6.5490 mm and P<0.001 as well as −1.6604 mm and P=0.049. Furthermore, males presented non-significant differences in the rest eyebrow measurements with a trend towards smaller male values, i.e., respectively −0.8785 mm and P=0.434, −0.4370 mm and P>0.99, −0.5773 mm and P>0.99, −0.4041 mm and P>0.99, −0.6248 mm and P>0.99, −0.9283 mm and P=0.612, as well as −1.4062 mm and P=0.052 in EEnD, EPDm, ELmD, EPD, ELlD, EPDl, and EExDl.

Among Caucasians, males had significantly smaller EPD, ELlD, EPDl, EExD, and EExDl but significantly larger EL than females, with a difference of −1.4414, −2.3084, −2.3272, −2.6123, −1.6143, and 8.1700 mm, respectively (P<0.001). Males also tended to have non-significant differences in EEnD, ELmD, and EPDm, with a difference and P value of −0.1643 mm and P>0.99, −0.6053 mm and P=0.394, as well as 0.2479 mm and P>0.99, respectively.

Compared to Chinese males, Caucasian females exhibited significantly smaller EL and larger ELlD, EPDl, EExD, and EExDl, with a difference of −7.1708, 2.0272, 3.6808, 4.9821, and 2.9100 mm, respectively (P<0.001). Non-significant differences were observed between Caucasian females and Chinese males in EEnD (smaller) and EPDm, ELmD, and EPD (larger), with a difference and P value of −1.0265 mm and P=0.104, 0.0923 mm and P>0.99, 0.6016 mm and P=0.965, as well as 0.4728 mm and P>0.99, respectively.

Furthermore, compared to Caucasian males, Chinese females had significantly smaller EL and larger EEnD and EPD, with a difference and P value of −7.5482 mm and P<0.001, 2.0693 mm and P<0.001, as well as 1.3728 mm and P=0.005, respectively. Chinese females also presented non-significantly smaller EPDl and EExD than Caucasian males (differences of −0.4253 mm and −0.7093 mm, P>0.99), and non-significantly larger EPDm, ELmD, ELlD, and EExDl, with a difference and P value of 0.0968 mm and P>0.99, 0.5810 mm and P=0.886, 0.9060 mm and P=0.313, as well as 0.1104 mm and P>0.99, respectively.

Discussion

In this study, we recruited young Caucasian and Chinese individuals, assessed their 3D periocular morphologies, and investigated ethnic and sex disparities. To the best of our knowledge, this is the first study to assess the periocular region of Chinese populations using this detailed and standardized 3D stereophotogrammetric protocol, comparing it with Caucasian counterparts. Our findings established gender- and ethnicity-specific 3D anthropometric data for young Caucasian and Chinese adults, revealing significant inter-racial and inter-gender variations of the periocular soft tissue morphology. This contributes to the existing 3D baseline anthropometric database, enhancing its utility in diagnosing periocular diseases, planning rejuvenation surgeries, and evaluating surgical outcomes across diverse sexual and ethnic groups.

The present study revealed larger palpebral fissure measurements for most parameters in young Caucasians compared to Chinese. Chinese males exhibited the significantly smallest PFH, followed by Chinese females, Caucasian males, and Caucasian females (10.73, 11.52, 11.61, and 11.63 mm, respectively). PFH is influenced by craniofacial development, levator muscle, tarsal, and skin (29), and excessive pursuit of large PFH during blepharoplasty or blepharoptosis surgery may disrupt the size balance, leading to disharmony and even dry eye syndrome. PFW was the smallest in Chinese females, followed by Caucasian females, Chinese males, and Caucasian males (28.63, 29.69, 30.24, and 31.15 mm, respectively), which may be influenced by canthal relaxation, eyelid retraction, and exophthalmos (31). The PFI described the fissure shape by PFH to PFW ratio, with females showing the largest PFI, with no significant differences, followed by males. These differences are crucial in eyelid and canthus surgeries.

The quantitative analysis of upper and lower eyelid lengths holds significant clinical importance, aiding in diagnosing eyelid diseases, determining reconstruction strategies following lesion resection, and simulating surgical outcomes (2). In this study, Caucasian males exhibit the largest UPML, significantly distinct from Caucasian and Chinese females (41.04, 39.36, and 38.65 mm, respectively). Chinese males, despite their smaller PFH, display a UPML comparable to others (39.96 mm), possibly due to a compensatory wider PFW. Caucasian females and Chinese males share similar LPMLs, significantly differing from Caucasian males and Chinese females (33.16, 33.23, 34.87, and 31.63 mm, respectively). Males generally have longer LPMLs, potentially attributed to a broader palpebral fissure.

The MCA plays a pivotal role in determining the overall shape and aesthetics of the eye and its surrounding structures. In our study, the MCA was defined as the angle between the medial canthus and vertical points to the pupil center at the upper and lower palpebral margins. Similarly, the lateral canthus defines the LCA. Both angles are crucial in diagnosing and managing various eye conditions, e.g., tendon laxity or rupture, eyelid malpositions, and epicanthus. These angles can vary among individuals and may change with age and other factors. Chong *et al.* (14) revealed that while the exocanthion shifts medially with age, the endocanthion remains stable. Cosmetic surgeons can manipulate these angles to enhance patients' appearance. Our findings indicate that Chinese females exhibit the largest MCA, significantly differing from Caucasian females, males, and Chinese males (44.21°, 40.80°, 39.11°, and 39.10°, respectively). This observation may be attributed to the epicanthus. Notably, despite Chinese males having a smaller PFH, their MCA is comparable to that of Caucasians, potentially due to the epicanthus's proximity to the angle's defining points (32). Moreover, Chinese males exhibited the smallest LCA at 32.21°, significantly distinct from others, potentially attributed to their smaller PFH. Caucasian females, on the other hand, had the largest LCA of 38.16°, possibly due to their narrower PFW compared to males. Despite Chinese females having a significantly smaller PFW than Caucasian males, there was no notable difference in LCA between them (36.24° *vs.* 36.21°). This could be explained by the fact that the narrower PFW in Chinese females is primarily due to a shorter medial half caused by the epicanthus, while the lateral half remains comparable to Caucasian males. Additionally, the CAI is calculated by dividing the LCA by the MCA. While there was no gender difference within either the Caucasian or Chinese populations, a racial difference was observed between the two groups. Caucasian females had the highest CAI of 0.94, coinciding with their largest LCA. Conversely, Chinese females had the lowest CAI of 0.82, coinciding with their largest MCA. Caucasian males, who possess a larger LCA than Chinese males but similar MCA, exhibited a higher CAI of 0.93 compared to 0.83 for Chinese males.

Previous studies have established that palpebral fissure inclinations are greater in attractive individuals, with females exhibiting a higher exocanthion than males, resulting in a more slanted appearance (12,33). In the 2D plane, a higher exocanthion correlates with a smaller CT_2D. Korean females, for instance, have been reported to have a mean CT_2D value of 171.1° to 172°, which gradually increases with age (3,34). Our findings align with these observations, revealing the highest exocanthion in Chinese females, followed by Chinese males, Caucasian females, and Caucasian males (173.99°, 175.11°, 177.60°, and 179.22°, respectively). Furthermore, 3D CT analysis revealed similar trends, with Chinese females exhibiting the highest exocanthion, followed by Chinese males, Caucasian females, and Caucasian males (164.27°, 165.65°, 171.53°, and 178°, respectively). The CT, which characterizes the 3D orientation of the exocanthion in the x, y, and z axes, holds particular significance in the frontal view (x and y axes, i.e., CT_2D) due to its critical aesthetic importance. In oculoplastic clinical practice, the height of the exocanthion is of prime concern. Our findings prompt the question of whether, during surgeries such as lower eyelid blepharoplasty or lateral tarsus strip surgery, the exocanthion should be positioned higher in Chinese individuals and Caucasian females than Caucasian males (33). Additionally, a laterally oblique and gently ascending palpebral fissure is associated with a youthful appearance. The CT_2D values obtained in this study may serve as a reference for surgeons performing lateral canthopexy or oculoplastic surgeries (3). Furthermore, lateral canthopexy or canthoplasty may be more effective in achieving a rejuvenated look compared to procedures that shorten the lower lid, e.g., wedge excision or the Kuhnt-Szymanowski procedure, as these tend to further narrow and round out the palpebral fissure (2,35).

Furthermore, proportional analysis of the orbital region has been utilized to establish the ideal proportion for visually appealing eyes (3), particularly through the ratio of EnD to ExD. Previous studies indicate that inter-iris distance (ID) and PD are racial characteristics, remaining relatively constant within individuals of each ethnic group (3,36). Consequently, ID is utilized as a constant for calibrating 2D photo-based measurements. No significant gender or age-related differences were revealed in 2D horizontal corneal diameter (CD, akin to ID) among Caucasian individuals, averaging 11.8±0.6 mm in females and 11.9±0.7 mm in males (33). Our findings demonstrated a descending order of ID values in Caucasian males, Caucasian females, Chinese males, and Chinese females (12.11, 11.83, 11.55, and 11.44 mm, respectively). Notably, no significant differences were observed within the Chinese population, which aligns with previous research. However, a statistically significant, albeit minor (0.2799 mm), difference was observed between Caucasian males and females.

On the micro level, PD exhibits inter-individual variations, which are crucial for accurate glasses fitting and microscope usage. Kim *et al.* reported no significant PD difference between Korean beauty pageant contestants and average young females (60.8±2.0 *vs.* 61.2±2.9 mm) (3). However, attractive Korean faces exhibited a higher PD-to-face width ratio than average Korean faces (44.99% *vs.* 42.32%), similar to the 44.9% observed in Caucasian faces (36). Our study found no significant PD difference between ethnicities in either sex, yet sexual dimorphism was evident. Chinese males had the largest PD, followed by Caucasian males, Chinese females, and Caucasian females (65.34, 63.93, 62.03, and 60.36 mm, respectively).

The distance between Ens exhibits ethnic variation but remains relatively stable. Previous studies have shown that Malaysian Chinese (MC) males and females possess wider EnD than Malaysian Malay (MM) and Malaysian Indian (MI) counterparts (37.1 *vs.* 35.2 *vs.* 33.8 mm in males and 36.2 *vs.* 34.1 *vs.* 32.9 mm, respectively) (4). This aligns with Wu *et al.*'s findings in the Chinese population (37.51 mm in males, 35.55 mm in females) (18) and Patil *et al.*'s report in Indians (32.8 mm in males, 32.7 mm in females) (13). In our study, Chinese males exhibited the largest EnD, comparable to Chinese females and significantly larger than that of Caucasian males and females (37.28, 36.06, 32.12, and 30.35 mm, respectively). This difference may be attributed to the presence of epicanthus in the Chinese population.

Significant sexual dimorphism and ethnic disparities were observed in ExD. Chinese males exhibited the significantly largest ExD, followed by Caucasian males, Chinese females, and Caucasian females (95.67, 92.55, 91.13, and 87.9 mm, respectively). Notably, Chinese females did not significantly differ from Caucasian males, while Caucasian females differed significantly from the other groups. Regarding the CI, ethnic disparities were evident, but no significant sexual differences were observed (0.40 and 0.39 in Chinese females and males, 0.35 and 0.35 in Caucasian counterparts).

The well-defined double-eyelid crease is crucial for an attractive eye appearance (29). Cai *et al.* categorized Chinese eyelid creases into five types based on a 2D photogrammetric analysis: single-fold (39.53%), parallel fold (26.58%), open-ended crescent (7.97%), classic crescent (21.93%), and hidden-fold (3.99%) (29). However, they only measured the crease height when the eyelid was closed (1.79 mm). Clinically, only parallel fold and classic crescent (48.51%) may be considered double eyelids, aligning with 50% in a previous study on East Asian females (29). Prior studies quantitatively assessed the double eyelid by measuring the vertical distance between the highest points of the upper eyelid margin and crease when the eyes were gently closed or gazing straight. Caucasian females exhibited a larger 2D distance than males, averaging 3.0 mm in females and 2.1 mm in males (33). This study measured the double-eyelid fold using seven vertical distances from the eyelid margin to the crease. We found non-significant differences between Caucasian males and females. Chinese males had significantly the smallest measurements across all locations, except when compared to Chinese females at FExDl (non-significant difference). Chinese females also had smaller measurements than Caucasians at all locations. However, differences among Caucasian males, females, and Chinese females were statistically non-significant at FPD. Therefore, FPD may not accurately reflect morphological differences between

Chinese and Caucasians. Given the complexity of East Asian eyelid morphology, clinical diagnosis and treatment, particularly in cosmetic blepharoplasty, require a more detailed approach to quantify the double-eyelid fold.

The eyebrows play a crucial role in facial recognition and sexual dimorphism (4). Prior studies have failed to provide a precise description of the eyebrow's ideal position (37). In our study, Caucasian males exhibited the smallest EPD, significantly differing from Chinese and Caucasian females. Chinese males followed, with Chinese and Caucasian females ranking last (9.48, 10.45, 10.86, and 10.93 mm, respectively). No significant differences were observed among the latter three groups. Our findings align with previous research indicating that EPD is slightly larger in females (4). Caucasian females had a larger average EPD than males (11.8 and 9.4 mm, P=0.0001) (33). Similarly, Han Chinese and Asian individuals also showed larger values for both sexes (12.1 and 11.67 mm, 12.5 and 11.93 mm, or 12.3 and 12.5 mm in males and females) (18,34,38). However, variations in EPD definition, photography conditions, and camera settings can lead to significant differences or even contradictory results across studies. For instance, Kunjur *et al.* reported smaller EPD measurements of 6.7 and 7.8 mm in Caucasian and Indian males but larger EPD of 7.8 and 10.5 mm in females (37), while Malays and Indians exhibited larger EPD in males. Therefore, it is crucial to standardize measurement techniques and consider ethnic differences when studying eyebrow morphology (13).

In our study, we comprehensively characterized the lower eyebrow shape using eight parameters, including the central eyebrow height (EPD) and seven additional measures. The endocanthion eyebrow height (EEnD) did not differ between the sexes in Chinese and Caucasians, with Chinese females having the largest EEnD, potentially attributed to the epicanthus in Chinese. No significant sexual dimorphism or ethnic disparity was observed in the medial eyebrow height measures of EPDm and ELmD. Caucasian females stood out with significantly the highest lateral eyebrow height values in ELlD, EPDl, EExD, and EExDl, potentially reflecting their distinct brow peaks. In ELlD, EPDl, and EExDl, Chinese females, Chinese males, and Caucasian males did not differ significantly. However, sexual dimorphism was evident in EExD, with Caucasian females having the largest value, followed by Caucasian males, Chinese females, and Chinese males (18.53, 15.92, 15.21, and 13.55 mm, respectively). Notably, Chinese males differed significantly from the other groups in EExD. The difference between Chinese females and Caucasian males was statistically insignificant, possibly due to the compensation of the tilted exocanthion in Chinese and the tendency for higher lateral eyebrows in females. Additionally, females tended to have shorter eyebrows than males across ethnicities.

The current study has limitations. There is a disparity in the sample sizes of the ethnic groups, which might introduce potential bias to some degree. We enrolled volunteers at a ratio of approximately 1:2. There are 38 and 84 eyes in Chinese and Caucasian males and 54 and 118 eyes in Chinese and Caucasian females. Although eyes are fewer in the Chinese group than in the Caucasian one, the difference is not huge. The bias resulting from the differences in sample size might be small. However, the Chinese males are relatively fewer, which might cause a certain degree of bias. Therefore, to reduce the potential error in the statistical analysis, we used multivariate ANOVA with Bonferroni adjustment to evaluate differences among four groups and determined significance, which is far more strict than simple ANOVA without Bonferroni adjustment. On the other hand, in the future, we plan to accumulate more than 10 years of data and publish further data on Chinese people when the number of Chinese people is enough to make up for the shortcomings of inadequate numbers of eyes in this study. Furthermore, although our Chinese volunteers, consisting of Han students from northern and southern China studying in Germany, offer a representative cross-section, the small sample size of international Han students aged 20–30 years necessitates larger studies due to the vast diversity of facial morphologies across China's multi-ethnic and geographically diverse population. Future research should involve multi-center studies encompassing diverse age groups and occupations, utilizing uniform equipment and landmark location methods. Additionally, although we employed a standardized periocular landmark positioning technique to quantify the 3D periocular morphology, alternative measurement methods may also be explored. Future studies could explore additional landmark positioning approaches to assess morphological differences among ethnicities, enhancing the precision of periocular treatments.

Conclusions

In summary, this study offers a comprehensive analysis of 3D sex- and ethnicity-related periocular morphological differences between young Chinese and Caucasian adults. While our anthropometric data on 3D periocular morphology may not serve as absolute surgical planning criteria, they provide valuable insights to practitioners, including oculoplastic surgeons, face recognition experts, and artists, among others, in understanding the relative differences between the two ethnic groups. Specifically, Chinese males exhibit smaller palpebral fissure and double-eyelid fold measurements than Chinese females, while Caucasian males and females display less pronounced differences. Ethnically, Caucasians tend to have more prominent palpebral fissure and upper lid fold measurements than Chinese. Eyebrow measurements exhibit limited sexual and ethnic differences, except for Caucasian females with a larger lateral eyebrow height. Our findings establish sex- and ethnicity-specific 3D anthropometric data for young Chinese and Caucasian adults, facilitating clinical practices across diverse sexual and ethnic backgrounds.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-1113/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-1113/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional ethics board of the University of Cologne (No. 17-199), and written informed consent was obtained from all individual participants.

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