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Research article

Correlation between different points on the face and the width of maxillary anterior teeth

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A B S T R A C T

Statement of problem: There is currently no consensus on the relationship between maxillary anterior teeth and different facial anthropometric measurements. Additionally, whether these relationships vary by age and sex remains unreported.

Purpose: This clinical study aimed to investigate the relationship between the intercanine distance (ICaD) and intercanthal distance (ICD), interpupillary distance (IPD), interalar width (IAW), and intercommissural width (ICW), and to compare whether these relationships differ between different age and sex populations.

Material and methods: Participants (n = 409) were enrolled according to the inclusion criteria, and their standardized digital images were taken to measure facial and oral segments through an image processing program. The differences between ICaD and four facial measurements and the sexual differences for all measurements were compared using the 1-sample *t*-test. The differences among different age groups for all measurements were compared using the one-way analysis of variance (ANOVA) test, and a least significant difference (LSD) test was used for multiple comparisons. The association between ICaD and the four facial measurements was evaluated using Pearson correlation analysis. The correlation between ICaD and four facial measurements was evaluated using linear regression. Differences in regression equations among the subgroups were evaluated through subgroup regression analysis and the significance test of the difference between the two regression coefficients. Tests of significance were two-sided, with alpha level of 0.05. The reliability of the results was evaluated by calculating intraclass correlation coefficients.

Results: The ICD, IPD, ICW, and IAW significantly differed from the ICaD in both sexes ($P < 0.01$). All measurements were significantly greater in men than in women ($P < 0.01$). The differences among the age groups were statistically significant for all measurements except IPD ($P < 0.05$). A significant positive correlation was found between all facial measurements (r = 0.258 [ICD], r = 0.334 [IPD], r = 0.389 [ICW], and r = 0.393 [IAW]) and the ICaD in both sexes. The highest correlation was found between ICW(r = 0.345) and ICAD in men and IAW (r = 0.285) and ICAD in women. Except for the 20–29 and 50–59 age groups, the mathematical equations of ICaD and facial anthropometric measurements differed among the other age groups and sexes.

Conclusions: ICD, IPD, ICW, and IAW cannot be directly used to determine ICaD in both sexes. Nevertheless, when observed from the frontal aspect, by the use of digital images, all facial measurements correlated to the intercanine distance, with a high probability. The mathematical formulae combined with facial anthropological measurements can help ensure the combined width of the six maxillary anterior teeth, but the effects of sex and age differences should be considered.

1. Introduction

The self-esteem of edentulous patients improves when dentures appropriately and harmoniously restore the shape of the teeth, which is an essential aspect of prosthodontic treatment [1,2]. The maxillary anterior teeth have the greatest aesthetic influence in

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social activities; therefore, the selection and alignment of the maxillary anterior teeth are crucial for complete denture restoration [3,4]. The selection of the anterior tooth size for complete dentures involves determining width and height. The height can be determined by reliable parameters such as upper lip length, smile line, and smile arc, while the width is often more challenging to estimate owing to inadequate reference indicators, particularly in the absence of pre-extraction records [4,5].

One classic tooth selection theory of complete dentures suggests that the corners of the relaxed mouth are the positions of the distal surfaces of most natural maxillary canines [6]. However, one study suggests that the distal surface of the maxillary canine in natural dentition is approximately 4 mm within the corner of the mouth [7]. In addition, the corners of the mouth in edentulous patients are reportedly often deformed because of missing teeth and age-related changes [3,8].

Intercanine distance (ICaD) is the straight-line distance between the distal surfaces of maxillary canines, measurable from a frontal digital photograph and related to the location of the maxillary canines [9]. When choosing artificial anterior teeth width according to a tooth mold chart, the distance between the distal contact points of the canines is used, rather than the distance between the canine cusps [10]. Therefore, the ideal reference landmark in the clinic for tooth selection is the distal surface of the canine rather than the cusp tip [11]. A few facial anthropometric measurements have been suggested to assist in determining the width of artificial maxillary anterior teeth in patients with edentulism. These measurement items include intercanthal distance (ICD), interpupillary distance (IPD), interalar width (IAW), and intercommissural width (ICW) [9,11–17]. However, consensus on an effective method remains unavailable [9,11,15,17].

ICD matures between 8 and 11 years and remains stable onward [18]. Al Wazzan [12] reported that the ratio of the intercanthal width to the combined width of the six anterior teeth was 1:1.426, which could help in estimating the overall widths of the six anterior teeth. IPD remains constant in adulthood and is significantly correlated with ICaD [9,13,19]. In addition, IAW aids in estimating the distance between the maxillary canines [6,11,14,20,21]. This is based on the theory that the premaxilla supporting the maxillary anterior teeth is homologous to the alar of the nose during face embryogenesis [22]. The studies on the relationship between ICW and ICaD are based on the hypothesis that the distal surface of the maxillary canine should be located at the corner of the mouth [6]. Some scholars have found a significant positive correlation between ICW and ICaD [9,15]. Moreover, Isa et al. [23] and Latta et al. [24] reported that more than one variable is needed to determine the best maxillary anterior tooth width.

Most relevant studies have been conducted in the white population, and relevant studies in other races are required to improve satisfaction with the appearance of complete dentures in each population [25–27]. The dimensions of face landmarks and teeth vary according to sex and differ regarding age and ethnicity of the population [21,26,28]. Selection of artificial teeth appropriate for the sex and age of the patient is essential in establishing an acceptable dentofacial appearance [29]. However, most previous studies have only selected participants in a narrow age range and did not report the possible impact of sex and age on the dental-facial relationship.

Therefore, this study aimed to explore the potential relationship between the four facial anthropological measurements (ICD, IPD, IAW, and ICW) and ICaD and compare whether the above relationships differ among different sex and age groups. The null hypothesis of this study is that facial anthropometric parameters and ICaD are not correlated and the relationships do not vary across gender and age groups.

2. Material and methods

This descriptive research is approved by the Ethics Committee of the Shanxi Provincial People's Hospital (SPPH-2022-418). A non-probability convenience sampling method was used to recruit participants on the basis of a set of eligibility criteria. Informed consent was obtained from the participants; 409 participants aged between 20 and 59 years were enrolled in the study from the Shanxi Provincial People's Hospital. And the participants were divided into 20–29 years old group, 30–39 years old group, 40–49 years old group and 50–59 years old group. The sample size was calculated with "Power Analysis and Sample Size software program (PASS, version 21.0.3, NCSS, LLC, Kaysville, Utah, USA)". Based on the pre-experimental results of our study, the mean value of ICaD was 39.48 ± 2.03 mm, controlling the alpha error to 5% with a confidence level of 95%, the estimated sample size was calculated to be 382

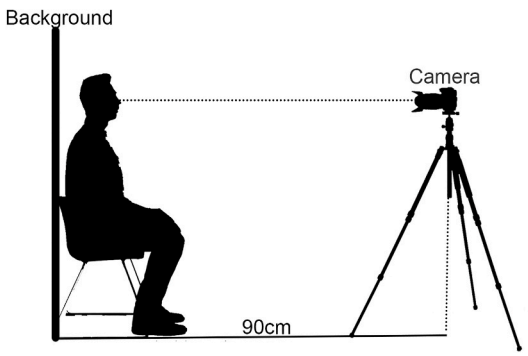

Fig. 1. Standardized photographic setup of participant and camera.

(considering a population of 34, 000, 000). The inclusion criteria were normal occlusion (Angle classIocclusion, normal overjet and normal overbite), Han nationality in Shanxi province, normal facial development, complete intact dentition (except the third molars), well-aligned, the midline of the face consistent with the midline of the dentition, no major crowding or spacing, and no periodontal disease; tooth wear within 1°. The exclusion criteria were history of facial deformities, tumors, anterior teeth or facial trauma, history of orthodontic treatment (maxillofacial or cosmetic surgery), and anterior teeth with significant defects, caries, wear, loosening, or deformity.

Study images were obtained using a digital single-lens reflex camera (Nikon D7200; Nikon Corp.) and a macro lens (Nikon AF-S VR105 f/2.8G; Nikon Corp.). The photographs were taken by the same operator (J.W.) and the camera was placed at the same distance (Fig. 1). Each participant was seated upright on a comfortable chair with the head held straight, facing forward, and maintaining a natural head position (NHP) [30]. NHP is a small range of repeatable physiological position of the head when the head is upright in a relaxed state and the eyes are looking straight ahead, which has been shown to be the most accurate and reproducible head position for photographic analysis. A specially designed device was used to ensure the standardization of photographic conditions by placing earpieces into the external auditory canals. A segment of metric ruler was fixed on the forehead as a reference to correlate the image size to the actual tooth size. Two standardized digital photographs of the participants were obtained from the front. The full-face image was taken in a relaxed rest position (Fig. 2A). Keeping all other conditions the same, the intraoral image was taken when the entire maxillary anterior dentition was exposed using a cheek retractor (Cotisen CR02, Huanghua COTISEN Medical instruments Co, Ltd) (Fig. 2B).

The following measurements were performed on the photographs using image software (Image Processing and Analysis in Java; US National Institutes of Health): ICaD, the distance between the most apparent distal points of the canine teeth in a straight line from the front view (Fig. 2B); IPD, the distance between the mid pupillary points on both sides; ICD, the distance between the medial angles of the palpebral fissures of the eyes; IAW, the distance between the outer points of the ala of the nose; and ICW, the distance between the commissure in its passive state (Fig. 2A). Magnification error control for the photographs was performed using the Set Scale function of ImageJ software, and the actual size of the measured values was obtained. To ensure data reliability, all photographs were repeated thrice by the same trained operator (J.W), and the average value was used for data analysis. The procedure was repeated if the difference between measurements was >0.2 mm. Subsequently, 20% of the study images were randomly selected and re-measured by the same operator (J.W) 2 weeks after the start of the measurements. The intraclass correlation coefficients (ICC) of the two measurements were subsequently calculated to clarify researcher reliability ($\alpha = 0.05$).

Statistical Package for the Social Sciences (IBM SPSS Statistics, version 25; IBM Corp) was used for data analysis and statistics. The Kolmogorov–Smirnov test and normal distribution plot were used to test whether the data conformed to a normal distribution, and

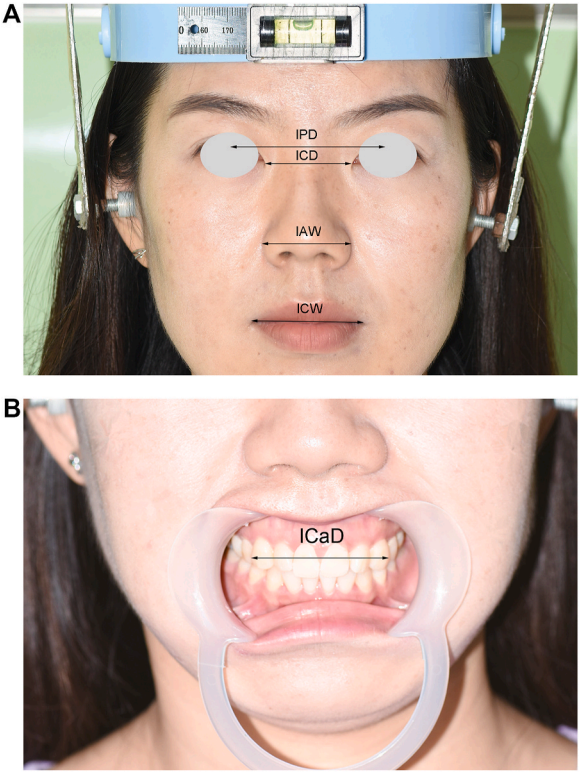

Fig. 2. A, Standardization of participant for photography with extraoral measurements. B, Using mouth retractors to visualize entire width of maxillary anterior teeth.

Levene's test was used to test whether the data conformed to chi-squareness. Independent samples *t*-test was used to compare the differences between ICaD and the four facial measurement parameters and the sex differences of all measurements. One-way analysis of variance (ANOVA) was used to compare the differences between age groups of all measurements, and the least significant difference (LSD) method was used for pairwise comparisons. Pearson correlation analysis was used to investigate the relationship between ICaD and the four facial measurement parameters. Group regression analysis and regression coefficient difference test were used to examine whether the mathematical regression equations between facial anthropometric parameters and ICaD differed between sex and age groups. The test level was set at two-sided ($\alpha = 0.05$).

3. Results

The sample comprised 199 men and 210 women with a mean age of 38 (37.95 ± 11.2) years. The ICC of the data from the two measurements before and after the start of the measurement = 0.89 ($P < 0.001$). Since the ICC was >0.80, the operator repeatability was considered high and clinically acceptable [31]. The descriptive statistics results and comparisons between sexes for all measurements are shown in Table 1. All measurements are presented as "mean ± standard deviation" because all variables fit or approximately fit a normal distribution. Significant sex differences were observed in all measurements ($P < 0.05$). The results of comparing facial anthropometric measurements with the ICaD are shown in Fig. 3. All four facial anthropometric measurements had relationships with ICaD ($P < 0.01$) that differed significantly between the sexes.

One-way ANOVA test and LSD pairwise comparisons were used to examine the differences between age groups for all measurements because the samples met the requirements of the chi-square test (Table 2). The results showed that ICaD ($P < 0.05$), ICD ($P < 0.01$), IAW ($P < 0.01$) and ICW ($P < 0.01$) significantly differed among age groups, while IPD remained relatively stable ($P > 0.05$).

The results of the Pearson correlation between ICaD and the four facial anthropometric parameters are shown in Table 3. A weak positive statistical correlation was identified between ICaD and the facial measurements ($P < 0.05$). The highest correlation with ICaD was observed for the IAW (r = 0.393) in overall participants. The correlation between ICW and ICaD was highest in men (r = 0.345). The correlation between IAW and ICaD was strongest in women (r = 0.285). The results of the age-based subgroup regression analysis are presented in Table 4. The ICD and IPD did not significantly affect ICaD in all age groups ($P > 0.05$). For the 20–29 and 50–59-year-old groups, the IAW and ICW affected ICaD ($P < 0.001$). In the 30–39-year-old group, only ICW affected ICaD ($P < 0.001$). For the 40–49-year-old group, only the IAW affected ICaD ($P < 0.001$). Since the regression models of both 20–29 and 50–59-year-old groups had the same independent variables, they were tested for differences in regression coefficients to clarify whether the equations for the two age groups differed, the results are presented in Table 5. The results showed that the regression coefficients of the variables between the 20–29 and 50–59 age groups did not differ significantly ($P > 0.05$).

The sex-based subgroup regression analysis is presented in Table 6. The results revealed that the regression equation for men using facial anthropometric measurements to estimate ICaD was $y = 24.642 + 0.174ICW + 0.145ICD + 0.115IAW$ ($P < 0.001$). The regression equation for estimating ICaD using facial anthropometric measurements in women was $y = 22.691 + 0.167IAW$ ($P < 0.001$).

4. Discussion

The results of this study rejected the null hypothesis and concluded that facial anthropometric parameters and intercanine distance are related; however, the mathematical relationship has sex- and age-related differences.

The values of each anthropological measurement in the present study (Table 1) were close to those of Ashwini Y. Kini [15] and Isa et al. [23], possibly owing to the racial similarity of the participants. In addition, this study revealed that IPD, ICD, IAW, and ICW were not equal to ICaD in both sexes ($P < 0.05$). Therefore, direct reliance on any of the facial anthropological measurements (IPD, ICD, IAW, and ICW) alone to determine the position of the canines was unreliable in this study.

Furthermore, this study found that the value of facial dimensions and ICaD were significantly larger in men than in women, consistent with the findings of most previous studies [11,32–35], which indicated that men and women should be analyzed separately for dentofacial relationships. However, no sex differences in IPD were observed respectively in the studies of Freihofer HP [36] and Gomes [9], which may be attributed to differences in race or measuring methods.

ICaD could decrease progressively with age; however, the mean difference between the 20–29-year-old and 50–59-year-old groups was only approximately 0.7 mm, and this slight difference between age groups might be owing to long-term tooth adjacent surface wear or mesial movement [37]. For IPD, this study found that the IPD size remained relatively stable between age groups, consistent

Table 1
All measurements in total sample and according to sex (mean and standard deviation, mm).

	Total		Man		Woman			
Variables	Mean	±SD	Mean	±SD	Mean	±SD	*t*	*P*
ICaD	39.84	±2.08	40.52	±2.00	39.19	±1.94	6.790	<0.01
ICD	35.50	±3.05	36.23	±3.05	34.81	±2.88	4.829	<0.01
IPD	63.49	±3.65	65.43	±3.38	61.64	±2.86	12.213	<0.01
IAW	40.45	±3.14	42.48	±2.66	38.53	±2.22	16.334	<0.01
ICW	49.31	±3.63	51.11	±3.41	47.61	±2.96	11.086	<0.01

ICaD, distance between the most apparent distal points of the canine teeth in a straight line; ICD, intercanthal distance; IPD, interpupillary distance; IAW, interalar width; ICW, intercommissural width; SD, standard deviation.

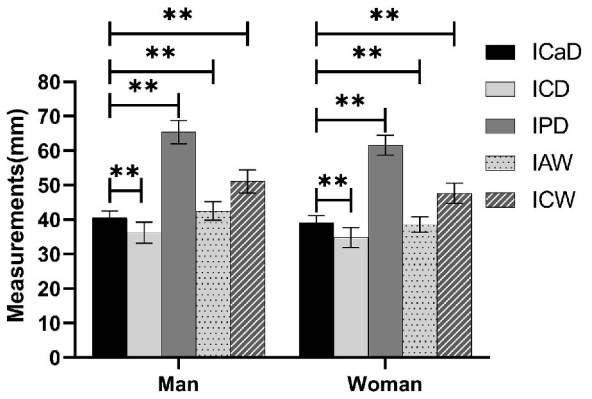

Fig. 3. Independent samples *t*-test results for comparing intercanine distance and facial measurements in both sexes.
(**represents that the two columns of data are significantly different at the level of $P < 0.01$).

Table 2
One way ANOVA and LSD multiple comparison test results of all measured values between different age groups (mean and standard deviation, mm).

Dental and facial measurements	Age group				*F*	*P*
	20~29 ($n = 125$)	30~39 ($n = 110$)	40~49 ($n = 86$)	50~59 ($n = 88$)		
ICaD	40.00 ± 1.89^{a}	40.11 ± 2.33^{a}	39.80 ± 1.83^{ab}	39.30 ± 2.15^{b}	2.91	<0.05
ICD	36.28 ± 3.10^{a}	35.92 ± 2.75^{ab}	35.32 ± 3.02^{b}	34.06 ± 2.87^{c}	10.774	<0.01
IPD	63.22 ± 3.60^{ab}	64.06 ± 3.50^{a}	63.85 ± 3.88^{ab}	62.79 ± 3.60^{b}	2.482	0.061
IAW	39.40 ± 2.89^{b}	40.69 ± 3.02^{a}	40.72 ± 3.24^{a}	41.38 ± 3.16^{a}	8.087	<0.01
ICW	48.29 ± 3.48^{b}	49.45 ± 3.57^{a}	49.67 ± 3.09^{a}	50.24 ± 4.10^{a}	5.729	<0.01

Values not sharing the same superscript letter in the same row differ significantly ($P < 0.05$).

Tabel 3
Pearson correlation coefficient (r) between ICaD and 4 facial measurements.

Facial measurements	ICaD		
	Total	Man	Woman
IPD	0.334*	0.176*	0.245**
ICD	0.258*	0.219**	0.179**
ICW	0.389*	0.345**	0.215**
IAW	0.393*	0.242**	0.285**

ICaD, Intercanine distance; ICD, intercanthal distance; IPD, interpupillary distance; IAW, interalar width; ICW, intercommissural width. *$P < 0.05$ **$P < 0.01$.

Table 4
Results of subgroup regression analysis based on age.

Variables	ICaD				
	20~29	30~39	40~49	50~59	Total
Constant	24.172**	27.060**	19.954**	18.933**	22.904**
ICD	−0.097	0.002	0.111	0.11	0.077
IPD	0.094	−0.067	0.066	−0.004	0.03
IAW	0.187**	0.172	0.203**	0.161*	0.142**
ICW	0.125*	0.208**	0.071	0.204**	0.133**
R^2	0.25	0.192	0.378	0.344	0.221
F	9.991**	6.244**	12.331**	10.896**	28.724**

*$P < 0.05$ **$P < 0.01$.

with the results of previous studies [19]. Moreover, the results of this study suggest that these facial anthropometric measurements, with the exception of IPD, change lateral with age. The majority of patients requiring full denture treatment are elderly, so age-related changes in facial morphology must therefore be taken into account by the practitioner so that more specific treatment can be rendered to older patients. Although these changes in the horizontal axis direction will not affect the vertical exposure of patients when they smile or speak, this discovery is also meaningful to complete denture restoration procedure. This finding disproves the notion that the

Table 5
Results of the test for differences in regression coefficients between the 20–29-year-old and 50–59-year-old groups.

Age group		Variables	Regression coefficient (b1)	Regression coefficient (b2)	Difference	*t*	*P*
20~29	50~59	IAW	0.187	0.161	0.027	−0.36	0.72
		ICW	0.125	0.204	−0.079	0.008	0.994

Table 6
Results of subgroup regression analysis based on sex.

	ICaD		
Variables	Total	Man	Woman
Constant	22.904**	24.642**	22.691**
ICD	0.077	0.145*	0.02
IPD	0.03	−0.048	0.094
IAW	0.142**	0.115*	0.167**
ICW	0.133**	0.174**	0.074
R^2	0.221	0.173	0.118
F	28.724**	10.151**	6.877**

*$P < 0.05$ **$P < 0.01$.

distal surface of the upper canines can be directly localized using the width of nasal or commissura labiorum.

Although the four facial measurements cannot be used to directly help in determining ICaD, in our study, a significant positive correlation between all four facial anthropological measurements and intercanine distance existed, consistent with the studies of Pisulkar et al. [38], Abdullah et al. [35], Lucas et al. [39], and Kini et al. [15]. According to our study, the correlations found can be used as a reference for anterior teeth selection in removable dentrures. Then the linear regression equations express the best estimation of the intercanine distance, which is the dependent variable (Y), given the anthropometric measurements obtained through frontal photograph, which are the independent variables (X). The facial measurements can be used to ensure the suitable perceived width of the anterior teeth in a straight line during the try-in appointment of the denture. Thus, it might be intriguing to refine the use of facial horizontal distances as a guide for choosing teeth, as this could reduce the reliance on subjective experience-based decisions. However, the coefficient of determination (R2) of the linear regression models derived in this study were at a moderate level, which did not ensure that narrow prediction intervals were obtained. This needs to be further improved in future studies.

The difference in the magnitude of the effect of facial anthropometric measures on ICaD was insignificant between the 20–29-year-old and the 50-59-year-old groups ($P < 0.05$)(Table 5). However, the multiple linear regression models of facial measurements for the combined width of the six maxillary anterior teeth fitted for other age groups and different sexes completely changed (Tables 4–6). The results of this study clarify the variability of mathematical regression models between sex and age groups and are clinically instructive. This implies that using the same quantitative relationship as a generalized guide to determine the width of anterior teeth for different sexes or age groups might be inappropriate. Instead, clinicians should consider the differences between sexes and age groups in the measurements obtained through photogrammetry when using dentofacial relationships to determine the width of artificial anterior teeth. The identification of the mathematical relationships in different populations provides the possibility of applying artificial intelligence to the maxillary anterior tooth selection of complete dentures, which may contribute to digital dentistry and clinical decision-making in the future. The authors are unaware of studies that have evaluated differences in dentofacial relationships between different sexes and age groups, which might confuse clinicians when applying those guidelines in selecting tooth widths.

Therefore, in the absence of pre-extraction records or when patients are dissatisfied with their original appearance, clinicians may refer to the mathematical equations for different gender and age groups to determine the ICaD and, thus, the appropriate position of the canines. The limitation of this study was the error caused during photography or photographic measurements and the failure to obtain participants' arch form. Furthermore, this study was conducted on a specific population. Studies have found that the anthropological measurements and tooth size vary significantly among different races [26,28]. Hence, the results may be constrained by the influence of fixed regions and racial factors. In future studies, it would be interesting to develop a convenient and accurate method to predicting ICaD using the concept and outcome of this study and to evaluate the prediction accuracy.

In the absence of pre-extraction records, the use of digital images and facial analysis can be a guide to estimate the width of the upper anterior teeth, and the variability across age groups or sex populations should be considered. However, the patient should always be involved in decision-making regarding the treatment plan for the complete denture, and the practitioner should consult the patient at the time of fitting in.

5. Conclusions

Within the limitations of this study, the following conclusions can be drawn.

1 The ICD, IPD, ICW, and IAW could not directly help in determining ICaD.

2 The mathematical equations derived from dentofacial relationships can be used to ensure the suitable perceived width of the anterior teeth in a straight line during selecting artificial teeth or the try-in appointment of the denture.
3 The influence of sex and age should be considered when using ICD, IPD, ICW, and IAW to guide in determining the perceived width of the artificial upper anterior teeth.

Ethics approval statement

This study was reviewed and approved by the Ethics Committee of the Shanxi Provincial People's Hospital, with the approval number: SPPH-2022-418.

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Clinical implications

The use of anthropometry and digital images can assist in selecting maxillary anterior tooth widths that are harmonic with overall face esthetics, resulting in a more appealing result for dental rehabilitation therapies.

Data availability statement

Data will be made available on request.

Patient consent statement

All participants provided informed consent to participate in the study and all participants provided the informed consent for the publication of their anonymized images.

CRediT authorship contribution statement

Jing Wang: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Feng-Lan Li:** Supervision, Project administration, Conceptualization. **Hong-Xia Yang:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Li-Mei Li:** Methodology, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] P.F. Johnson, Racial norms: esthetic and prosthodontic implications, J. Prosthet. Dent 67 (1992) 502–508.
[2] M.V. Saintrain, E.H. de Souza, Impact of tooth loss on the quality of life, Gerodontology 29 (2012) e632–e636.
[3] L. Strajnić, Determination of placement of anterior teeth in removable dental prostheses, Med. Pregl. 55 (2002) 490–494.
[4] D. Krajicek, Natural appearance for the individual denture patient, J. Prosthet. Dent 10 (1960) 205–214.
[5] S.K. Sah, H.D. Zhang, T. Chang, M. Dhungana, L. Acharya, L.L. Chen, Y.M. Ding, Maxillary anterior teeth dimensions and proportions in a central mainland Chinese population, Chin. J. Dent. Res. 17 (2014) 117–124.
[6] P.J. Wehner, J.C. Hickey, C.O. Boucher, Selection of artificial teeth, J. Prosthet. Dent 18 (1967) 222–232.
[7] S.I. Silverman, Physiologic factors in complete denture esthetics, Dent, Clin. North Am. 17 (1967) 115–122.
[8] R. Guiglia, A. Musciotto, D. Compilato, M. Procaccini, L. Lo Russo, D. Ciavarella, L. Lo Muzio, V. Cannone, I. Pepe, M. D'Angelo, G. Campisi, Aging and oral health: effects in hard and soft tissues, Curr. Pharm. Des. 16 (2010) 619–630.
[9] V.L. Gomes, L.C. Gonçalves, C.J. do Prado, I.L. Junior, B. de Lima Lucas, Correlation between facial measurements and the mesiodistal width of the maxillary anterior teeth, J. Esthetic Restor. Dent. 18 (2006) 196–205.
[10] F.M. Varjão, S.S. Nogueira, Correlating the curve distance between the distal of the canines to the combined width of the six anterior teeth when selecting denture teeth for different ethnic groups, J. Prosthet. Dent 107 (2012) 400–404.
[11] N. Srimaneekarn, T. Arayapisit, O. Pooktuantong, H.R. Cheng, P. Soonsawad, Determining of canine position by multiple facial landmarks to achieve natural esthetics in complete denture treatment, J. Prosthet. Dent 127 (2022) 860–865.
[12] K.A. Al Wazzan, The relationship between intercanthal dimension and the widths of maxillary anterior teeth, J. Prosthet. Dent 86 (2001) 608–612.
[13] S. Tripathi, R.D. Singh, P. Chand, L. Kumar, G.K. Singh, A study to correlate various facial landmarks with intercanine distance, Indian J. Dent. Res. 29 (2018) 440–444.
[14] S. Tripathi, H. Aeran, S. Yadav, S.P. Singh, R.D. Singh, P. Chand, Canine tip marker: a simplified tool for measuring intercanine distance, J. Prosthodont. Implant Esthet. Reconstr. Dent. 20 (2011) 391–398.

[15] A.Y. Kini, G.S. Angadi, Biometric ratio in estimating widths of maxillary anterior teeth derived after correlating anthropometric measurements with dental measurements, Gerodontology 30 (2013) 105–111.
[16] F.M. Varjão, S.S. Nogueira, Intercommissural width in 4 racial groups as a guide for the selection of maxillary anterior teeth in complete dentures, Int. J. Prosthodont. (IJP) 18 (2005) 513–515.
[17] N. A.L.K, B.T. Garib, Selecting maxillary anterior tooth width by measuring certain facial dimensions in the Kurdish population, J. Prosthet. Dent 115 (2016) 329–334.
[18] L.G. Farkas, J.C. Posnick, T.M. Hreczko, G.E. Pron, Growth patterns in the orbital region: a morphometric study, Cleft Palate-Craniofacial J. 29 (1992) 315–318.
[19] B. Bindra, R.M. Basker, J.N. Besford, A study of the use of photographs for denture tooth selection, Int. J. Prosthodont. (IJP) 14 (2001) 173–177.
[20] W. Hoffman Jr., T.J. Bomberg, R.A. Hatch, Interalar width as a guide in denture tooth selection, J. Prosthet. Dent 55 (1986) 219–221.
[21] U. Hasanreisoglu, S. Berksun, K. Aras, I. Arslan, An analysis of maxillary anterior teeth: facial and dental proportions, J. Prosthet. Dent 94 (2005) 530–538.
[22] P.T. Moore Kl, M.G. Torchia, The Developing Human: Clinically Oriented Embryology, sixth ed., Saunders, Philadelphia, 2008, pp. 237–253.
[23] Z.M. Isa, O.F. Tawfiq, N.M. Noor, M.I. Shamsudheen, O.M. Rijal, Regression methods to investigate the relationship between facial measurements and widths of the maxillary anterior teeth, J. Prosthet. Dent 103 (2010) 182–188.
[24] G.H. Latta Jr., J.R. Weaver, J.E. Conkin, The relationship between the width of the mouth, interalar width, bizygomatic width, and interpupillary distance in edentulous patients, J. Prosthet. Dent 65 (1991) 250–254.
[25] S.C. Deogade, S.S. Mantri, K. Sumathi, S. Rajoriya, The relationship between innercanthal dimension and interalar width to the intercanine width of maxillary anterior teeth in central Indian population, J. Indian Prosthodont. Soc. 15 (2015) 91–97.
[26] S. Radia, M. Sherriff, F. McDonald, F.B. Naini, Relationship between maxillary central incisor proportions and facial proportions, J. Prosthet. Dent 115 (2016) 741–748.
[27] E.G. Owens, C.J. Goodacre, P.L. Loh, G. Hanke, M. Okamura, K.H. Jo, C.A. Muñoz, W.P. Naylor, A multicenter interracial study of facial appearance. Part 1: a comparison of extraoral parameters, Int. J. Prosthodont. (IJP) 15 (2002) 273–282.
[28] E.J. Schmidlin, M. Steyn, T.M.R. Houlton, N. Briers, Facial ageing in South African adult males, Forensic Sci. Int. 289 (2018) 277–286.
[29] P.N. Sellen, D.C. Jagger, A. Harrison, The selection of anterior teeth appropriate for the age and sex of the individual. How variable are dental staff in their choice? J. Oral Rehabil. 29 (2002) 853–857.
[30] S.K. Verma, S. Maheshwari, S.N. Gautam, K. Prabhat, S. Kumar, Natural head position: key position for radiographic and photographic analysis and research of craniofacial complex, J Oral Biol Craniofac Res 2 (2012) 46–49.
[31] J.L. Fleiss, The Design and Analysis of Clinical Experiments, John Wiley & Sons, New York, 1986, pp. 17–26.
[32] L. Strajnić, I. Vuletić, P. Vucinić, The significance of biometric parameters in determining anterior teeth width, Vojnosanit, Pregl 70 (2013) 653–659.
[33] A. Kurien, K.P. Cherian, S. Mhatre, R.G. Tharakan, A comparative study on the relationship between inter alar width, and inter commissural width on circumferential arc width of maxillary anterior teeth in different age groups, J. Indian Prosthodont. Soc. 14 (2014) 352–357.
[34] V.A. Cesario Jr., G.H. Latta Jr., Relationship between the mesiodistal width of the maxillary central incisor and interpupillary distance, J. Prosthet. Dent 52 (1984) 641–643.
[35] M.A. Abdullah, Inner canthal distance and geometric progression as a predictor of maxillary central incisor width, J. Prosthet. Dent 88 (2002) 16–20.
[36] H.P. Freihofer, Inner intercanthal and interorbital distances, J. Maxillofac. Surg. 8 (1980) 324–326.
[37] J.A. Kaidonis, G.C. Townsend, L.C. Richards, Brief communication: interproximal tooth wear: a new observation, Am. J. Phys. Anthropol. 88 (1992) 105–107.
[38] S. Pisulkar, S. Nimonkar, A. Bansod, V. Belkhode, S. Godbole, Quantifying the selection of maxillary anterior teeth using extraoral anatomical landmarks, Cureus 14 (2022) e27410.
[39] B.L. Lucas, R. Bernardino-Júnior, L.C. Gonçalves, V.L. Gomes, Distance between the medialis angles of the eyes as an anatomical parameter for tooth selection, J. Oral Rehabil. 36 (2009) 840–847.