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https://doi.org/10.4047/jap.2022.14.1.1

Biometry of width between labial transitional line angles in anterior teeth: an observational study

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Received August 14, 2021 /
Last Revision December 26, 2021 /
Accepted February 7, 2022

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This study was supported by the National Key R&D Program of China (2019YFB1706900); the Beijing Training Project for the Leading Talents in S & T (Z191100006119022); Project 2019BD021 supported by the PKUBaidu Fund; and Program for New Clinical Techniques and Therapies of Peking University School and Hospital of Stomatology(PKUSSNCT-20B07).

PURPOSE. The maximum width between the mesial and distal labial transitional line angles, described as "esthetic width" herein, could significantly influence the visual perception of the teeth and smile. This study aimed to conduct biometric research on esthetic width and to explore whether regular distribution exists in the esthetic width of human teeth. **MATERIALS AND METHODS.** A total of 4,264 maxillary and mandibular anterior teeth were measured using the Geomagic studio software program. The proportions of maxillary to mandibular homonymous teeth and proportions between the adjacent teeth were calculated. Bilateral symmetry and the correlation between the esthetic and mesiodistal widths were both accounted for during the measurement procedures. **RESULTS.** The mean esthetic widths were 6.773 ± 0.518 mm and 4.329 ± 0.331 mm for maxillary and mandibular central incisors, respectively, 5.451 ± 0.487 mm and 5.008 ± 0.351 mm for maxillary and mandibular lateral incisors, respectively, and 3.340 ± 0.353 mm and 5.958 ± 0.415 mm for maxillary and mandibular canines, respectively. Except for the mandibular canines, no significant difference in esthetic width was found among homonymous teeth from the same jaw. A high linear correlation was found between the esthetic and mesiodistal widths of the same tooth, except for the maxillary canines. Esthetic width proportions among different tooth categories showed some regular patterns, which were similar to those of the mesiodistal width. **CONCLUSION.** Esthetic width is regularly distributed among the teeth in the Chinese population. This could provide an important reference for anterior dental restorations and dimension recovery in esthetic reconstruction of anterior teeth. [J Adv Prosthodont 2022;14:1-11]

KEYWORDS
Odontometry; Tooth crown; Dental esthetics; Dental prosthesis design

https://doi.org/10.4047/jap.2022.14.1.1

INTRODUCTION

Transitional line angles (or line angles), known as the contour height of marginal ridges, mark the transition from the labial (buccal) and lingual surface to the proximal surface.[1] Labial transitional line angles (LTLAs) delimit the labial surface of the tooth and significantly influence the visual perception of the teeth and smile.[1-3] When light strikes, the area between the LTLAs directly reflects it back, giving the tooth's perceived length and width, while the area outside the LTLAs deflects the light and is less noticeable (illusion phenomenon).[2,3] The closer or further the lines are to the tooth's center, the narrower or wider the tooth appears.[3,4] The interaction of LTLAs with adjacent teeth optimizes the appearance of the smile. Restorative studies have identified LTLAs as the primary anatomy for restorations, and their recreation has been emphasized for wax-up and prosthesis design.[5,6] Improper reproduction of the lines results in the restoration appearing different, even if it is identical in size to the contralateral tooth.[2,7]

Correct placement of LTLAs is essential to achieve a natural result; however, the reproduction technique remains challenging. It has been suggested that the effects of these lines on the tooth's perceived dimensions are due to the labial mesiodistal dimension,[8] which is also referred to as the "virtual width,"[9,10] "apparent tooth width,"[11] "perceived width of tooth,"[12] and "apparent face width."[13] Some authors have also proposed that the distance between the LTLAs could be used to verify the size and symmetry of homonymous teeth.[14] However, this has not yet been reported.

It has been proposed that the most important region for smile design is the 20 mm^2 area between the mesiolabial line angles of the maxillary central incisors at the level of the interproximal contact.[12] Some authors have indicated that the development of LTLAs follows the contour of the tooth's morphological shape.[3] Closer observations have revealed that the widest part between the mesial and distal LTLAs in the anterior teeth appears at the level of the interproximal contact above and below, where the maximum width of the tooth is evident. The labial surface of the maxillary canines is divided into mesial and distal parts, and the distal halves are usually used to adjust the diastemas in the anterior areas that are outside the esthetic focus. In this study, the maximum width between the LTLAs of the incisors and mandibular canines (that is, the labial mesiodistal dimension), as well as the maximum width between the mesial LTLA and axial ridge of the maxillary canines were all measured and described as the "esthetic width" to facilitate presentation.

The primary aims of this biometric study were to measure the esthetic width of maxillary and mandibular anterior teeth, assess the possible asymmetry between homonymous teeth of the same dental arch, and explore the relationship of the esthetic width between the maxillary and mandibular homonymous teeth as well as that between adjacent teeth. The secondary aim was to explore the relationship between the esthetic and mesiodistal widths of the same teeth.

MATERIALS AND METHODS

Before sample collection, approval from the Medical Ethics Committee was obtained (Ethics Approval No. PKUSSIRB-202057122). The study was conducted in accordance with the principles of the Declaration of Helsinki.

This study was performed on 781 digital casts stored in the hospital, which were obtained from Chinese patients who visited the Department of Prosthodontics between 2016 and 2019. All patients provided informed consent prior to restorative treatment stating that their unidentifiable clinical data could be used for academic and non-commercial research purposes. Digital casts with at least half of the anterior teeth that were anatomically complete were included in the study. The exclusion criteria were as follows: digital casts with orthodontic brackets and casting or scanning defects on the labial surface, restorations, tooth rotation and malformation, and incisal or cuspal wear identifiable to the naked eye in over one third of the anterior teeth. Furthermore, unidentifiable teeth in selected casts, irrespective of whether they had perfect restorations, or clinical evidence or a history of adjustments on the labial surfaces were excluded from the study. A total of 4,264 maxillary and mandibular anterior teeth were enrolled in this study, including 771 central incisors, 942 lateral incisors, and 754 canines in the maxillary arch, as well as 447 central incisors, 721 lateral incisors, and 629 canines in the mandibular arch.

A digital method was adopted to perform esthetic width measurements in this study. Digital casts in the STL file format were imported into the Geomagic Studio software program (Geomagic Studio 2012; 3D System, Morrisville, NC, USA) for unified visualization of the transitional line angles. The "Light Theme" in the "Lighting" options was set at "3 Lights," both "Ambient" and "Reflectivity" were set at 100%, and the "Brightness" was set at 60%. The position and rotation of the analyzed tooth were adjusted to place the labial surface perpendicular to the view direction and to level the incisal edge parallel to a horizontal line. All measurements of esthetic width in this study were performed with the cast in this orientation. Under the set conditions, marginal ridges appeared as bright strips extending from the cervical to incisal areas on the screen. The LTLAs at the center of the bright strips were clearly visible from the labial and occlusal perspectives. A schematic plot of the measurement is shown in Figure 1. For the maxillary and mandibular incisors and mandibular canines, the most convex point on the distal transitional line angle was selected, while the other point was selected on the mesial transitional line angle such that the line connecting the two points was parallel to the incisal edge (perpendicular to the long axis of the tooth crown). The distance between the two points was then recorded (esthetic width). For maxillary canines, the most convex point on the mesial transitional line angle was chosen, and the other was chosen on the centerline of the labial ridge such that the line connecting the two points was perpendicular to the long axis of the tooth crown. The distance between the two points was measured and recorded (esthetic width). The selected points were confirmed using the occlusal view (Fig. 2). The long axis of the tooth crown and other reference elements were determined based on the previous literature[15].

Measurements were independently completed by one investigator (C.W.). To eliminate memory effects, measurements of the teeth on the left and right sides were performed at intervals of at least 1 week. To assess the reliability of the measuring method, 60 central incisors (30 each in the maxillary and mandibular arches) were selected. The measurements were performed three times by the same investigator (C.W.) and two other clinicians with 10 (H.Y.) and 20 (Y.S.) years of clinical experience, respectively, at intervals of at least 1 week. The investigator (C.W.) also performed the measurements using a digital caliper (Deli DL91150; Deli, Ningbo, Zhejiang, China) with the pre-

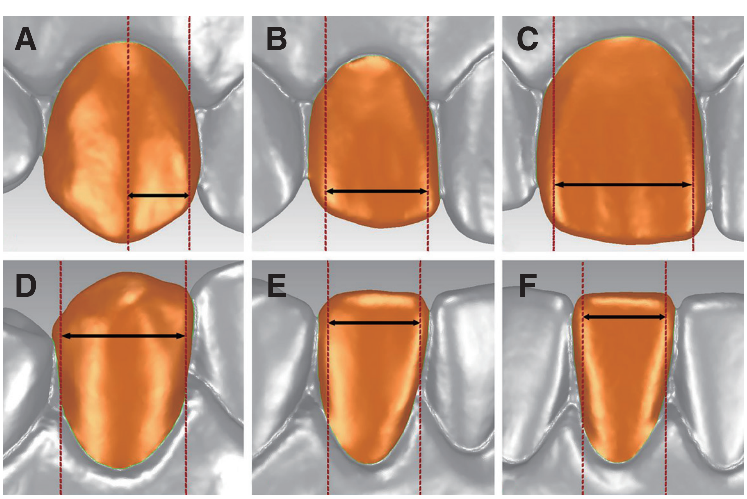

Fig. 1. Measurement of esthetic width in the anterior teeth. Black lines represent the esthetic width. (A) maxillary canine, (B) maxillary lateral incisor, (C) maxillary central incisor, (D) mandibular canine, (E) mandibular lateral incisor, (F) mandibular canine.

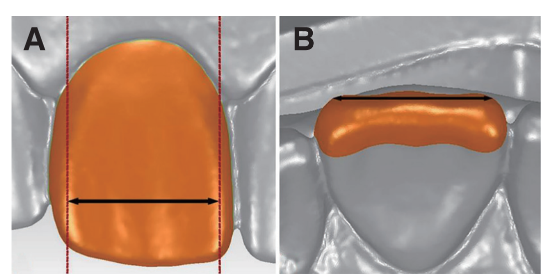

Fig. 2. (A) Esthetic width (black lines) in view direction, (B) Esthetic width (black lines) verified from occlusal view.

cision of 0.01 mm on the corresponding 60 central incisors three times on plaster casts (measuring plot as shown in Fig. 3). The intraclass correlation coefficients (ICC) with their 95% confidence intervals of intraexaminer and inter-methods were both calculated based on single measurement, absolute-agreement, and 2-way mixed-effects model; that of interexaminer reproducibility was calculated based on single measurement, absolute-agreement, and 2-way random-effects model.

To analyze the correlation between the esthetic and mesiodistal widths, 20 teeth each of maxillary and mandibular central incisors, lateral incisors, and canines were selected to perform a correlation analysis. Each tooth was repositioned to allow a complete view, and two points on the largest mesiodistal diameter of the tooth crown were selected, as reported in previous studies, with the measurement plane perpendicular to the long axis of the clinical crown.[15]

The primary observable variables were the esthetic width of maxillary and mandibular central incisors, lateral incisors and canines; asymmetry between homonymous teeth in the bilateral maxillary and mandibular jaws; proportions of maxillary to mandibular homonymous teeth; and proportions between adjacent teeth. The secondary observable variables were the correlation and the proportion between the esthetic width and mesiodistal width.

Normality of data was assessed using the Kolmogorov-Smirnov test. A paired *t*-test was used to assess differences in esthetic width between homonymous teeth on the left and right sides. A Bonferroni correction with a type I error of 0.008 (0.05/6) was applied. The Pearson correlation coefficient was used to analyze the correlation between proportions as well as between the esthetic and mesiodistal widths. Meanwhile, a linear regression equation was established with the mesiodistal width as the independent variable and esthetic width as the dependent variable. The coefficient of determination (R^2) was used to gauge the overall model fit. The statistical significance of the equation was examined by analysis of variance (ANOVA). The overall alpha level chosen for the analysis was 0.05.

All the data were recorded and analyzed independently by an investigator (C.W.). Statistical analyses were performed using SPSS (IBM SPSS Statistics 18; IBM, Armonk, NY, USA). Continuous-tone images were obtained using the "Capture" tool in the Geomagic Studio software program, with the marker lines added, typeset, and cut in Photoshop (Photoshop 2018 CC; Adobe Systems Incorporated, San Jose, CA, USA). All line-art images were drawn using Origin (Origin 2018; OriginLab, Northampton, MA, USA).

RESULTS

Results of the reliability evaluation are shown in Table 1. For the intraexaminer, interexaminer and inter-methods ICC results, lower bounds of their 95% confidence interval ranges were all higher than 0.75 (for upper central incisors, it was even higher than 0.9 for intraexaminer methods). Therefore, based on statistical inference, we can conclude the level of reliability to be "good" to "excellent" on the whole based on existing literature.[16]

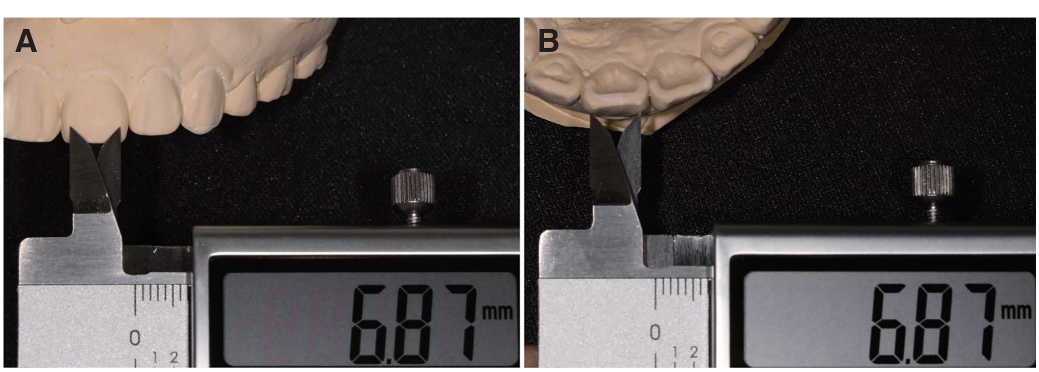

Fig. 3. (A) Caliper-based measurement of esthetic width in the view direction, (B) Caliper-based measurement of esthetic width verified from the occlusal view.

Table 2 shows the means, standard deviations, ranges (maximum and minimum), and the corresponding sample sizes for each anterior tooth in the entire sample. The esthetic width varied considerably according to the type of tooth, with the greatest width on the central incisors in the maxillary arch and canines in the mandibular arch. All tooth measurement categories followed a normal distribution.

The descriptive statistics of the proportions of maxillary to mandibular homonymous teeth and proportions between adjacent teeth are shown in Table 3. Values of the proportion items were closer to a fixed value. Most correlation coefficients for the teeth involved were within 0.214 and 0.697 and only that of proportion “12/13” was not statistically significant (P = .129).

The esthetic width distributions of bilateral homonymous teeth and statistical tests with significance values of comparisons between the left and right sides are shown in Figure 4. Statistically significant differences were found in the mandibular bilateral canines (P values were below the Bonferroni-adjusted significance threshold of 0.008). No significant difference was observed among other bilateral homonymous teeth, which showed bilateral symmetry.

Table 4 shows the measurements, proportions, and correlations between the esthetic and mesiodistal widths of teeth on the right side, which conformed to a normal distribution. The proportions of the esthetic width to the mesiodistal width of different tooth categories (except maxillary canines) were between 0.70 and 0.88, with a highly significant linear correlation (r

Table 1. Results of the reliability evaluation of the measurements (N = 30)

Tooth	Intraexaminer	Interexaminer	Inter-methods
UCIs	0.944 (0.901 - 0.971)	0.869 (0.769 - 0.931)	0.937 (0.869 - 0.970)
LCIs	0.938 (0.888 - 0.968)	0.889 (0.779 - 0.946)	0.910 (0.817 - 0.957)

UCIs: upper central incisors, LCIs: lower central incisors.

Table 2. Esthetic width of each tooth (mm)

Tooth	N	Mean (SD)	Range
11	349	6.739 (0.516)	5.576 to 8.285
21	422	6.802 (0.518)	5.456 to 8.186
UCIs	771	6.773 (0.518)	5.456 to 8.285
12	454	5.432 (0.489)	4.262 to 6.772
22	488	5.468 (0.484)	4.050 to 7.191
ULIs	942	5.451 (0.487)	4.050 to 7.191
13	317	3.352 (0.335)	2.372 to 4.298
23	437	3.332 (0.365)	2.411 to 4.410
UCs	754	3.340 (0.353)	2.372 to 4.410
41	212	4.306 (0.322)	3.512 to 5.163
31	235	4.349 (0.338)	3.519 to 5.598
LCIs	447	4.329 (0.331)	3.512 to 5.598
42	363	4.997 (0.349)	4.152 to 6.592
32	358	5.019 (0.353)	3.965 to 6.029
LLIs	721	5.008 (0.351)	3.965 to 6.592
43	263	5.907 (0.420)	4.902 to 7.264
33	366	5.994 (0.408)	5.153 to 7.293
LCs	629	5.958 (0.415)	4.902 to 7.293

The Fédération Dentaire Internationale tooth numbering system has been used. UCIs: upper central incisors, ULIs: upper lateral incisors, UCs: upper canines, LCIs: lower central incisors, LLIs: lower lateral incisors, LCs: lower canines, SD: standard deviation.

https://doi.org/10.4047/jap.2022.14.1.1

Table 3. Proportions with corresponding relationships of maxillary to mandibular homonymous teeth and between adjacent teeth

Proportion	N	Mean (SD)	Range	Correlation Coefficient	*P*
11/41	110	1.557 (0.113)	1.330 to 1.888	0.554	< .001
21/31	141	1.567 (0.117)	1.238 to 1.821	0.553	< .001
12/42	223	1.102 (0.088)	0.885 to 1.347	0.488	< .001
22/32	239	1.097 (0.092)	0.823 to 1.365	0.462	< .001
13/43	183	0.569 (0.056)	0.424 to 0.758	0.468	< .001
23/33	280	0.558 (0.056)	0.390 to 0.684	0.445	< .001
11/12	247	1.244 (0.103)	0.963 to 1.587	0.510	< .001
21/22	302	1.249 (0.114)	0.908 to 1.620	0.408	< .001
41/42	155	0.869 (0.064)	0.670 to 1.100	0.479	< .001
31/32	170	0.865 (0.059)	0.690 to 1.030	0.575	< .001
12/13	210	1.642 (0.212)	1.126 to 2.246	0.105	.129
22/23	312	1.657 (0.208)	1.181 to 2.297	0.214	< .001
42/43	174	0.848 (0.059)	0.720 to 1.000	0.542	< .001
32/33	229	0.846 (0.051)	0.720 to 1.020	0.601	< .001

The Fédération Dentaire Internationale tooth numbering system has been used. SD: standard deviation.

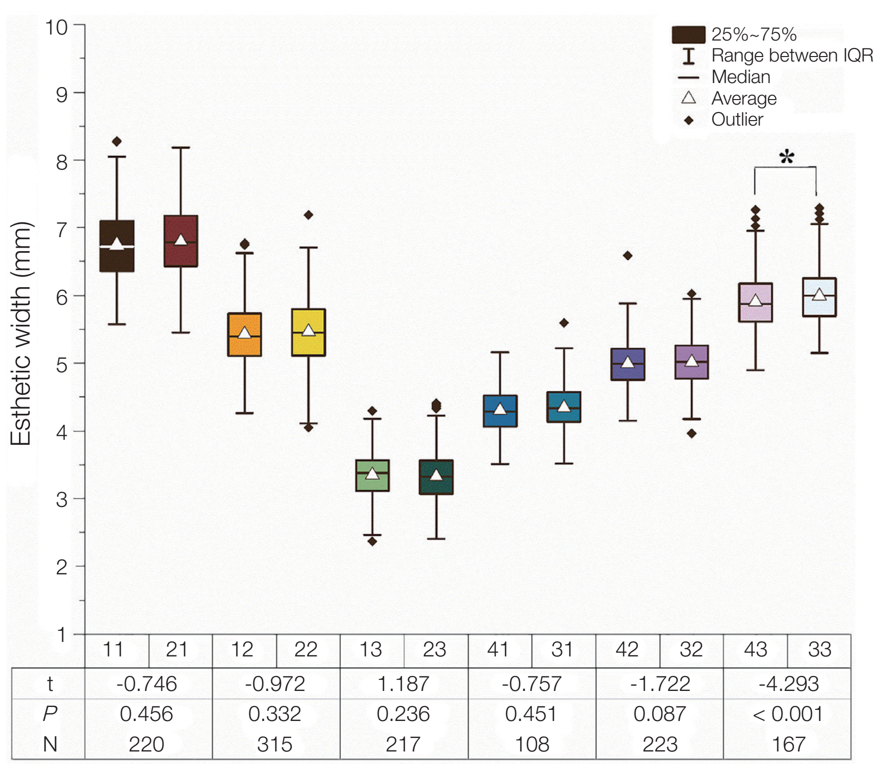

Fig. 4. Comparison of esthetic width between the right and left central incisors, lateral incisors, and canines. The Fédération Dentaire Internationale tooth numbering system has been used. *P value was less than the Bonferroni-adjusted significance level of 0.008 (0.05/6).

> 0.7). Figure 5 shows the fit of the linear regression models between the esthetic and mesiodistal widths for each tooth category. ANOVA showed that all regression equations were statistically significant. Mandibular canines showed a good fit (R^2 = 0.785) while other tooth categories showed a fair fit (R^2= 0.585 ~ 0.675), except for maxillary canines which showed a poor fit (R^2 = 0.264).

Table 4. Measurements (mm), proportions, and Pearson correlation coefficients with *P* values of the esthetic and mesiodistal widths of each individual tooth on the right side (N = 20)

Tooth	EW	MW	Proportion (EW/MW)			R	*P*
	Mean (SD)	Mean (SD)	Mean (SD)	95%CI	Range		
11	6.852 (0.681)	8.596 (0.626)	0.797 (0.045)	0.775 to 0.818	0.697 to 0.883	0.821	< .001
12	5.627 (0.535)	7.148 (0.543)	0.787 (0.047)	0.765 to 0.809	0.712 to 0.883	0.787	< .001
13	3.413 (0.347)	7.856 (0.490)	0.435 (0.038)	0.417 to 0.453	0.359 to 0.494	0.514	.020
41	4.400 (0.341)	5.647 (0.345)	0.779 (0.037)	0.762 to 0.796	0.721 to 0.844	0.787	< .001
42	4.978 (0.321)	6.116 (0.343)	0.811 (0.031)	0.797 to 0.826	0.762 to 0.872	0.765	< .001
43	5.891 (0.369)	7.004 (0.374)	0.841 (0.024)	0.830 to 0.852	0.782 to 0.876	0.884	< .001

The Fédération Dentaire Internationale tooth numbering system has been used. EW: esthetic width, MW: mesiodistal width, CI: confidence interval, SD: standard deviation.

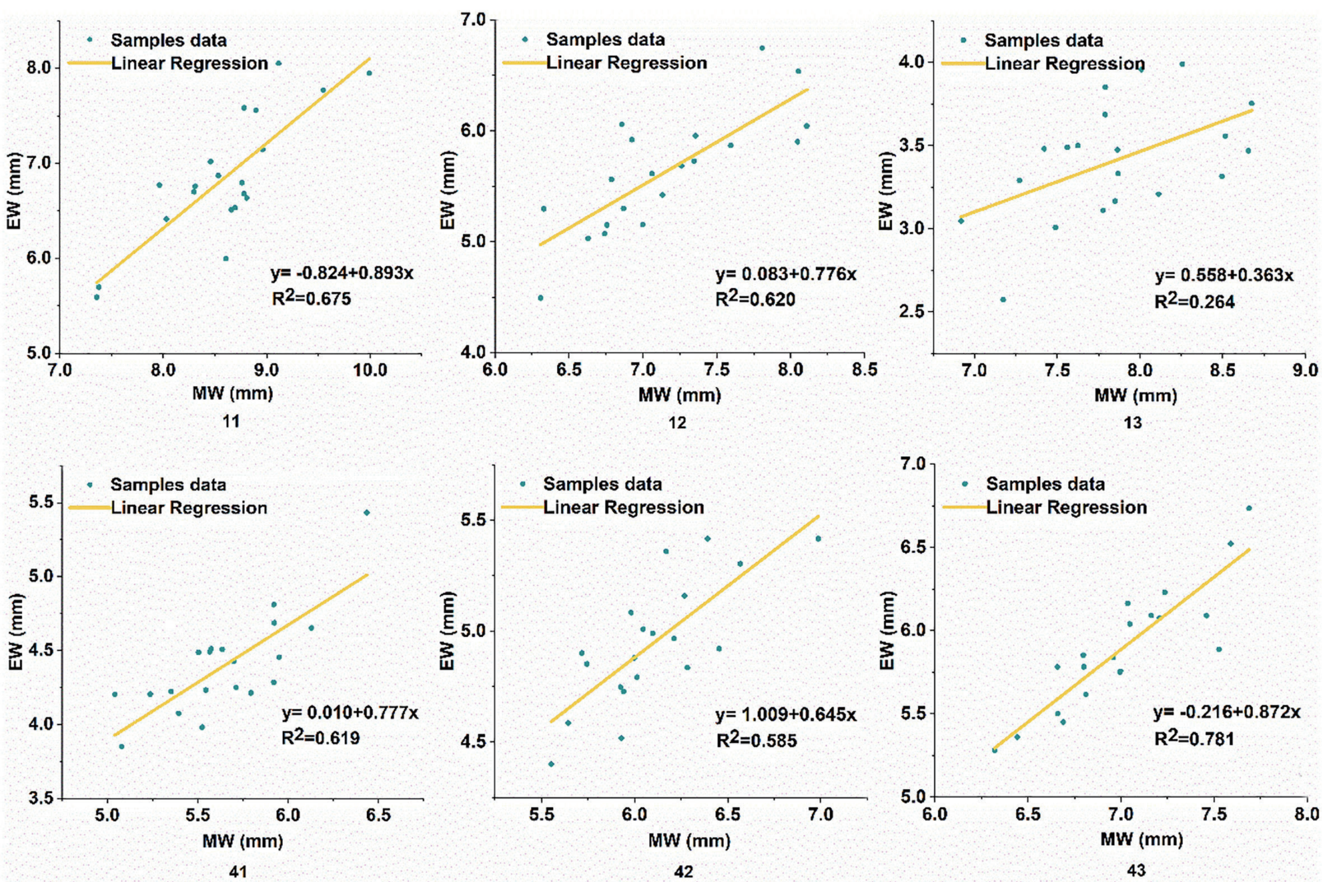

Fig. 5. Linear regression analyses between the mesiodistal width and esthetic width.
The Fédération Dentaire Internationale tooth numbering system has been used. EW: esthetic width, MW: mesiodistal width.

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DISCUSSION

This biometric study analyzed the esthetic widths of 4,264 anterior teeth corresponding to 781 digital casts, a larger sample than that of previous biometric studies on human teeth.[17-19] All the values of esthetic width were relatively constant to a certain range across different tooth categories. The results of this study showed that the esthetic width could serve as a dimensional parameter of the tooth and as a reference for the esthetic rehabilitation of anterior teeth in Chinese patients.

Several methods have been employed to measure tooth dimensions.[15,18,20,21] Owing to the opalescence and translucency of the natural tooth crown, it is difficult to accurately recognize subtle anatomical structures such as LTLAs using digital photography. Plaster casts can easily wear out during storage, transportation, and repetitive measurements, thereby causing measurement errors. Three-dimensional (3D) measurements provide instant accessibility of 3D information without the need for retrieval of plaster models from a storage area, and the anatomical details can also be easily identified in a diversity of ambient settings, which ensures higher measurement accuracy. In this study, the uniform measurement software was specified, and the lights in the measuring environment of the software were adjusted and unified to ensure that the junctions (or the LTLAs) between the labial and interproximal surfaces could be clearly recognized. The unified setting of orientation based on previous literature could help correct selection of points; and the position of selected points could be verified by rotating the casts to the occlusal direction, which reduces the error associated with subjectivity. There were also some factors that may lead to error in the measurements. For example, considering the “double-shoveling” trait, the distal marginal ridge is typically less pronounced than the mesial ridge.[11] Hence the corresponding distal LTLA is less prominent, which could make the accurate selection of points difficult. The peak of the labial axial ridge was relatively flat in some canines, and the junction between the mesial and distal halves was not as clear as the mesial LTLA. As a result, the points for measurement could only be selected on the centerline of the labial ridge as an alternative. Erosion and wear tend to accelerate with age, softening the marginal ridges, which become difficult to identify.[11] Therefore, more errors in point selection may occur among older patients. Even so, with the good to excellent reliability results of interexaminer, intraexaminer and inter-methods, we could conclude that our measurement results are scientific enough to be referred to.

Good bilateral symmetry of esthetic width in incisors and maxillary canines found in the present study is consistent with the results of previous studies on other tooth dimensions.[17] Significant differences found between the bilateral mandibular canines may have resulted from subjective bias. However, some studies have also reported fluctuation asymmetry in tooth development in canines,[22-24] which is a slight deviation from perfect bilateral symmetry that cannot be detected at the population level and is related to the buffering capacity of adaptability and resistance to interference.[23,25] However, it is important to differentiate between statistically and clinically significant differences, as symmetry is still the determinant factor of an attractive smile.[26] Bilateral symmetry results remind us that symmetrical esthetic width of bilateral homonymous teeth may help achieve a natural and appropriate esthetic effect.

The proportional relationships between dimensions for tooth categories could be used as predictive factors for the size of anterior teeth. In many cases, the maxillary anterior teeth are given more attention during esthetic treatment as they are the key components of a smile. The proportion of maxillary to mandibular homonymous teeth could be a good reference as a predictor for the esthetic width of maxillary anterior teeth, especially when all teeth require restoration and the proportions between adjacent teeth cannot be used. The proportions of all maxillary to mandibular homonymous teeth as well as the proportions between adjacent teeth were relatively stable, and the low to moderate correlations suggest that these proportions could be used with caution as a rough estimate during clinical treatment.

As characteristic landmarks of marginal ridges, transitional line angles are strongly correlated with the expression of the double-shovel shape. The double-shovel shape refers to the presence of mesial and distal marginal ridges on both the labial and lingual surfaces, and it is most pronounced on the maxillary incisor teeth. It was suggested that the double-shovel shape mostly occurs in Asian populations and in those of Asian descent, especially in East and North Asian and American populations, with medium frequency in Southeast Asian and derived Pacific populations, and is much less common in European, African, and Australian populations.[20] Furthermore, the double-shovel shape trait was also reported to be prominent in certain other Asian groups.[27,28] Different degrees of the double-shovel shape in different populations may directly affect the esthetic width. The sample explored in this study was from China (Asian descent), and the results may not be generalizable to other populations.

Relationships between tooth dimensions have attracted the attention of many scholars. Studies have shown a significant correlation between the mesiodistal width and buccal-lingual width of a tooth crown,[29] and the corresponding dimensions are also significantly correlated for the crown and cervix of a tooth.[30] A significant positive correlation has been found between the degree of the double-shovel shape and the mesiodistal width, which was determined by the same genes.[31,32] This study found a highly significant correlation between the esthetic and mesiodistal widths in both maxillary and mandibular incisors and mandibular canines ($r > 0.7$), with a proportion of approximately 0.80; the linear fit of the regression equation was moderate (R^2 between 0.58 and 0.78). Although these findings may be easily explained, the relatively stable proportion observed may provide a reference to inexperienced young technicians for the fabrication of more natural restorations, the high correlation of which could also indicate a good predictive value. Besides, given the rarity of such reports, this correlation study could provide some specific data references and support further investigations on the underlying mechanisms.

This study has the limitation that constant values of esthetic width were found in both maxillary and mandibular anterior teeth in this sample; this prevented an accurate assessment of the sample for minor statistical differences. Further studies in other races with larger sample sizes are needed to expand the generalizability and confirm these results in the future. Besides, sexual dimorphism has been widely reported for other tooth dimensions, and we will investigate this characteristic in the context of esthetic width in depth in the future.

CONCLUSION

The esthetic width shows a regular distribution among the teeth of a Chinese population. Esthetic width in most bilateral homonymous teeth showed good symmetry except for mandibular canines. A proportion of nearly 1.56 was proposed for the esthetic width of maxillary to mandibular incisors. Other proportions of esthetic width between maxillary to mandibular homonymous teeth as well as that between adjacent teeth also seemed relatively stable with moderate correlation, except for proportions of bilateral maxillary lateral incisors to canines. A high correlation and similar distribution pattern existed between the esthetic and mesiodistal widths, with the proportion between both dimensions being nearly 80%. The esthetic width could serve as a reliable dental dimension parameter in Chinese populations.

ACKNOWLEDGEMENTS

We thank Mr. Weiqiu Zhong for his contribution to the conception of this study.

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