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Original Article

Crown forms and gingival phenotypes: Insights from a diverse Asian population

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ABSTRACT

Objective: This study aimed to classify the crowns of maxillary central incisors into distinct categories and to examine the associations between these crown forms and morphometric characteristics in an ethnically diverse Asian population. This is significant for the treatment planning and management of cases, especially for the anterior teeth, from the restorative and aesthetic points of view.

Method and Materials: Clinical measurements and photographic data were collected from 160 participants, comprising students, staff, and patients of the Faculty of Dentistry, Universiti Kebangsaan Malaysia. The crown length, crown width, contact surface, papilla height, papilla fill, keratinized mucosa width, and gingival tissue thickness were measured. Cluster analyses were performed to identify the different crown form categories and corresponding characteristics.

Results: The mean crown width measured 7.093 ± 0.637 mm, while the mean crown length was 10.209 ± 0.966 mm. Three crown-form clusters were identified: triangular (50 %), square/tapered (23.1 %), and square (26.9 %) shapes. The triangular cluster had a significantly higher mean papilla height (4.64 mm ± 0.818) and the highest incidence of incomplete papilla fill (17.5 %). The chi-squared test showed a significant difference in crown forms between the different ethnicities, $\chi 2$ (2, 160) = 0.033.

Conclusion: Within this diverse Asian population, the crown form demonstrates three clusters: triangular, square/tapered, and square, characterized by a notably small average crown width and crown length. Most participants predominantly exhibited triangular crown forms with reduced crown width, crown length, and crown width/crown length ratio. Furthermore, noticeable variations in crown forms and their morphometric attributes were observed among the three ethnic groups: Malays, Chinese, and Indians.

1. Introduction

Different dimensions of teeth and their associated periodontal characteristics can have a significant impact on the outcomes of a planned treatment. This includes effects on aesthetics, bone volume, susceptibility to recession, pocketing in the natural dentition, and ridge shrinkage for prosthetic tooth replacement (Gobbato et al., 2012). A triangular crown form with a comparatively smaller coronal contact area is correlated with a thin gingival biotype, while a square crown shape with more substantial and apically positioned contact points is associated with a thick gingival biotype (Olsson & Lindhe, 1991; Olsson et al., 1993). The crown form is also related to the degree of papilla fill in the interdental area, where a crown width: crown length (CW/CL) ratio of 0.87 is associated with competent papilla (Chou et al., 2008). The other important roles of crown form include its contribution to the aesthetics of a smile and its influence on the aesthetic perception of a person's appearance (Anderson et al., 2005). Prosthetic tooth replacements, such as dentures, also typically use the crown form of the original teeth as a guide when choosing the dimensions and form of the tooth replacement.

Abbreviations: CW/CL, Crown width/crown length; CS/CL, Contact surface/crown length; UNC-15, University of North Carolina – 15; ANOVA, Analysis of Variance; UKM, Universiti Kebangsaan Malaysia.

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Various authors have adopted different approaches to categorizing crown forms, although most use the maxillary central incisors. Ollsen & Lindhe (1991) arbitrarily categorized crown forms into "long narrow" (CW/CL ± 0.5) and "short wide" (CW/CL ± 1) crown forms, while de Rouck et al. (2009) used a cluster analysis method to categorize crown forms into "slender" (CW/CL = 0.79) and "quadratic" (CW/CL = 0.88) crown forms. Gobbato et al. (2012) utilized contact surface/ crown length (CS/CL) ratio in three forms: "triangular" (<43 %), "square" (>57 %) or "square/tapered teeth" (43 %-57 %). Other subjective descriptions include those from Anderson et al. who used the "square, square-round, and round" subjective descriptions and Mahn et al. (2017) who utilized five hybrid combinations: oval-rectangular, triangular-rectangular, triangular-oval, square-oval with flat lateral incisors, and square-oval with scalloped lateral incisors.

While previous studies have investigated gingival phenotypes and their associated crown forms, only the report by Gobbato et al. specifically defined the tooth shape, such as triangular, square/tapered, or square, based on crown forms and the CS/CL ratio. Other studies utilized gingival characteristics, such as mucosal thickness and pocket depth, as the features for partitioning during the cluster analysis (Olsson & Lindhe, 1991; Olsson et al., 1993; Mahn et al., 2017; Müller and Eger, 1997; De Rouck et al., 2009; Kan et al., 2010). These studies were also designed to investigate periodontal phenotypes, with crown forms considered as just one among numerous factors incorporated into the cluster analyses.

To date, studies on gingival phenotypes and associated crown form categorizations using cluster analysis have predominantly been conducted in Caucasian populations Mahn et al., 2017; Müller and Eger, 1997; Müller et al., 2000). Patients from Asian populations have been reported to have a more slender crown form and a thinner gingival phenotype compared to their Caucasian counterparts (Tsukiyama et al., 2012; Kao et al., 2020). However, categorizations of crown forms specifically for the Asian population are currently unknown. This is of significance for healthcare professionals worldwide who provide treatment to individuals of Asian heritage.

It is hypothesised that the crown forms of Asians are significantly different from those of Caucasian heritage. Hence, the purpose of this clinical study was to: (a) classify the crown of the maxillary central incisors into different crown form categories using the CW/CL and CS/CL ratios; and (b) determine the association between crown forms and gingival phenotypes as well as other morphometric characteristics in an ethnically diverse Asian population.

2. Material and methods

2.1. Study design

This was a prospective cross-sectional study involving 160 participants recruited from the students, staff, and patients of the Faculty of Dentistry, Universiti Kebangsaan Malaysia (UKM). The study was carried out for 12 months, from December 2021 until December 2022. The study was conducted as part of a gingival phenotype study following the Declaration of Helsinki and was approved by the ethical committee of UKM. Written, informed consent was obtained from all participants.

2.2. Participants

The inclusion criteria were as follows: (i) partially or fully dentate with the presence of upper central incisors; (ii) more than 18 years old; (iii) systematically healthy; and (iv) no signs and symptoms of periodontal disease. The exclusion criteria were as follows: (i) pregnancy; (ii) lactating females; (iii) extensive gingival recession on the examined teeth; (iv) extensive restorations on the upper anterior teeth; (v) periodontal disease; (vi) smokers; (vi) patients who are taking medications that can affect the periodontium. Written consent was obtained from all participants before data collection.

For the photographic documentation, the exclusion criteria were photographs with poor image quality. This included photographs with low resolution, images that are out of focus at the region of interest, and images in which the probe used as a scale for the digital measurements cannot be clearly visualized.

2.3. Sample size calculation

Sample size calculation was conducted based on Dalmaijer et al., 2022. Based on previous studies, a maximum of five expected clusters were estimated (Mahn et al., 2018). The sample size was estimated at 156, with a minimum of 30 observations per group and a drop-out rate of 5 %.

2.4. Data collection

Standardized clinical photographs were used to assess the study parameters. The photographs were captured using a digital single-lens reflex camera (Nikon D5500, Japan) with 24 megapixels, 300 dpi horizontal and vertical resolution, the exposure time of 1/80 s, the f/stop at f/20, and the ISO speed at ISO-320. The occlusal plane was aligned to be parallel to the floor, while the midsagittal plane was perpendicular to the floor. Photographs were captured with similar lighting and minimal ambient light. The distance from the camera was standardized at about 1.3 m.

2.5. Calibration

A comparative evaluation between clinical and digital readings was conducted on the first 20 participants to validate the measurements using ImageJ software (National Institutes of Health, Bethesda, Maryland, USA) with the clinical measurements taken chairside. Three readings were collected for two examiners to calculate the intra- and inter-rater reliability.

2.6. Study parameters

The photographic measurements were assessed in all participants, as shown in Fig. 1. Both examiners (HYZ, NZZ) recorded parameters using ImageJ for parameters (a) to (f) in millimetres. The mean of the measurements was then calculated.

a) Crown length (CL): The CL was measured from the incisal edge to the cementoenamel junction (Olsson & Lindhe, 1991).
b) Crown width (CW): The CL was partitioned into three equivalent sections, and the CW was evaluated at the junction between the cervical and middle third of the crown (Olsson & Lindhe, 1991).
c) Contact surface (CS): The CS was measured from the most apical part of the contact area to the most incisal part on the mesial surfaces of the central incisors (Gobbato et al., 2012).
d) Papillary fill: The papilla index from Jemt et al. (1997) scores were used to evaluate the degree of the papilla fill (absent, <50 %, >50 %, complete, and overgrown, respectively) on the mesial segment of the tooth (Jemt, 1997).
e) Papilla height: The papillary height was determined from the apex of the papilla to the bridging line of the adjacent gingival zeniths, extending from teeth 12 to 22.
f) Width of keratinized mucosa: The width of the keratinized mucosa was identified as the distance between the most apical position of the gingival margin and the mucogingival margin based on the colour and texture changes between keratinised and non-keratinised tissues.
g) Gingival thickness: Measurements were performed by inserting an endodontic probe (Hu-Friedy Mfg. Co., LLC, Chicago, IL) transgingivally perpendicular to the long axis of the axial plane of the tooth (Kloukos et al., 2018), 1 mm apical to the zenith of the mid-

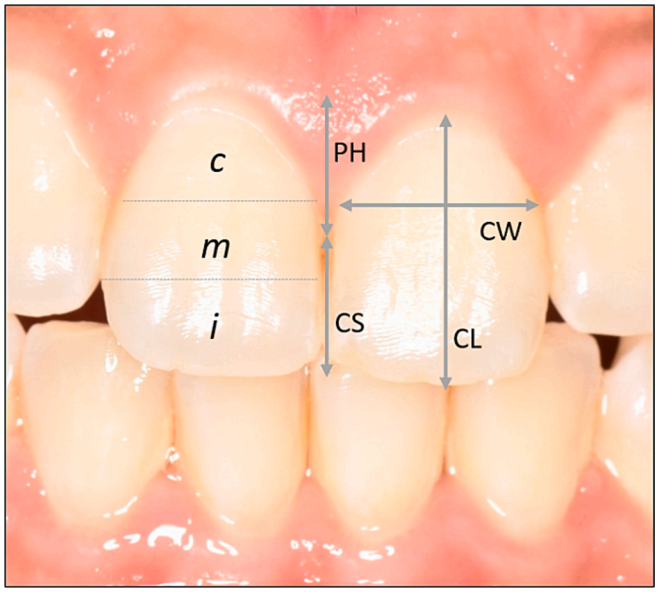

Fig. 1. Shows the location of the measurements in relationship to the maxillary anterior tooth. The CL was divided into three portions namely the cervical (c), middle (m), and incisal (i). CW was measured at the junction between sections C and M. CL - crown length, CW - crown width, PH - papilla height, CS - contact surface.

facial gingival margin of the upper central incisor until tactile resistance was felt under topical anaesthesia. A digital calliper with a sensitivity of 0.01 mm was used to measure the distance between the stopper and the probe tip.

2.7. Statistical analysis

Pearson's correlation coefficient was used to assess the inter-examiner reliability for the continuous variables. To identify clusters in the morphometric data, the hierarchical clustering method based on the Euclidean distance of the CW/CH ratio and the CS/CL ratio was utilised. Non-hierarchical disjunct cluster analysis with a K-means technique was used to iteratively enhance the clustering of participants, reducing the within-group sum of squares. One-way analysis of variance (ANOVA) and the post-hoc Tukey's test were applied to investigate the differences between the clusters ($p < 0.05$).

3. Results

A total of 160 periodontally healthy participants were recruited, including 41 (25.6 %) males and 119 (74.4 %) females. The mean age of the participants was 25.29 ± 8.652.

3.1. Inter-Rater agreement

Inter-rater agreement was conducted on a sample of 20 participants. Pearson's correlation coefficients were 0.933 ($p < 0.001$), 0.923 ($p < 0.001$), and 0.722 ($p < 0.001$) for the CW/CL ratio, the width of keratinized mucosa, and papillary height, respectively. Evaluations showed scores ranging between 0.60 and 1.0 for both examiners, which indicated good reliability and reproducibility of the data from the digital readings. Inter-rater reliability was also calculated to determine the level of agreement between both examiners; it showed scores above 0.90, indicating excellent reliability.

3.2. Morphometric analysis

The mean crown width was 7.093 ± 0.637 mm (range: 5.038 – 8.792), the mean crown length was 10.209 ± 0.966 mm (range: 7.834 – 13.608), and the mean contact surface was 6.065 ± 1.196 mm (range: 2.464 – 9.292). The mean and standard deviations for the other study parameters are shown in Table 1.

The Pearson correlation revealed a statistically significant correlation $r_s = -0.468$ ($p < 0.001$) between the CW/CL ratio and the papilla height, and a similarly significant correlation between the CS/CL ratio and the papilla height $r_s = -0.846$ ($p < 0.001$), as illustrated in Fig. 2. No additional correlation were found between the remaining study parameters.

3.3. Cluster analysis based on morphometric characteristics

Hierarchical cluster analysis was used to analyze the CW/CL ratio and the CS/CL ratio from all 160 participants, and three distinct groups were generated. The partitioning algorithm using K-means was used to further characterize the three groups. The three crown-gingival groups were named "triangular", "square/tapered," and "square" based on the CW/CL and CS/CL ratio. Fig. 3 shows the clinical examples of each crown-gingival group and the relevant measurements.

Table 1
Table shows the specific features of each cluster, while Fig. 4 shows the distribution of the parameters according to the clusters. There was a significant difference between the three clusters identified for the CW/CL ratio, CS/CL ratio, and papilla height parameters using the one-way ANOVA test. Post hoc Tukey's test showed differences between all three clusters for CW/CL ratio and papilla height. Regarding the CS/CL ratio, Cluster A was significantly different from Cluster C, and Cluster B was significantly different from Cluster C. Chi-squared test showed a significant difference between the papilla fill of the three different clusters, $\chi 2\ (2, 160) = 0.010$.

	Cluster A "Triangular" (n = 80); 50 %	**Cluster B "Square/Tapered" (n = 37); 23.125 %**	**Cluster C "Square" (n = 43); 26.875 %**	**Total (n = 160)**
Ethnicity	61 (38.1)	30 (18.8)	25 (15.6)	116 (72.5)
Malay; n (%)	11 (6.9)	6 (3.8)	8 (5.0)	25 (15.6)
Chinese; n (%)	7 (4.4)	1 (2.7)	10 (6.3)	18 (11.3)
Indian; n (%)	1 (0.6)	0	0	1 (0.6)
Other; n (%)				
CW/CL Ratio; mean (SD)	0.639 (0.046)	0.792 (0.071)	0.735 (0.074)	0.698 (0.09)
CS/CL Ratio; mean (SD)	0.56 (0.07)	0.53 (0.09)	0.72 (0.07)	0.595 (0.108)
Gingival Thickness; mean (SD)	1.33 (0.31)	1.25 (0.29)	1.28 (0.27)	1.30 (0.298)
Keratinized Mucosa; mean (SD)	4.072 (0.911)	4.337 (0.943)	4.239 (1.062)	4.193 (0.978)
Papilla Height; mean (SD)	4.640 (0.818)	4.337 (0.943)	2.798 (0.755)	4.040 (1.161)
Papilla Fill	71 (44.0)	28 (19.9)	42 (26.3)	141 (88.1)
Complete; n (%)	9 (17.5)	9 (5.6)	1 (0.6)	19 (11.9)
More than 50 %; n (%)	0	0	0	0
Less than 50 %; n (%)				

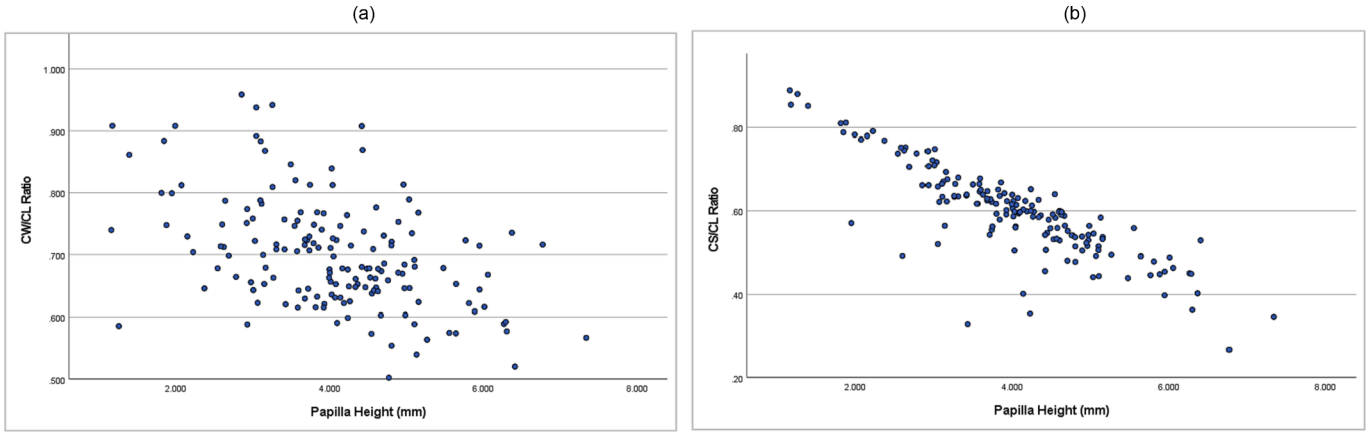

Fig. 2. (a) Scatter plot demonstrating the relationship between CW/CL ratio and papilla height. (b) Scatter plot demonstrating the relationship between CS/CL ratio and papilla height.

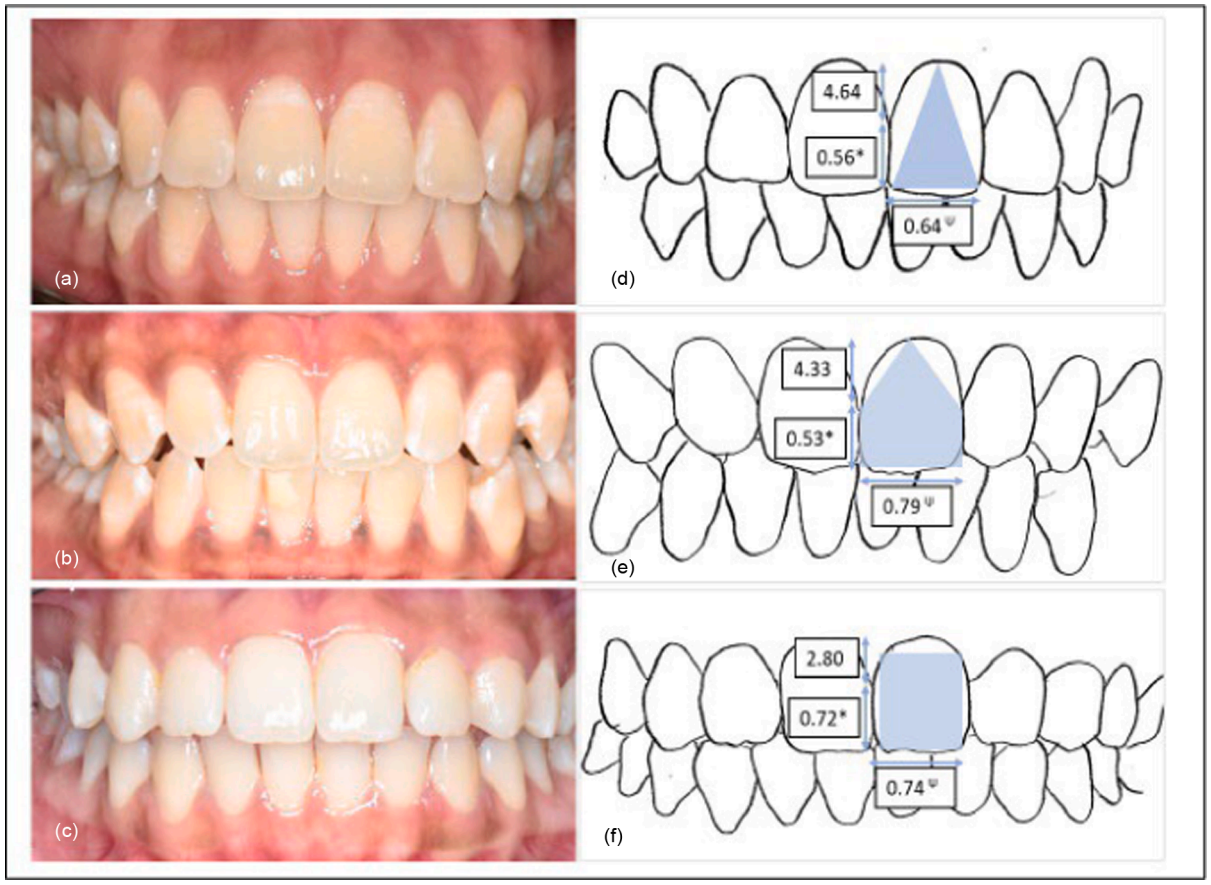

Fig. 3. The clinical example for each cluster: (a) triangular, (b) square/tapered, and (c) square. The line drawings of the crowns of the teeth in the clinical cases in (a)-(c) are shown in (d)-(f). The associated crown form is shown in blue, with the papilla height in mm included. *CS/CL ratio, $^{\Psi}$ CW/CL ratio.

3.4. Crown forms and gingival morphometric characteristics between Ethnicity

Chi-squared test showed a significant difference in the crown forms between the different ethnicities, $\chi 2$ (2,160) = 0.033. The Malay participants mainly had triangular-shaped crowns, while the Indian participants had square crowns. The Chinese participants had a high prevalence of both triangular- and square-shaped crowns.

One-way ANOVA test showed that the CS was significantly different between the different ethnicities, F (2,156) = 4.261, p = 0.016. Post-hoc Tukey's test indicated that the mean CS was different in Malays compared to Indians, p = 0.011. In addition, the CS/CL was significantly different between the different ethnicities, F (2,156) = 5.054, p = 0.007. Post-hoc Tukey's test also indicated that the mean CS/CL was different in Malays compared to Indians, p = 0.005.

There was no statistically significant difference in crown length, crown width, CW/CL, gingival thickness, anterior keratinized mucosa width, and papillary height between the different ethnicities.

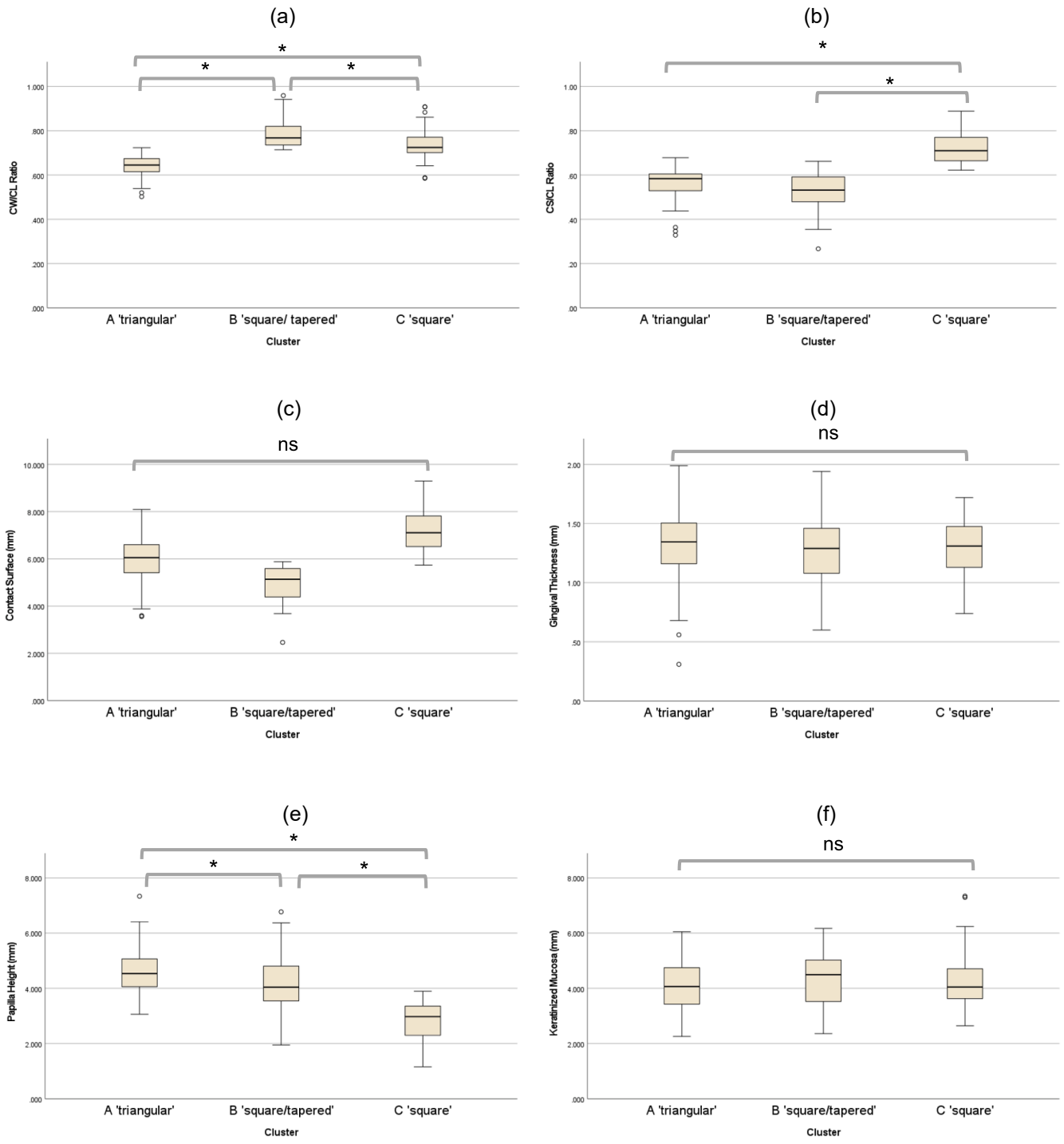

Fig. 4. a-f. Box plots demonstrating the distribution of the clinical parameters according to the clusters as well as the results of the ANOVA test for the (a) CW/CL ratio, (b) CS/CL ratio, c) contact surface (CS), d) gingival thickness, e) papilla height, and f) keratinized mucosa. *$p < 0.05$, ns = no significant difference between the measurements.

4. Discussion

A comprehensive understanding of crown forms and their associated morphometric characteristics is imperative for the successful implementation of dental treatment in the anterior maxilla. In this study, we aimed to classify the crown of the maxillary central incisors into different crown form categories and investigate the association between crown form and other morphometric features in an ethnically diverse Asian population. This holds significance to clinicians treating Asian patients worldwide.

The mean crown width and length in this study measured 7.09 ± 0.637 and 10.209 ± 0.966, respectively. The dimensions are smaller than those reported in Caucasian populations and other Asian groups, such as Taiwanese, Japanese, and Chinese (Chou et al., 2008; De Rouck et al., 2009; Tsukiyama et al., 2012; Shao et al., 2018). These findings provide valuable benchmarks for the design of anterior teeth in

prosthetics and various surgical interventions such as crown lengthening for Asian populations globally. The smaller crown length and width observed in this study suggest that denture tooth forms like Portrait® IPN® and Bioform® IPN® by Dentsply Sirona, as well as the Yamahachi Dental Ace mould by Yamahachi Dental MFG, featuring a minimum crown width of 7.7 mm and a crown length of 8.7 – 8.8 mm, might not be well-suited for individuals from Asian populations.

Similarly, the mean CW/CL in this study was 0.698 ± 0.889 mm, demonstrating a lower value than those reported in other Asian populations such as Chou et al. (0.74 ± 0.07) in Taiwanese subjects, Tsukiyama (0.72 ± 0.04) in Japanese subjects, and Shao et al. (0.82 ± 0.07) in Chinese subjects from Nanjing, China. Additional studies have consistently shown that Asians exhibit lower mean CW/CL values in contrast to Caucasians. For instance, the de Rouck et al. reported a figure of 0.81 ± 0.11 and a systematic review reported an average CW/CL ratio of 0.87 ± 0.11 in populations with a thick biotype and 0.80 ± 0.12 in populations with a thin biotype. This suggests that Asian populations, as observed in the current study, tend to possess narrow and slender crown forms, distinguishing them from their Caucasian counterparts.

In this study, cluster analysis was employed to identify individuals with similar morphometric characteristics using CW/CL and CS/CL ratios. Only one other study used similar characteristics for the classification of the maxillary teeth (Gobbato et al., 2012). The CS/CL ratios within the different clusters in our research, at 53 %, 56 %, and 72 %, surpassed those reported by Gobbato et al. who reported cutoffs of 43 % and 57 % to distinguish between clusters. These variations may be attributed to ethnic disparities between the two study populations. Interethnic comparisons of maxillary tooth crown forms are lacking in the literature.

To our knowledge, differences in crown forms between different ethnicities are limited to a report by Tsukiyama et al. (2012) in a study comparing the anterior maxillary teeth CW/CL ratio. The authors found that Asian subjects have more slender crown forms than those in Caucasian subjects. The present study found differences in crown forms, CS/CL ratio, and CS between the three ethnic groups, thus confirming the previously reported ethnic predilection for crown forms.

The results showed the participants can be classified into three crown-gingival groups, where a majority were in the triangular group with a narrow crown form and the greatest papilla height. The triangular group also had a high incidence of incomplete papilla fill despite the relatively young age of the participants. While a conventional hypothesis suggests an association between thin gingiva and triangular crown forms, as well as reduced keratinized mucosal width, our study did not establish a significant correlation between these parameters. This is in line with the systematic review by Zweers et al. (2014), which reported a moderate to weak relationship between gingival thickness and tooth dimensions.

One limitation of this study is that it utilized convenience sampling with a mean age of 25.29 ± 8.652, which may compromise the representativeness of the overall population. The limited sample size of Chinese and Indian participants may compromise the study's ability to reliably identify significant differences among these ethnic groups. The study also did not evaluate teeth for attrition or wear, resulting in unadjusted measurements for these factors.

5. Conclusion

Within this diverse Asian population, the crown form demonstrates three clusters: triangular, square/tapered, and square, characterized by a notably small average crown width and crown length. Most participants predominantly exhibited triangular crown forms characterized by reduced crown width, crown length, and CW/CL ratio. Distinctions in crown forms and their morphometric attributes were observed among the different ethnic groups.

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CRediT authorship contribution statement

Nik-Madihah Nik-Azis: Conceptualization, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Siti Nuramanina Abd-Shukor:** Validation. **Masfueh Razali:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Hanis Yasreena Zakaria:** Methodology. **Nur Zafira Zabarulla:** Methodology.

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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Ethics approval and consent to participate.

Study is approved by the ethical committee of UKM (ethics ref. no.: UKM/111/18/JEP-2021-037).

Informed consent was obtained from all individual participants included in the study.

References

Anderson, K.M., Behrents, R.G., McKinney, T., Buschang, P.H., 2005. Tooth shape preferences in an esthetic smile. Am. J. Orthod. Dentofacial. Orthop. 128, 458–465.
Chou, Y.H., Tsai, C.C., Wang, J.C., Ho, Y.P., Ho, K.Y., Tseng, C.C., 2008. New classification of crown forms and gingival characteristics in taiwanese. Open Dent. J. 2, 114.
Dalmaijer, E.S., Nord, C.L., Astle, D.E., 2022. Statistical power for cluster analysis. BMC Bioinform. 23, 1–28.
De Rouck, T., Eghbali, R., Collys, K., De Bruyn, H., Cosyn, J., 2009. The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. J. Clin. Periodontol. 36, 428–433.
Gobbato, L., Tsukiyama, T., Levi Jr, P.A., Griffin, T.J., Weisgold, A.S., 2012. Analysis of the shapes of maxillary central incisors in a caucasian population. Int. J. Periodont. Restorative Dent. 32, 69.
Jemt, T., 1997. Regeneration of gingival papillae after single-implant treatment. Int. J. Periodont. Restor. Dent. 17, 326–333.
Kan, J.Y., Morimoto, T., Rungcharassaeng, K., Roe, P., Smith, D.H., 2010. Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int. J. Periodont. Restorat. Dent. 30, 237–243.
Kao, R.T., Curtis, D.A., Kim, D.M., Lin, G.H., Wang, C.W., Cobb, C.M., Hsu, Y.T., Kan, J., Velasquez, D., Avila-Ortiz, G., Yu, S.H., Mandelaris, G.A., Rosen, P.S., Evans, M., Gunsolley, J., Goss, K., Ambruster, J., Wang, H.L., 2020. American Academy of periodontology best evidence consensus statement on modifying periodontal phenotype in preparation for orthodontic and restorative treatment. J. Periodontol. 91, 289–298.
Kloukos, D., Koukos, G., Doulis, I., Sculean, A., Stavropoulos, A., Katsaros, C., 2018. Gingival thickness assessment at the mandibular incisors with four methods: a cross-sectional study. J. Periodontol. 89, 1300–1309.
Mahn, E., Walls, S., Jorquera, G., Valdés, A.M., Val, A., Sampaio, C.S., 2018. Prevalence of tooth forms and their gender correlation. J. Esthet. Restor. Dent. 30, 45–50.
Müller, H.P., Eger, T., 1997. Gingival phenotypes in young male adults. J. Clin. Periodontol. 24, 65–71.
Müller, H.P., Schaller, N., Eger, T., Heinecke, A., 2000. Thickness of masticatory mucosa. J. Clin. Periodontol. 27, 431–436.
Olsson, M., Lindhe, J., 1991. Periodontal characteristics in individuals with varying form of the upper central incisors. J. Clin. Periodontol. 18, 78–82.
Olsson, M., Lindhe, J., Marinello, C.P., 1993. On the relationship between crown form and clinical features of the gingiva in adolescents. J. Clin. Periodontol. 20, 570–577.
Shao, Y., Yin, L., Gu, J., Wang, D., Lu, W., Sun, Y., 2018. Assessment of periodontal biotype in a young chinese population using different measurement methods. Sci Rep. 8, 11212.
Tsukiyama, T., Marcushamer, E., Griffin, T.J., Arguello, E., Magne, P., Gallucci, G.O., 2012. Comparison of the anatomic crown width/length ratios of unworn and worn maxillary teeth in asian and white subjects. J. Prosthet. Dent. 107, 11–16.
Zweers, J., Thomas, R.Z., Slot, D.E., Weisgold, A.S., Van der Weijden, F.G., 2014. Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. J. Clin. Periodontol. 41, 958–971.