Analysis of Crown Morphology and Gingival Shape in the Maxillary Anterior Dentition

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From a sample of 108 periodontally healthy volunteers with different combinations of morphometric data related to maxillary central anterior teeth and the surrounding soft tissues, this article aims to categorize gingival phenotypes according to tooth and gingival parameters, as well as assess the relationships between tooth shape and gingival characteristics, such as the papillary height (PH) and faciolingual thickness (FLT) of the papilla base. The periodontal phenotypes of 108 volunteers were confirmed using the periodontal probe transmission method for Kan classification. The FLT, PH, and the crown width to crown length (CW/CL) ratio for maxillary anterior teeth were measured. K-clustering was used to classify the anterior tooth shape into three groups: triangular, square, and compound. The mean CW/CL ratio for the maxillary anterior tooth position of the thick phenotype was greater than that of the thin phenotype. The PH and FLT for the maxillary anterior interdental papillae were greater for the thin phenotype group than for the thick phenotype group. A negative correlation was observed between the CW/CL ratio and both PH and FLT (P < .05 for both). However, a significant positive correlation was observed between FLT and PH. CW/CL ratio, FLT, and PH were all associated with the gingival phenotype with significant statistical correlations (P < .05 for all). Triangular teeth were correlated with scallop-shaped gingiva in the faciolingual area, while square teeth were associated with a flat gingiva. Int J Periodontics Restorative Dent 2020;40:925–931. doi: 10.11607/prd.4696

Dentists should apply their knowledge and clinical skills to restoring the proper tooth shape and esthetics after replacing a tooth with a crown. Periodontal quantification and qualification of the parameters are mandatory to provide satisfactory and successful dental treatment. The gingival phenotype is now known to influence the indications and outcomes of various treatment therapies routinely performed in dental clinics. There was a recent consensus among the American Academy of Periodontology and the European Federation of Periodontology regarding the use of the term “gingival phenotype” instead of “gingival biotype.” Therefore, in consideration of the clinical presentation of the teeth and periodontium, the authors have used the term “phenotype” in this analysis. The term “gingival phenotype” is used to describe the different characteristics and thickness of the gingiva in the buccolingual dimension of the tooth. Ochsenbien and Ross reported that there were two gingival phenotypes, namely “scalloped and thin” and “flat and thick.” Studies have shown that wide and short teeth are associated with the thick phenotype while slender and long teeth are associated with the thin phenotype. Individuals with triangular crowns have a thinner phenotype, making them more...
susceptible to gingival recession\textsuperscript{5–10} and predisposing them to black triangles,\textsuperscript{11} whereas a thick periodontal phenotype encourages interdental filling.\textsuperscript{12} However, a relationship between the gingival phenotype and the clinical outcome could not be established.\textsuperscript{13}

Dentists should focus on the basic characteristics and anatomical dimensions used to define gingival phenotypes. One important parameter that contributes to maintaining esthetics is the papillary height (PH) between the maxillary anterior teeth with reference to the crest of the gingival zenith. Teeth with short and wide crowns have large contact areas and are associated with a flat gingival margin and a low PH.\textsuperscript{9–11} The faciolingual thickness (FLT) is a novel papilla parameter and a potentially influential factor in the papilla fill and adjacent implant restoration.\textsuperscript{14–16} In 2011, Kim et al\textsuperscript{15} reported that the FLT values of the papillary base had no association with the interdental papilla. However, Chang and Wennström\textsuperscript{16} reported that FLT values of the papillary base were responsible for a complete papilla fill. However, no conclusive studies have been published in the literature to date.

Therefore, the purpose of the present study was to assess the distinctive relationships between different tooth shapes and gingival characteristics, such as FLT and PH, and to categorize gingival phenotypes according to tooth and gingival parameters.\textsuperscript{3} The null hypotheses of the study were that there was no correlation between FLT, PH, and the different tooth shapes (triangular, square, and compound), and that no correlations would be identified between the gingival phenotypes and various tooth and gingival parameters. The null hypotheses were accepted when \( P > .05 \) and rejected when \( P \leq .05 \).

Materials and Methods

Subjects

The present clinical study comprised of 108 adult volunteers (51 men and 57 women) with an age range of 19 to 25 years (mean age: 22.7 ± 0.7 years) who were recruited from the Department of Stomatology at the Xiamen Medical College in Xiamen, China. The inclusion criteria were: volunteers with symmetric faces; complete dentition; overbite; no anterior crowding or spacing; no signs of incisal attrition, gingival recession, or gingival overgrowth; good oral hygiene; and a bleeding on probing rate < 10%. Subjects with probing depths of more than 3 mm with intact interdental papillae were also included.

Subjects with decayed teeth, periodontal diseases, orthodontic treatment history, and systemic or familial diseases were excluded from the study. Subjects were also excluded if they were taking medication with any effects on periodontal soft tissues. All subjects provided informed consent for this experiment before the start of the study.

Materials and Methods

A Williams periodontal probe (Hu-Friedy) was inserted into the periodontal space after the administration of surface anesthesia.\textsuperscript{17} The outline of the probe was clear in the thin phenotype and could not be seen in the thick phenotype (Fig 1).

Impressions for the maxillary arch were made using irreversible hydrocolloid impression material (Aroma Fine Plus, GC) and were immediately placed in dental stone (yellow New Plastone II, GC) according to the manufacturer’s instructions. The FLT, PH, crown width (CW), and crown length (CL) were measured from the right canine to the left canine:

- FLT: The distance between the midpoints of the most apical facial and lingual margins of the two adjacent teeth\textsuperscript{18} (Fig 2).
• PH: The distance from the highest point of the papilla to the line connecting the gingival zenith\(^{18}\) to the adjacent teeth.\(^{19}\) The distal and mesial PHs were measured and averaged to procure the total value for individual tooth positions. The PHs of the subjects were also calculated according to phenotype\(^{15}\) (Fig 3).

• CW: The mesiodistal width between the border of the middle and cervical thirds of the crown length (Fig 3).

• CL: The distance between the highest margin of the crown and the cementoenamel junction (CEJ), which has the longest distance. If the CEJ was hard to recognize, it could be replaced by the free gingiva (Fig 3).

These clinical measurements of the anterior maxillary teeth (central incisors, lateral incisors, and canines) were calculated using digital calipers (Mitutoyo) with a sensitivity of 0.01 mm (Figs 2 and 3).

Data Analysis

The data were normalized, and all measurements were performed by one examiner (C.Z.). Analyses were performed using SPSS version 17.0 (IBM). \(P \leq .05\) was considered statistically significant. The Euclidean distances of three uniform parameters (FLT, PH, and CW/CL ratio) were used. Cluster analysis was performed to identify groups exhibiting similar clinical characteristics. Samples with a low CW/CL ratio, high PH, and thick FLT were included in the triangular group (Cluster A1). Samples with a high CW/CL ratio, low PH, and thin FLT were included in the square group (Cluster B). Samples with an intermediate CW/CL ratio, PH, and FLT were included in the compound group (Cluster A2). The relativity of the double variants was analyzed. Subsequently, one-way analysis of variance and least significant difference post hoc comparison were conducted to evaluate statistically significant differences between groups.

Results

There were no significant differences between genders for any of the parameters. The gingival phenotype characteristics (CW/CL ratios, PHs, and FLTs) were calculated (mean ± SD) separately for thick and thin phenotype populations. Pearson correlation analysis revealed a statistically significant correlation between different groups of measurements (including CW/CL ratios, PH, and FLT) and phenotypes.
The mean values of the CW/CL ratios, PHs, and FLTs for all gingival phenotypes are presented in Appendix Table 1 (all Appendix Tables can be found in the online version of this article at quintpub.com/journals). The mean CW/CL ratio of the maxillary anterior teeth for the thick phenotype (82% ± 9%) was greater than that of the thin phenotype (73% ± 5%; P < .05). However, the PH was greater in the thin phenotype group (4.17 ± 0.50 mm) than in the thick-phenotype group (3.53 ± 0.46 mm) (P < .05). The mean thin-phenotype FLT was 8.48 ± 0.45 mm and the thick-phenotype FLT was 7.73 ± 0.37 mm (P < .001).

CW/CL ratios were 80% ± 12% for both the right and left canines; 76% ± 10% and 0.72% ± 0.12% for the right and left lateral incisors, respectively; and 83% ± 11% and 84% ± 11% for the right and left central incisors, respectively (Appendix Table 2). The results showed that the central incisors had the largest CW/CL ratio amongst the three groups, while the lateral incisors had the smallest CW/CL ratio.

PH values were 3.65 ± 0.83 mm and 3.61 ± 0.79 mm for the right and left canines, respectively; 3.53 ± 0.75 mm and 3.47 ± 0.74 mm for the right and left lateral incisors, respectively; and 3.62 ± 0.74 mm and 3.57 ± 0.70 mm for the right and left central incisors, respectively (Appendix Table 3). The canines had higher PH values than the central and lateral incisors.

FLT values were 8.11 ± 0.62 mm and 8.07 ± 0.60 mm for the right and left canines, respectively; 7.92 ± 0.59 mm and 7.82 ± 0.58 mm for the right and left lateral incisors, respectively; and 8.12 ± 0.59 mm and 8.09 ± 0.58 mm for the right and left central incisors, respectively (Appendix Table 4). The results showed that the central incisors had the highest FLT values, while the lateral incisors had the lowest FLT values.

The correlations between the PH, FLT, and CW/CL ratios are presented in Fig 4. A negative correlation was observed between PH and CW/CL ratio (r = –0.538; P < .001). FLT and CW/CL ratio also showed a negative correlation (r = –0.463; P < .001). A positive correlation was found between PH and FLT (r = 0.582; P < .001).

Cluster analysis evaluation of the subjects based on the CW/CL ratio, PH, and FLT is presented in Appendix Table 5. The partitioning method divided the 108 participants into three groups (A1, A2, and B) per the values of the CW/CL ratio, PH, and FLT. Cluster A1 had a slender crown with a high PH and thick FLT. Cluster B had a thick crown with a low PH and thin FLT. Cluster A2 was somewhere in between A1 and B. Cluster A1 comprised 22 individuals (20.37%) with a mean CW/CL ratio of 74% ± 6%, PH of 4.38 ± 0.51 mm, and FLT of 8.73 ± 0.31 mm. Cluster A2 comprised 54 subjects (50.00%) with a mean
CW/CL ratio of 77% ± 7%, PH of 3.67 ± 0.30 mm, and FLT of 7.98 ± 0.32 mm. Cluster B comprised 32 individuals (29.63%) with a mean CW/CL ratio of 85% ± 11%, PH of 2.85 ± 0.31 mm, and FLT of 7.52 ± 0.37 mm. The FLT and PH values for the three clusters had statistically significant differences (P < .001), unlike the CW/CL values. There were statistically significant differences between A2 and B and between A1 and B (P < .001), but no statistically significant differences were found between A1 and A2 (P > .05). This indicated that the CW/CL ratio had weak differences amongst the three clusters.

Discussion

Researchers noted that identification of the phenotypes was mandatory to obtain successful esthetic and functional results. Therefore, it is important to consider the phenotype when planning the treatment. A simple and effective method for assessing the phenotype is to place the probe in the facial sulcus. Periodontal probing has a number of benefits, such as being nontraumatic, noninvasive, quick, and objective.

The present study revealed that a long, narrow crown with a high PH and broad faciolingual base is associated with the thin phenotype, while a short, wide crown with a low PH and narrow faciolingual base is associated with the thick phenotype. This is similar to other studies’ findings, including those of Stellini et al in 2012. Consistent with previous findings, correlation analysis showed that a smaller CW/CL ratio was correlated with a greater PH and a thicker faciolingual papillary base. In other words, triangular teeth were correlated with a scallop-shaped gingiva in the faciolingual area, while square teeth were associated with a flat gingiva. In 2004, Kois explained that square teeth have a longer proximal contact area, so more of the tooth structure is available to fill the interdental area, which further reduces the risk of black triangles. The present study was conducted in a Chinese population, and therefore lower values were obtained for the CW/CL ratio (79%) and PH (3.57 mm) compared to the values obtained by Nayak et al.

The current study showed a positive correlation between the PH and FLT values. This is why numerous soft tissue management approaches generally reconstruct the peri-implant papillae. However, due to minimal blood supply in this area, surgeons have achieved limited success with these approaches. Therefore, it is necessary to augment the soft tissues of the peri-implant papillae in the crown-root and faciolingual directions to ensure sufficient blood supply. The present study demonstrated that PH contributes to soft tissue management in the crown-root direction, and increased FLT contributes to the maintenance of PH.

Cluster analysis in this study identified 38 thin-phenotype samples and 70 thick-phenotype samples. Out of 38 thin-phenotype samples, 22 showed triangular teeth with a scalloped gingival margin and a broad faciolingual papillary base, which corresponded to the features of the triangular group (Cluster A1). Out of the 70 thick-phenotype samples, 32 had square teeth with a flat gingival margin and a narrow faciolingual papillary base, which corresponded to the features of the square group (Cluster B). The remaining 16 thin-phenotype samples and 38 thick-phenotype samples (54 total samples) comprised a compound group (Cluster A2) in which the PH and FLT measurements ranged somewhere between Clusters A1 and B. Only about one-third of the 108 samples (Cluster B, 32 samples) showed a clear thick phenotype. This observation is important, as it shows that a clear thick gingiva is present in only about half of the population. The results of this study are consistent with the results of previous published studies. This observation highlights a possible impact of racial and genetic variations on the morphology of teeth and soft tissues.

Limitations

The sample size was limited and obtained from only one region in China. The assessment of some soft tissue parameters, such as the midfacial pocket depth, were not performed in this study. Therefore, more studies should be conducted that focus on the correlation between midfacial pocket depth and gingival phenotype and other parameters.
Conclusions

Using a simple and reproducible method for the assessment of gingival phenotype, the existence of gingival phenotypes was confirmed in this study. The CW/CL ratio, FLT, and PH were associated with the gingival phenotype and significant statistical correlations were found among them. Based on the present findings, the null hypotheses were rejected. One-third of cases exhibited a thick phenotype—characterized by square teeth, a flat gingival margin, and narrow faciolingual papillary base—which provided a reference for treatment in the esthetic zone. The authors concluded that triangular teeth were correlated with scallop-shaped gingiva and thick FLT, while square teeth were associated with flat gingiva and narrow FLT.

Acknowledgments

This study was funded by the educational and scientific research project of young and middle-aged teachers in Fujian Education Department; and Innovative training project of Xiamen Medical College. The authors declare no conflicts of interest.

References


Appendices

### Appendix Table 1 CW/CL ratio, PH, and FLT of the Subjects by Phenotype

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>n</th>
<th>CW/CL ratio, %</th>
<th>PH, mm</th>
<th>FLT, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin</td>
<td>38</td>
<td>73 ± 5</td>
<td>4.17 ± 0.50</td>
<td>8.48 ± 0.45</td>
</tr>
<tr>
<td>Thick</td>
<td>70</td>
<td>82 ± 9</td>
<td>3.25 ± 0.46</td>
<td>7.73 ± 0.37</td>
</tr>
<tr>
<td>Total</td>
<td>108</td>
<td>79 ± 9</td>
<td>3.57 ± 0.65</td>
<td>8.00 ± 0.54</td>
</tr>
</tbody>
</table>

CW = crown width; CL = crown length; PH = papillary height; FLT = faciolingual thickness.
All values are shown as mean ± SD.

### Appendix Table 2 CW/CL Ratio of the Subjects by Tooth

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Right</th>
<th>Left</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine</td>
<td>80 ± 12</td>
<td>80 ± 12</td>
<td>80 ± 10</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>76 ± 10</td>
<td>72 ± 12</td>
<td>74 ± 10</td>
</tr>
<tr>
<td>Central incisor</td>
<td>83 ± 11</td>
<td>84 ± 11</td>
<td>84 ± 11</td>
</tr>
</tbody>
</table>

CW = crown width; CL = crown length.
All values are shown as mean ± SD, measured in percentages.

### Appendix Table 3 PH of the Subjects by Tooth

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Right</th>
<th>Left</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine</td>
<td>3.65 ± 0.83</td>
<td>3.61 ± 0.79</td>
<td>3.64 ± 0.73</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>3.53 ± 0.75</td>
<td>3.47 ± 0.74</td>
<td>3.50 ± 0.69</td>
</tr>
<tr>
<td>Central incisor</td>
<td>3.62 ± 0.74</td>
<td>3.57 ± 0.70</td>
<td>3.60 ± 0.71</td>
</tr>
</tbody>
</table>

PH = papillary height.
All values are shown as mean ± SD, measured in millimeters.

### Appendix Table 4 FLT of the Subjects by Tooth

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Right</th>
<th>Left</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine</td>
<td>8.11 ± 0.62</td>
<td>8.07 ± 0.60</td>
<td>8.09 ± 0.58</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>7.92 ± 0.59</td>
<td>7.82 ± 0.58</td>
<td>7.87 ± 0.56</td>
</tr>
<tr>
<td>Central incisor</td>
<td>8.12 ± 0.59</td>
<td>8.09 ± 0.58</td>
<td>8.11 ± 0.57</td>
</tr>
</tbody>
</table>

FLT = faciolingual thickness.
All values are shown as mean ± SD, measured in millimeters.
## Appendix Table 5 Cluster Analysis for the Subjects Based on CW/CL Ratio, PH, and FLT

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Prevalence, n (%)</th>
<th>CW/CL ratio, %</th>
<th>PH, mm</th>
<th>FLT, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>22 (20.37)</td>
<td>74 ± 6</td>
<td>4.38 ± 0.51</td>
<td>8.73 ± 0.31</td>
</tr>
<tr>
<td>A2</td>
<td>54 (50.00)</td>
<td>77 ± 7</td>
<td>3.67 ± 0.30</td>
<td>7.98 ± 0.32</td>
</tr>
<tr>
<td>B</td>
<td>32 (29.63)</td>
<td>85 ± 11</td>
<td>2.85 ± 0.31</td>
<td>7.52 ± 0.37</td>
</tr>
</tbody>
</table>

One-way ANOVA

- A1 vs A2: > .05 < .001 < .001
- A2 vs B: < .05 < .001 < .001
- A1 vs B: < .05 < .001 < .001

LSD post hoc comparison

- CW = crown width; CL = crown length; PH = papillary height; FLT = faciolingual thickness; ANOVA = analysis of variance; LSD = least-significant difference.

A1, A2, and B values are shown as mean ± SD unless otherwise stated.