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Relationships between different tooth shapes and patient's periodontal phenotype

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Background and Objective: The purpose of the present study was to establish whether any correlation exists between tooth shapes and patient-related factors such as gingival and periodontal characteristics.

Material and Methods: Clinical measurements, including the width and the height of maxillary central incisor crowns, the apico incisal height of the keratinized mucosa (KM), the buccal gingival thickness (GT), the depth of the sulcus (SD), the bone-sounding depth (BS) and the height of the interproximal maxillary central papilla (Ph), were investigated in 50 healthy individuals. These individuals were then divided into three groups based on the shape of their maxillary central incisor crowns: triangular; square; or square-tapered. The three groups were analyzed to determine any significant differences among the groups in the values obtained for clinical measurements.

Results: There were no significant differences among the three groups in terms of the SD ($p = 0.11$) or the BS ($p = 0.54$), whilst statistically significant differences were observed for the KM ($p < 0.001$), the GT ($p = 0.012$) and the Ph ($p < 0.001$).

Conclusion: The results of this study indicate that different tooth shapes are associated with significantly different values for the extent of the KM, its bucco-lingual thickness and the height of the interproximal maxillary central papilla.

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Previous studies in the literature have reported a correlation between the shape of the maxillary central incisors and periodontal features typical of the various gingival phenotypes (1). In the dictionary (The Oxford English Dictionary [OED], Oxford University, 2nd revised edition), the following definitions are given: genotype is defined as an organism's full hereditary information; biotype is defined as a group of individuals who have the same genotype; and phenotype is defined as an organism's actual observed properties, such as morphology, development or behavior. The authors decided to use the term "phenotype" because they felt that this term best described the shape of the teeth and the alveolar process discussed in this paper.

In particular, teeth with elongated crowns and short contact surfaces are associated with a thin, highly scalloped, gingival architecture and a thin maxillary alveolar bone, whilst teeth with square crowns and long contact surfaces are associated with a thick, flat, gingival architecture and a thick maxillary alveolar bone (2). Establishing the gingival phenotype of a patient will aid immeasurably in communications among the dental surgeon, the restorative dentist, the dental laboratory and the patient. Moreover, tooth shape is a critical factor when dental-implant prostheses are considered in the esthetic zone. Anticipating treatment limitations by understanding the morphologic characteristics of the underlying bone is an important phase of the treatment-planning discussion with a patient.

It is important to consider phenotype when planning treatment, as a thin gingival margin is more prone to gingival recession (3,4). This is particularly relevant after the placement of dental implants (5) as the gingival margin is less stable in the long term (6,7). Moreover, a thin gingival margin has shown a higher failure rate after periodontal therapy (8) and less stability with the prosthetic margins (9,10).

In a recent study (11), Gobbato *et al.* defined and quantified three types of tooth shape – triangular, square-tapered and square – with a view to providing a basis for analyzing the relationship between the shape of the maxillary central incisor crowns and the periodontal phenotypes. A cluster analysis on 100 maxillary central incisors identified the following: one group of 17 individuals with triangular teeth, with a ratio of < 43% between the length of the contact surface and the length of the crown; a second group of 33 patients with square teeth, with a ratio of > 57% between the length of the contact surface and the length of the crown; and a third group of 50 subjects with square-tapered teeth, with a ratio of 43–57% between the length of the contact surface and the length of the crown.

The ratio between the length of the contact surface and the length of the crown thus provides parameters for defining a tooth as triangular, square-tapered or square, but does not consider how these tooth-shape groups correlate with the gingival parameters most commonly used to define an individual's periodontal phenotype (3,4,12,13), such as the bucco-lingual thickness, the extent of free and attached gingiva and the height of the interproximal maxillary central papilla. The purpose of the present study was to seek any distinctive relationships between different tooth shapes and patient-related factors such as gingival and periodontal characteristics.

Material and methods

Subjects

Fifty Caucasian subjects (31 men and 19 women; age range, 23–28 years) from the predoctoral program at the University of Padua, School of Dental Medicine (Padua, Italy), were randomly selected for this study. The study protocol was approved by the institutional review board (protocol number 46,751) and was carried out in accordance with the ethical standards outlined in the 1964 declaration of Helsinki, as revised in 2000. All patients were fully informed of the investigation and signed informed consent forms before examination. Subjects were in good physical health and had both permanent maxillary central incisors present. During recruitment of the volunteers, the following exclusion criteria were employed: the presence of destructive periodontal disease (i.e. probing depth >3 mm, apical displacement of the gingival margin from the cemento–enamel junction, bleeding on probing and a visual plaque index of > 20% (14)); pregnancy or lactation; taking any medication that might affect the thickness of the periodontal soft tissues (cyclosporine A, calcium-channel blockers or phenytoin); extensive restorations affecting tooth shape and the occlusal margin of the tooth; subgingival restoration or replacement of the maxillary central incisors; evidence of caries either on the interproximal surface or at the cemento–enamel junction; a history of tooth trauma causing a change of shape of the incisors; a history of orthodontic treatment; obvious craniofacial asymmetry (15); a history of periodontal surgery involving the maxillary central incisors; the presence of incisal abrasion, attrition or erosion reaching the dentin; and evidence of incomplete passive eruption.

For each patient, age, gender and smoking habit were recorded. Photographs were taken of each subject's mouth with the aid of a mouth prop and a millimeter-graduated ruler positioned immediately below the incisal margins of the central maxillary teeth

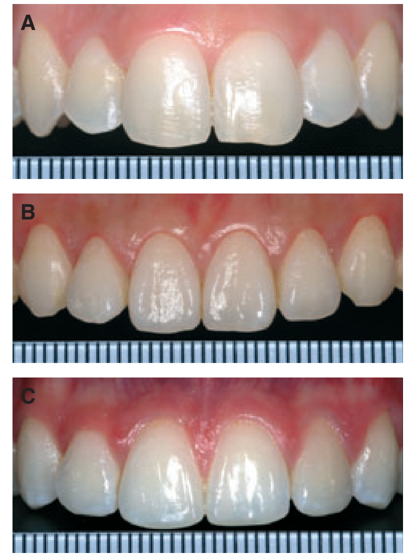

Fig. 1. Photographs were taken of each subject's mouth with the aid of a millimeter graduated ruler positioned immediately below the incisal margins of the central maxillary teeth. Photographs are shown of a square tooth shape (A), a square-tapered tooth shape (B) and a triangular tooth shape (C).

(Fig. 1). This provided a reference scale for the measurements subsequently recorded on a computer "**resolution 1680 × 1050 pixels**" using Adobe Photoshop®(Adobe Systems Inc., San Jose, CA, USA). To obtain standardized photographs, an enlargement ratio of 1 : 1.2 was always adopted and the photographs always included the maxillary teeth from one lateral incisor to the other (Fig. 1).

Clinical measurements— Clinical parameters were measured by the same operator 1 wk after reinforcement of oral-hygiene instructions to the patients. If the intervention of a professional dental hygienist was needed, an interval of at least 3 wk was allowed between the hygiene therapy and the measurement of clinical parameters.

The examiner received calibration training at the beginning of the study; the percentage agreement, to within 1 mm, with another experienced examiner was 96% (data not shown). The intra-examiner reliability, calibrated by re-examining the same 50 patients after a 1-week interval, was 90% (data not shown).

The parameters considered were measured on the vestibular surface of one of the two central incisors of the study, 10 min after the plexus infiltration of an anesthetic. The decision to obtain the measurements on the maxillary central incisor was dictated by the fact that the differences between periodontal phenotypes are more evident with these teeth, and their specific characteristics are more readily detectable than in the other tooth types in a set of teeth (2,3,12,16).

The following parameters were measured:

- the extent of keratinized mucosa (KM). This was measured from the free gingival margin to the mucogingival junction identified using the roll technique (17). Measurements were performed using an electronic gauge that provided values to one-hundredth of a millimeter, after compressing the tissue to identify the mucogingival junction more clearly;
- the depth of the sulcus (SD) of the periodontal sulcus. This was measured using a Williams PQW periodontal probe (with notches located at 1–10 mm; Hu-Friedy Manufacturing Co, Chicago, IL, USA);
- the bone-sounding depth (BS) (i.e. the distance from the free gingival margin to the alveolar bone crest). This was measured using a Williams PQW periodontal probe;
- the bucco-lingual gingival thickness (GT). This was measured using an electronic gauge (Electronic Digital Caliper IP67; Viareggio, Italy). This location was identified with a needle fitted with a rubber stop, at the connective tissue interface, the position of which was calculated by subtracting the SD from the BS;
- the height of the crown. Thus was measured from the most apical part of the gingival margin (zenith) to the most coronal point on the incisor margin, using the "Ruler" in Adobe Photoshop, after adjusting the measurement scale with the aid of the real ruler visible in the photographs (18);
- the width of the crown. This was measured by dividing the height of the tooth into three equal portions and measuring them horizontally at the boundary between the apical third and the median third, again using Adobe Photoshop, according to the method used in the studies by Olsson & Lindhe 1991 (3) and De Rouck 2009 (12);
- the height of the interproximal maxillary central papilla (Ph). This was measured in the space between the maxillary central incisors, calculated using Adobe Photoshop from the tip of the papilla to a line joining the zeniths of the two adjacent teeth on either side of the papilla, traced with the "Line" instrument;
- the contact surface length. This was measured using Adobe Photoshop, from the most apical part of the contact surface to the most coronal part of the medial surface of the maxillary central incisor (11).

Statistical analysis— From the measured parameters we also calculated:

- The ratio between the length of the contact surface and the length of the crown;
- the ratio of the width of the crown to the height of the crown of the maxillary central incisor (w/h) of the maxillary central.

Based on the tooth-shape classification proposed by Gobbato *et al.* (11), our 50 study subjects were divided into three groups according to the ratio between the length of the contact surface and the length of the crown. Then, for each group, as a result of the high asymmetry of the measured gingival parameters, the median value and the interquartile difference were calculated as a measure of variability to identify any statistically significant differences between the three groups (Table 1). This enabled us to identify the gingival phenotype parameters that differed most between the groups with different tooth shapes. Fisher's exact test with continuity correction was used for comparison of categorical variables. An *F*-test was chosen for comparison of continuous variables. Subgroup comparisons were performed using appropriate linear contrasts. *p*-Values were considered as significant and were reported for values < 0.05; otherwise, the nonsignificant indication was used. All analyses were performed using the R-System (Robert Gentleman and Ross Ihaka "R & R" of the Statistics Department of the University of Auckland, Auckland, New Zealand).

Results

Our sample consisted of 31 male and 19 female dental students with no periodontal probing depth of > 3 mm and no gingival recession. Six were smokers. The median age of the sample was 23 (21–24) years. For the whole sample, the median KM was 4.8, the median SD was 1.5 mm, the median BS was 3.10 mm and the median bucco-lingual GT was 1.51 mm (Table 1).

The numerically largest group identified according to Gobbato's definitions (11) had square-tapered teeth (group S-T; $n = 26$; 18 male and eight female subjects). This was followed by those with square teeth (group S; $n = 15$; seven male and eight female subjects) and then by those with triangular teeth (group T; $n = 9$; six male and three female subjects). The differences between the two genders in the three groups were not statistically significant ($p = 0.34$). When the two genders were analyzed separately, 58% of all male subjects had square-tapered teeth, 23% had square teeth and 19% had triangular teeth, whilst 42% of the female subjects had square-tapered teeth, 42% had square teeth and 16% had triangular teeth. Regarding the subjects' smoking habits, two subjects in the S-T group smoked 10 cigarettes a day, three subjects in the S group smoked (two smoked 10 cigarettes a day and one smoked only two or three cigarettes a day) and one subject in the

Table 1. Distribution of the main instrumental parameters across the three classification groups

	Square-tapered	Square	Triangular	Overall	Overall difference	Pairwise difference tests		
	(n = 26)	(n = 15)	(n = 9)	(n = 50)	test	Triangular vs. Square	ST vs. Square	ST vs. Triangular
Age	21.0/23.0/24.0	22.5/23.0/25.0	21.0/22.0/24.0	21.0/23.0/24.0	NS	NS	NS	NS
Gender: male	69% (18)	47% (7)	67% (6)	62% (31)	NS	NS	NS	NS
Smoker								
10 cigarettes/day	8% (2)	13% (2)	11% (1)	10% (5)	NS	NS	NS	NS
2–3 cigarettes/day	0% (0)	7% (1)	0% (0)	2% (1)	NS	NS	NS	NS
Nonsmoker	92% (24)	80% (12)	89% (8)	88% (44)	NS	NS	NS	NS
KM	4.38/4.88/5.25	4.23/5.44/6.04	3.60/4.38/4.68	4.19/4.80/5.64	< 0.001	NS	NS	NS
SD	1.20/1.50/1.77	1.50/1.60/2.00	1.00/1.50/1.60	1.20/1.50/1.80	NS	NS	0.037	NS
BS	2.92/3.10/3.65	3.00/3.10/3.75	2.60/3.00/3.20	3.00/3.10/3.57	NS	NS	NS	NS
GT	1.46/1.50/1.67	1.5150/1.58/1.72	1.23/1.32/1.50	1.45/1.51/1.66	0.012	0.002	NS	NS
w	6.88/7.20/7.83	7.25/7.67/7.80	7.40/7.55/7.77	7.05/7.48/7.80	NS	NS	NS	NS
h	10.23/10.64/11.43	9.62/10.18/10.70	10.46/10.86/11.63	10.16/10.60/11.17	0.023	0.005	NS	NS
Ph	4.83/5.06/5.23	3.76/4.01/4.31	6.20/6.30/6.70	4.33/4.96/5.81	< 0.001	< 0.001	< 0.001	< 0.001
CS	5.27/5.60/6.08	5.75/6.09/6.46	4.37/4.60/4.93	4.94/5.67/6.09	< 0.001	< 0.001	< 0.001	< 0.001

Values are given as percentage (absolute numbers) for categorical variables and as I quartile/median/III quartile for continuous variables.
Exact p -values are given if < 0.05. Otherwise NS (not significant) is used.
BS, bone sounding depth; CS, contact surface length; GT, gingival thickness; h, height of the crown; KM, keratinized mucosa; Ph, height of the interproximal maxillary central papilla; SD, depth of the sulcus; w, width of the crown.

T group smoked 10 cigarettes a day. The differences between the three groups were not statistically significant (p = 0.59), probably because of the limited number of smokers in the sample overall. In the S group, the median KM was 5.44 mm, the median GT was 1.58 mm and the median Ph was 4.01 mm (all values differed to a statistically significant degree from those of the S-T group), whilst the median SD and BS values of the S-T group were 1.50 mm and 3.10 mm, respectively. In the T group, the median KM was 4.38 mm, the median GT was 1.32 mm, the median Ph was 6.30 mm, the median SD was 1.50 mm and the median BS was 3.00 mm. Neither the SD (p = 0.11) nor the BS (p = 0.54) differed significantly between the three groups, but there were statistically significant differences for KM ($p <$ 0.001), GT (p = 0.012) and Ph ($p <$ 0.001) (Table 1).

Discussion

A relationship between the shape of an individual's maxillary central incisor teeth and their gingival phenotype has been demonstrated in numerous studies (2,3,8,12,13,19). Ochenbein & Ross, in 1969, and particularly Becker *et al.*, in 1997 (20,21), postulated that gingival phenotypes correlate with bone-crest contours, suggesting that there are three main types of gingival architecture – flat, scalloped and pronounced scalloped – which are associated with different thicknesses of KM. Two studies conducted in 1991 and 1993 by Olsson & Lindhe (3,22) further analyzed the relationship between the shape of the tooth and the gingival phenotype, indicating that long, narrow teeth were associated with the thin gingival phenotype and were more susceptible to gingival recession. These conclusions were confirmed by Weisgold in 1997 (1). In 2003, a study by Kan *et al.* (23). confirmed that subjects who have the thick tissue phenotype with a flat gingival architecture have a thicker band of KM than do those with a pronounced scalloped gingival architecture. In 2000, Muller (8) also included the buccolingual GT among the gingival parameters: GT was greater in subjects with the thick periodontal phenotype compared with subjects with the thin periodontal phenotype.

In our study we analyzed the gingival parameters for the three tooth-shape groups to identify any significant differences between the groups and to establish whether the different teeth shapes are consistent with the current classifications of gingival phenotypes, as described by Weisgold (1): a square tooth shape is associated with a flat gingival architecture and a thick gingival tissue, whilst a triangular tooth shape is associated with a scalloped gingival architecture and a thin gingival tissue.

The tooth shape determining the most apical point of the contact area is an important factor regarding restorative treatment in the esthetic zone. In 1992, Tarnow *et al*. (24). found that the papilla filled the interproximal space 100% of the time in the natural dentition when the distance between the level of the crestal bone and the most apical contact point was < 5 mm. In implant prostheses, the distance between the level of the crestal bone and the apical contact point is shorter than that in natural teeth. Therefore, in implant prostheses it is harder to achieve 100% papilla fill, as demonstrated by Salama *et al*. (25), because there is some vertical bone loss following tooth extraction (26,27).

In the present study we first of all looked for correlations between tooth shape's classification (according to previous literature reference 11) and variables such as gender, age and smoking habits. In our sample, gender did not seem to differ significantly between the three tooth-shape groups ($p = 0.34$); this finding is in contrast to reports in the literature of a prevalence of the triangular tooth-shape in the female gender (8,12,28). There were also no significant differences among the three groups in the age of our study participants ($p = 0.40$), in contrast to the findings reported by Vandana & Savitha, in 2005. This could be a result of the wider age range considered in the latter study (i.e. 16–39 years, as opposed to 18–29 years in the present study). Cigarette smoking reportedly contributes to a greater GT (29), but no significant difference was identified for this parameter between our two groups ($p = 0.59$), possibly because only 12% of our sample smoked.

We found significant differences in patient-related factors that were consistent with previous periodontal phenotype classifications for the following parameters: extent of KM ($p < 0.001$); bucco-lingual GT ($p = 0.012$); and mean Ph ($p < 0.001$). Patients with triangular teeth showed higher interproximal papilla, less keratinized tissue and thinner bucco-lingual GT than did patients with square-tapered teeth, and those patients showed higher inter-proximal papilla, less keratinized tissue and thinner bucco-lingual GT than did patients with square teeth. This confirmed the validity of the tooth-shapes classification of Gobbato *et al*. to distinguish between different groups (triangular, square and square-tapered) in terms of the two most significant characteristics considered to describe periodontal phenotypes, namely tooth shape (correlated to the gingival architecture) and GT (1).

The relationship between tooth shape and GT could also stem from the shape of the tooth's emergence profile: square teeth could occupy a larger recess apically at the enamel–cement interface, leaving space for a greater quantity of mucosa. This hypothesis would need to be verified in future studies.

Regarding the depth of the sulcus, there was evidence of a significant difference between groups S-T and S ($p = 0.037$), but not between groups S-T and T. There were no significant differences in BS between the groups.

Conclusions

No relationship emerged in this study between the shape of the maxillary central incisor crowns and the BS, so the biological extent of the gingiva does not appear to correlate directly with the shape of the crown. We also found no evidence of any correlation between the shape of the crown and the depth of the sulcus.

Instead, our findings indicate that the shape of the maxillary central incisor crowns correlates with the extent of the KM and its bucco-lingual GT, and with the Ph.

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