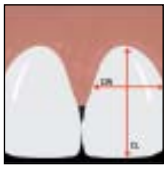
Analysis of the Shapes of Maxillary Central Incisors in a Caucasian Population



Luca Gobbato, DDS/Teppei Tsukiyama, DDS*/Paul A. Levi, Jr, DMD** Terrence J. Griffin, DMD***/Arnold S. Weisgold, DDS*****

The purpose of this study was to objectively define and quantify triangular, square, and square/tapered maxillary central incisors. In this study, the shape of maxillary central incisor crowns was investigated in 100 healthy individuals. The results showed that when the contact surface/crown length ratio is less than 43%, the tooth is triangular in shape; when the ratio is more than 57%, the tooth is square in shape; and when the ratio is between 43% and 57%, the tooth is defined as square/tapered. Since it has been shown that the morphologic characteristics of the gingiva and periodontium are partly related to the shape of the teeth, a means of truly defining the shapes of the incisors is now available. This is significant in predicting esthetics, bone volume, and susceptibility to recession, pocketing in the natural dentition, and ridge shrinkage for prosthetic tooth replacement. (Int J Periodontics Restorative Dent 2012;32:69–78.)

*Resident, Department of Periodontology, Tufts University School of Dental Medicine, Boston, Massachusetts.
**Clinical Associate Professor, Department of Periodontology, Tufts University School of Dental Medicine, Boston, Massachusetts.
***Associate Professor and Chair, Department of Periodontology, Tufts University School of Dental Medicine, Boston, Massachusetts.
****Adjunct Professor, Department of Periodontics, University of Pennsylvania School of Dental Medicine, Philadelphia, Pennsylvania.

Correspondence to: Dr Luca Gobbato, Department of Periodontology, 12th floor, Tufts University School of Dental Medicine, 1 Kneeland Street, Boston, MA 02111; fax: 1-617-636-0911; email: gobbatoluca@gmail.com.

The term *periodontal biotype* has been discussed and described in the literature by many authors.[1–5] From these papers, it appears as if the morphologic characteristics of the gingiva and periodontium are partly related to the dimensions of the alveolar process, the shape of the teeth, events that occur during tooth eruption, and the eventual inclination and position of the fully erupted teeth.[6,7]

There appears to be a good deal of confusion concerning terms commonly used in dentistry. In the dictionary, the following definitions are reported: *genotype* is defined as an organism's full hereditary information; *biotype* is defined as a group of individuals having the same genotype; and *phenotype* is defined as an organism's actual observed properties, such as morphology, development, or behavior. As a result, the authors selected the term *phenotype* since they felt it best described the shape of the teeth and alveolar process used in this paper.

The shape of the teeth is related to the thickness of the gingiva

Fig 1 *Facial view of the maxillary central incisors.*

and surrounding bone.[3–5,8–11] Studies suggest that teeth with tapered crown forms and short proximal contact areas seem to be associated with a highly scalloped gingival margin, a thin soft tissue complex, and a thin bony housing. Teeth with short but wide crowns and large contact areas, however, seem to be associated with a less scalloped gingival margin, a thick soft tissue complex, and a thick bony housing.[3–5] Although previous studies have investigated the type of phenotype according to the tooth form, there are no studies that specifically define the tooth shape, such as triangular, square/tapered, or square.

Today, tooth shape is a critical factor when dental implant prostheses are considered in the esthetic zone. To determine and analyze the relationship between the shape of the crown of the maxillary central incisors and the periodontal phenotype, it is essential to define a clear and well-understood means of classifying the different shapes of these teeth. This classification will aid immeasurably in communication between the surgeon, restorative dentist, dental laboratory, and patient.

The purpose of this clinical study was to demonstrate how to quantify and define the shape of the maxillary central incisors by determining a range of measurements that can be used to categorize the form of the crown of the maxillary central incisors into three different groups: triangular, square, and square/tapered.

Method and materials

One hundred Caucasian subjects (50 men, 50 women; age range, 21 to 25 years) from the predoctoral program at Tufts University School of Dental Medicine, Boston, Massachusetts, were randomly selected for this study. Subjects were in good physical health, had completed growth and development, and had both permanent maxillary central incisors present. The study design was reviewed and approved by the institutional review board at Tufts University School of Dental Medicine (no. 9230). During recruitment of the volunteers, the following exclusion criteria were employed: destructive periodontal disease, pregnancy or lactation, taking any medication that could possibly affect the thickness of the

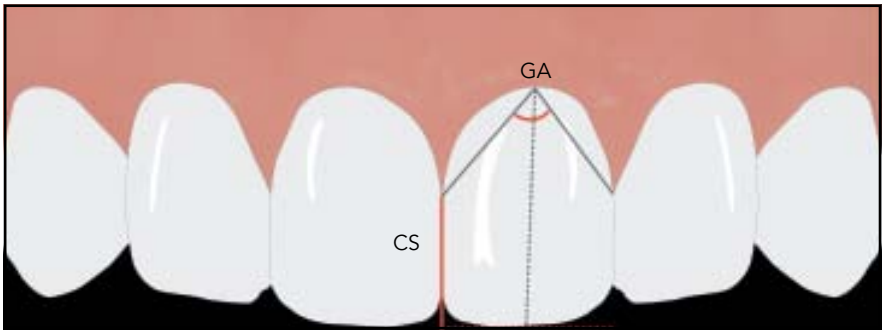


Fig 2a *Gingival angle* (GA) *was measured between the two lines that connect the most apical portion of the buccal gingival margin with the most coronal portions of the contact surface* (CS).

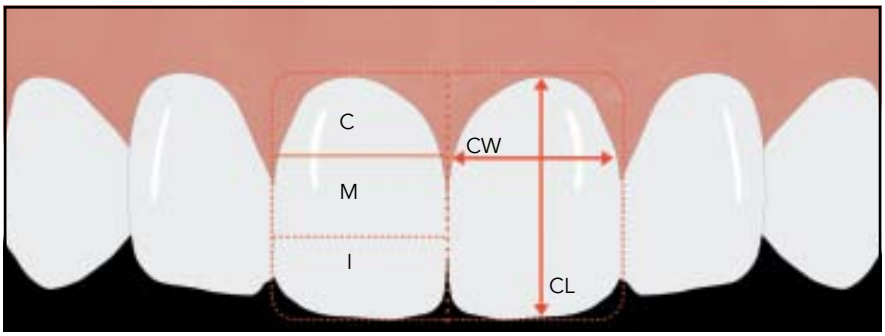


Fig 2b *Crown length* (CL) *was measured between the cementoenamel junction and the incisal edge of the crown. The crown length was divided into three equal portions: cervical* (C), *middle* (M), *and incisal* (I). *Crown width* (CW) *was measured between the approximal tooth surfaces at the junction between sections C and M.*

periodontal soft tissues (cyclosporine A, calcium-channel blockers, or phenytoin), extensive restorations or replacement of the maxillary central incisors, evidence of caries either on the interproximal surface or at the cementoenamel junction, history of tooth trauma causing a change of shape of the incisors, history of orthodontic treatment, obvious craniofacial asymmetry, history of periodontal surgery involving the maxillary central incisors, presence of incisal abrasion, attrition or erosion that reaches the dentin, and evidence of incomplete passive eruption.

Two consecutive photographs were taken from a straight-on view with a periodontal probe parallel to the occlusal plane (Fig 1). They captured both central incisors using metal retractors and a black background. The photographs were taken using a Canon 30D SLR camera with a 100-mm macrolens and Canon ring flash. The photographs were taken at a proportion of 1.5:1 with a 100 shutter speed and 14 f-stop in manual mode.

Clinical measurements

An image-processing program (ImageJ, National Institutes of Health) was used to measure the following assessments, as demonstrated by Olsson et al.[12] A special calibration tool built into the ImageJ software was used to convert all distances into millimeters.

Gingival angle (GA)

The degree of the curvature of the marginal gingiva was defined by the angle that forms at the intersection between two lines connecting the most apical portion of the facial gingival margin along the long axis of the tooth with the most apical portions of the contact points mesially and distally (Fig 2a). A special measurement tool built in the ImageJ software calculated this angle.

Crown length (CL)

This distance was measured between the most apical portion of the facial gingival margin and the incisal edge of the crown parallel to the long axis of the tooth (Figs 2b and 3). The incisal edge of the crown was defined as the most incisal point of the crown along the long axis of the tooth.

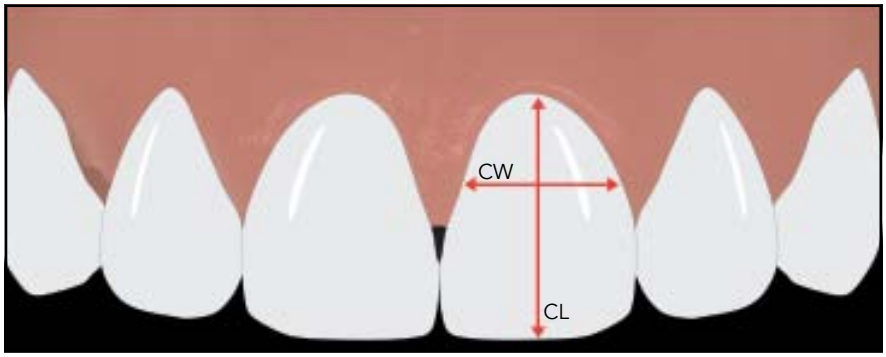


Fig 3 *Schematic illustration of measured distances in triangular teeth.*

Crown width (CW)

CL was divided into three equal portions (cervical, middle, and incisal) to determine where to measure CW (Figs 2b and 3). CW was then measured between the mesiodistal tooth surfaces at the junction between the cervical and middle sections of the CL. The CW measurement was taken at this junction to standardize the findings.

Contact surface (CS)

The length of CS was measured from the most apical portion of the contact area to the most incisal portion on the mesial surfaces of the central incisors (Fig 2a).

CW/CL ratio

CW/CL ratio was calculated by dividing CW by CL. This ratio represents a narrowness of one-third of the apical portion of the clinical crown.

CS/CL ratio

CS/CL ratio was generated by dividing CS by CL.

Data analysis

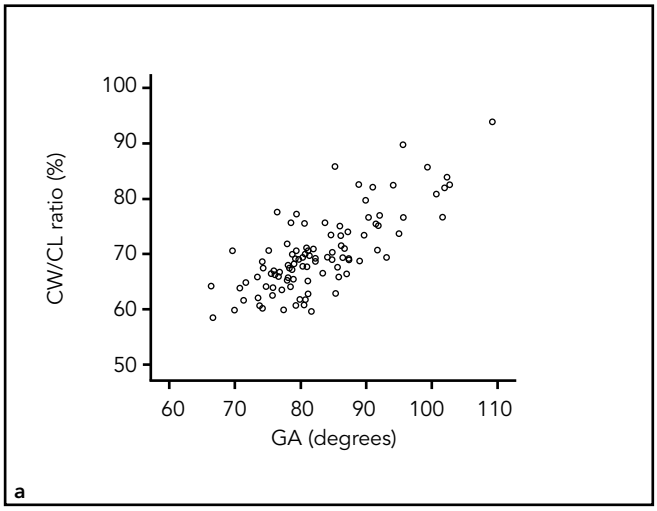
Descriptive analysis was performed to statistically demonstrate the correlation between different measurements. A Pearson correlation analysis was performed to assess the correlation between the three different groups of measurements (Figs 4a to 4c).

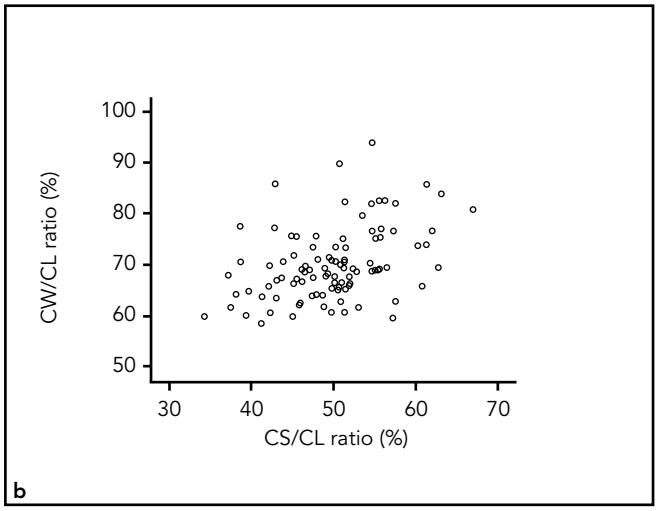
Analysis 1

Photographs of all subjects were randomly placed in a PowerPoint presentation (Microsoft) and were evaluated by two senior residents, one each from the postdoctoral periodontal and prosthodontic programs, and two periodontal faculty members from the department of periodontology who were not involved in the study. For each photograph, the evaluators arbitrarily and independently determined the shape of the central incisors, matching each subject with one of three different groups: triangular, square, and square/tapered. If the four evaluators were not in agreement, a fifth evaluator, a faculty member of the division of prosthodontics and operative dentistry, was selected to determine the final decision. Analysis of variance (ANOVA) was applied to search for differences among the groups.

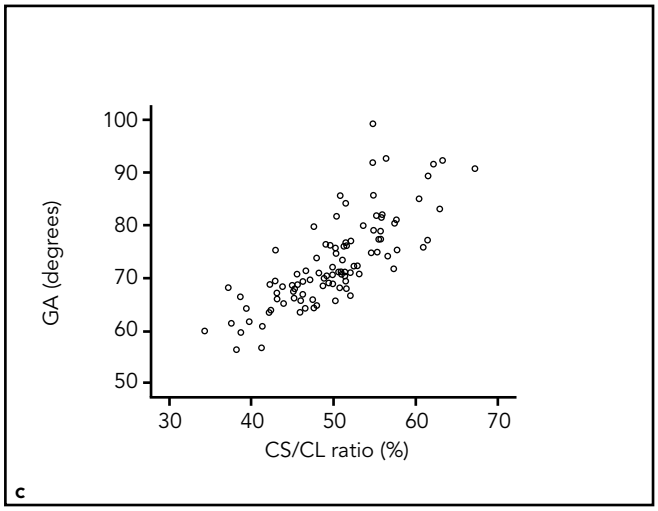
Analysis 2

An additional analysis was performed to eliminate the subjective factor by the five operators in determining tooth shapes. Subjects were partitioned into three clusters, which were interactively improved by nonhierarchical cluster analysis using a k-mean algorithm[13] to reduce the within-group sum of squares. Cluster analysis is a collection of statistical methods that identifies groups of samples that behave similarly or show similar





Figs 4a to 4c *Correlations between* (a) *CW/CL ratio and GA,* (b) *CW/CL ratio and CS/CL ratio, and* (c) *GA and CS/CL ratio* (P < *.001).*



characteristics. In common terms, it is referred to as "look-a-like groups." The simplest mechanism is to partition the samples using measurements that capture similarities or Euclidean distances between samples. In this way, clusters and groups are used interchangeably. An initial partition of the population into three clusters (triangular crown form, square/tapered crown form, and square crown form) was interactively improved by nonhierarchical cluster analysis. Therefore, cluster analysis was employed to more objectively divide the present population, similar to the method described by Müller et al.[14]

The Euclidean distance of three standardized parameters (GA, CW/CL ratio, and CS/CL ratio) was used as a measure of similarity. ANOVA was applied to search for differences among clusters.

Table 1 **Means and standard deviations for descriptive statistics***

	No. of subjects	Mean	Standard deviation
CW/CL ratio	100	0.70	0.07
GA (degrees)	100	82.93	8.39
CS/CL ratio	100	0.49	0.06

CW = crown width; CL = crown length; GA = gingival angle; CS = contact surface length.
*Pearson correlation revealed statistically significant correlations for all measurements ($P < .001$).

Table 2 **Minimum, maximum, and mean CS/CL ratio for the different tooth shapes**

Group	n	Minimum	Maximum	Mean	Standard deviation
Triangular	15	34.33%	42.94%	39.93%	2.51%
Square/tapered	46	43.10%	51.35%	48.06%	2.45%
Square	39	51.40%	67.06%	55.90%	3.92%
*P**				< .001	

*ANOVA.

Results

GA, CW/CL ratio, and CS/CL ratio were calculated separately for the entire study population. Means and standard deviations were calculated for each group of measurements (Table 1). Pearson correlation revealed a statistically significant correlation between the three different groups of measurements (Figs 4a to 4c). Data analysis demonstrated that the greater the GA, the greater the CW and the greater the CS/CL ratio. In other words, increased CW results in greater CS.

Analysis 1

Three separate groups of teeth were identified as triangular (n = 15), square/tapered (n = 46), and square (n = 39), as shown in Table 2. The data showed increasing CS among subjects. Those indentified by the

Table 3 Cluster analysis

Clusters	CW/CL ratio	Gingival angle (degrees)	CS/CL ratio
Cluster A, triangular (n = 17)	67.00%	75.06	43.20%
Cluster B, square/tapered (n = 50)	69.00%	83.36	51.67%
Cluster C, square (n = 33)	80.00%	96.95	57.72%
*P**			< .001

*ANOVA.

operators as having triangular central incisors showed a mean CS/CL ratio equal to 39.93% ± 2.51%. Similarly, subjects with square/tapered central incisors showed a mean CS/CL ratio equal to 48.06% ± 2.45%. Subjects with square central incisors showed a mean CS/CL ratio equal to 55.90% ± 3.92%.

ANOVA revealed a statistically significant correlation between the three different groups of measurements ($P < .001$).

Analysis 2

Patient means were calculated for all variables. The results of the cluster analysis of three different clusters are given in Table 3. The data showed an increase in CS associated with the three clusters. Subjects belonging to cluster A had a CS/CL ratio less than or equal to 43.2%, and they were considered to have triangular central incisors. Subjects belonging to cluster B with a CS/CL ratio between 43% and 57% were considered to have square/tapered central incisors. Subjects belonging to cluster C with a CS/CL ratio greater than or equal to 57.72% were considered to have square central incisors.

Similar to the first analysis, statistical correlation between the three different clusters of measurements was revealed ($P < .001$).

Discussion

It has been suggested that morphologic characteristics of the periodontium are partly related to the shape and form of the teeth.[3–5,8–11,15] Olsson and Lindhe[2,12] studied the relationship between tooth dimensions and biotype. Their results demonstrated that subjects with a long-narrow form of the maxillary central incisors had experienced more recession of the facial gingival margins than subjects who had a short-wide tooth form. They concluded that a long-narrow maxillary central incisor tooth form more likely represents a thinner biotype than a short-wide tooth form. Another study conducted by Müller et al[14] evaluated the relationship between masticatory mucosa and periodontal phenotype by classifying subjects into three categories according to gingival thickness and tooth form. This study indicated that there was an association between tooth form and biotype, which is consistent with the study by Olsson and Lindhe.[2] In the study by Becker et al,[1] it was noted that tooth length according to bone morphotype varied between three categories. The authors classified the maxillary anterior bony anatomy as flat, scalloped, and pronounced scalloped. Comparison of CW/CL ratios for the three bone morphotypes showed a tendency for a decrease in ratios between the flat to pronounced scalloped groups, with the flat bone anatomy having a slight tendency for greater CL when compared with the other two groups. CW for the pronounced scalloped group

Fig 5a *Triangular central incisors.*

Fig 5b *Square/tapered central incisors.*

Fig 5c *Square central incisors.*

was narrower than the other two groups. However, the results of this study did not confirm a definitive relationship between tooth shape and bone morphology. It has to be kept in mind that the authors did not estimate incisal wear (attrition), and the measurements were not corrected for these factors. The authors only evaluated bony anatomy and tooth size. The findings of Becker et al[1] together with Olsson and Lindhe[2,12] present important considerations when periodontal surgery or dental implant placement is considered in the maxillary anterior sextant. Likewise, Weisgold et al[4,5] considered long tapering teeth more susceptible to gingival recession, while square teeth appeared to have a greater zone of gingiva that was more resistant to gingival recession.

In 1992, Tarnow et al[16] found that the papilla filled the interproximal space 100% of the time in the natural dentition when the distance between the level of crestal bone and most apical contact point was less than 5 mm. In implant prostheses, the distance between the level of crestal bone and apical contact point is less than that in natural teeth.[17] Therefore, in implant prostheses, it is harder to achieve 100% papilla fill, as demonstrated by Salama et al,[18] since there is some vertical bone loss following tooth extraction.[19] Hence, the tooth shape determining the most apical point of the contact area is an important factor regarding restorative treatment in the esthetic zone. However, the literature is lacking in demonstrating what is a true triangular or square tooth.

In this investigation, two analyses were attempted to determine and quantify tooth shape. In the second analysis, the classification based on cluster analysis does not seem to be significantly different from the first analysis. Similarly, the cluster analysis identified three groups of 17, 50, and 33 subjects with triangular, square/tapered, and square teeth, respectively, showing that the majority of the subjects in the study population were in the square/tapered group. Looking at the CS/CL ratio, similar results were obtained. Subjectivity was minimal, and it can be concluded that if CS is less then 43% of CL, the tooth is triangular in shape; if CS is more then 57% of CL, the tooth shape is square.

Cluster analysis has been found to be useful in clinical research to objectively divide a large and complex population into easier survey fractions. However, cluster analysis is generally understood as a descriptive and exploratory method where the findings should be confirmed in independent populations.[20] One of the major objectives of this study was to confirm the presence of three different tooth shapes and to quantify the incidence of one shape over another. Since tooth size has been shown to vary between different racial groups,[21–23] the sample was limited to a Caucasian population.

It is important to point out that, in the first analysis, the fifth evaluator was not required in any decision regarding the triangular tooth shape. It appears as if determining a triangular tooth shape is easier and more clear for all evaluators than determining a square or square/tapered tooth shape.

To analyze tooth shape, this study quantified what is a true triangular and a true square crown (Figs 5a to 5c). The authors did not specifically quantify square/tapered crowns since the characteristics of this group related to either the triangular or square groups depending on how close the morphology of the crown resembled each shape. The results of this and other studies will have an impact on periodontal surgery, such as crown lengthening, full-coverage restorations at or apical to the gingival margin, and the placement of dental implants. Understanding tooth shape prior to periodontal surgery is an important factor for treatment planning to achieve acceptable esthetic outcomes. Commonly, in true triangular teeth, the gingival papilla will not completely fill the embrasure space. In this sense, the presence of a triangular central incisor that requires replacement with a single restoration where the adjacent central incisor is not to be replaced could result in a less than ideal esthetic result because of the presence of black triangles or nonsymmetric crown shapes. Anticipating treatment limitations by understanding the morphologic characteristics of the underlying bone is an important phase of the treatment planning discussion with a patient.

Conclusion

This study investigated the clinical crown shapes of maxillary central incisors in Caucasians. Within the limitations of this investigation, the following conclusions were drawn.

- The maxillary central incisors can be classified as triangular, square, or square/tapered according to the relationship between the lengths of the contact surface and the crown length.
- When the CS/CL ratio is less than 43%, a maxillary central incisor is categorized as triangular; when the ratio is between 43% and 57%, the tooth is defined as square/tapered; and when the ratio is more than 57%, the tooth is square.

References

1. Becker W, Ochsenbein C, Tibbetts L, Becker BE. Alveolar bone anatomic profiles as measured from dry skulls. Clinical ramifications. J Clin Periodontol 1997;24: 727–731.
2. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. J Clin Periodontol 1991;18:78–82.
3. Sanavi F, Weisgold AS, Rose LF. Biologic width and its relation to periodontal biotypes. J Esthet Dent 1998;10:157–163.
4. Weisgold AS. Contours of the full crown restoration. Alpha Omegan 1977;70: 77–89.
5. Weisgold AS, Arnoux JP, Lu J. Single-tooth anterior implant: A word of caution. Part I. J Esthet Dent 1997;9:225–233.
6. Daly CH, Wheeler JB 3rd. The use of ultra-sonic thickness measurement in the clinical evaluation of the oral soft tissues. Int Dent J 1971;21:418–429.
7. Wennström JL, Lindhe J, Sinclair F, Thilander B. Some periodontal tissue reactions to orthodontic tooth movement in monkeys. J Clin Periodontol 1987; 14:121–129.
8. Glickman I. The new practice of dentistry. Midwest Dent 1972;48(5):16–18.
9. Ochsenbein C, Ross S. A reevaluation of osseous surgery. Dent Clin North Am 1969;13:87–102.
10. Schluger S. Periodontics today: Dentistry tomorrow. J Dist Columbia Dent Soc 1977;Fall:6–8.
11. Steiner GG, Pearson JK, Ainamo J. Changes of the marginal periodontium as a result of labial tooth movement in monkeys. J Periodontol 1981;52:314–320.
12. Olsson M, Lindhe J, Marinello CP. On the relationship between crown form and clinical features of the gingiva in adolescents. J Clin Periodontol 1993;20:570–577.
13. Hartigan JA, Wong MA. Algorithm AS 136: A K-means clustering algorithm. J R Stat Soc Ser C Appl Stat 1979;28:100–108.
14. Müller HP, Heinecke A, Schaller N, Eger T. Masticatory mucosa in subjects with different periodontal phenotypes. J Clin Periodontol 2000;27:621–626.
15. Kan JY, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. Int J Oral Maxillofac Implants 2003;18:31–39.
16. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992;63: 995–996.
17. Kan JY, Rungcharassaeng K, Umezu K, Kois JC. Dimensions of peri-implant mucosa: An evaluation of maxillary anterior single implants in humans. J Periodontol 2003;74:557–562.
18. Salama M, Ishikawa T, Salama H, Funato A, Garber D. Advantages of the root submergence technique for pontic site development in esthetic implant therapy. Int J Periodontics Restorative Dent 2007; 27:521–527.
19. Iasella JM, Greenwell H, Miller RL, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: A clinical and histologic study in humans. J Periodontol 2003; 74:990–999.
20. Cohen ME. On the interpretation of microbial clusters in periodontal disease. J Periodontal Res 1997;32:47–53.
21. Lavelle CL. Morphological variations between English population samples. J Dent 1972;1:47–52.
22. Yaacob H, Nambiar P, Naidu MDK. Racial characteristics of human teeth with special emphasis on the Mongoloid dentition. Malays J Pathol 1996;18:1–7.
23. Lee GTR. Ethnic variations in teeth morphology. Proc Br Paedod Soc 1977;7: 23–27.