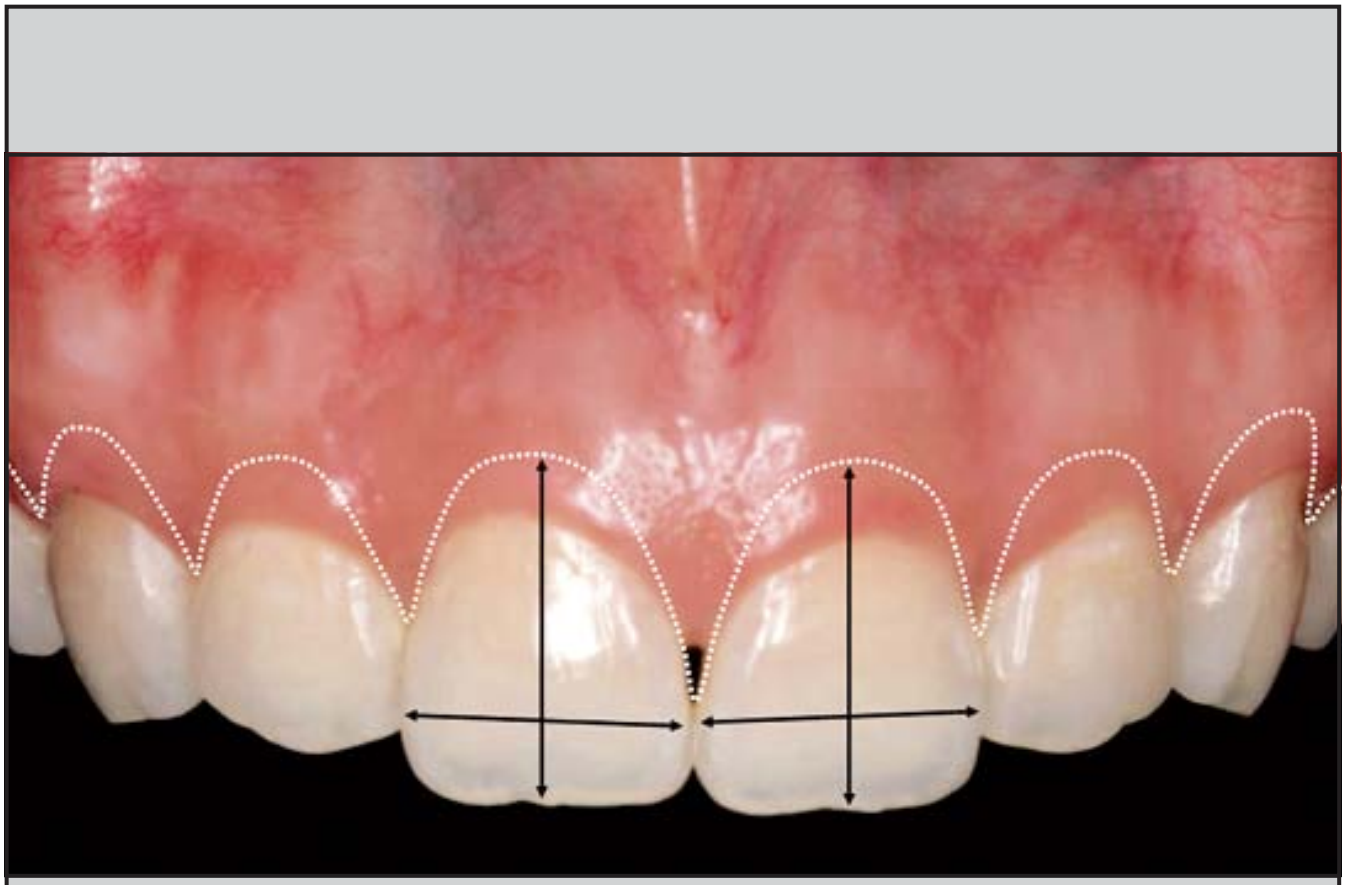

Anatomical Crown Width/Length Ratios of Worn and Unworn Maxillary Teeth in Asian Subjects

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Crown width/length ratios have been considered an important aspect in the esthetic zone. Because previous investigations focused on Caucasian populations, limited information is available on other ethnic groups to propose a comprehensive approach to anterior maxillary teeth. The purpose of this study was to analyze the dimensions of anatomical crowns of maxillary anterior tooth groups with respect to width, length, and width/length ratios among an Asian population. The tooth dimensions presented in this investigation may serve as guidelines for treatment planning in restorative dentistry and periodontal surgery for this particular ethnic group. (Int J Periodontics Restorative Dent 2011;31:495–503.)

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For many years, the establishment of health and function was the primary objective of dental professionals. However, the goal of modern dentistry includes not only health and function, but also a final esthetic result corresponding to the shape, size, color, texture, and harmony of natural healthy teeth and their surrounding tissues. Additional factors that might influence the ideal smile are ethnicity, personality, size, and position of teeth and clinical crowns, or simply the perception of what is "ideal" by a specific group or population. Dunn et al[1] established that there is no correlation between specific demographic groups and smile variables. The self-perception of smile attractiveness and the role of the smile line and other aspects were correlated with smile attractiveness and their influence on personality traits. The authors highlighted the psychosocial importance and dental significance of an attractive smile. Their results showed that the size of teeth, visibility of teeth, and upper lip position were critical factors in self-perception of smile

attractiveness (social dimension). Color of teeth and gingival display were critical factors in satisfaction with smile appearance (individual dimension).

In addition, the position and size of the anterior teeth might have a direct influence in the clinical appearance of the smile. It has been argued that with the diversity that exists in nature, the final result rarely follows all the mathematic rules of a proportionate smile.[2] It seems that a good balance in the composition of a smile is revealed by the equilibrium between the various visual tensions. However, this goes against the concept of absolute symmetry and the so-called objective of "perfection" of the dental arrangement, usually characterized by the total absence of visual tensions.

Among the objective criteria of natural oral esthetics, height and width of the maxillary anterior teeth have played an important role in restorative dentistry.[3] In 1991, Olsson and Lindhe[4] studied the relationship between teeth dimensions and biotype. Their results suggested that in subjects with a long-narrow form, the maxillary central incisors experienced more recession of the gingival margin at labial surfaces than subjects who had a short-wide tooth morphology. Furthermore, there was a significant influence of the crown width/length ratios on the probing attachment level and the amount of gingival recession on labial tooth surfaces. In 1999, another study conducted by Sterrett et al[5] analyzed the clinical crown width/length ratio of the maxillary anterior teeth from casts of healthy subjects. However, only data from the Caucasian group were analyzed and showed that the Caucasian population presented a mean width/length ratio of 81% for the three maxillary anterior tooth groups.[5]

In 2003, a similar study was conducted at the University of Geneva, Switzerland, using digital images of extracted maxillary teeth of white subjects. The authors differentiated unworn from worn teeth and concluded that the anatomical crown width/length ratios were 78% and 87% for unworn and worn central incisors, 73% and 79% for unworn and worn lateral incisors, and 73% and 81% for unworn and worn canines, respectively.[6]

Recently, Chu[7] introduced innovative esthetic measurement gauges with the purpose of enabling the clinician to perform esthetic surgical and restorative dentistry with success and predictability.[8] However, the predetermined dimensions used by Chu were not interchangeable for the different ethnic groups or respective tooth groups. These measurements were based on the mean width/length ratio of unworn central incisors of Caucasian subjects.[6]

Taking into consideration that data presented in previously published studies analyzing tooth width/length ratios have been generated mainly from Caucasian populations, extrapolating this data to other ethnic groups might be difficult without analyzing the anatomical characteristics of these populations. Thus, all these variations should be taken into consideration when designing a comprehensive and individualized treatment plan. The purpose of the present investigation was to analyze the anatomical crown dimensions of four maxillary tooth groups (central incisors, lateral incisors, canines, and first premolars) in Asian subjects with respect to width, length, and width/length ratios.

Method and materials

Two hundred sixty-four extracted human maxillary teeth from Asian subjects (91 central incisors, 76 lateral incisors, 54 canines, and 43 first premolars) were collected from Kyushu University School of Dentistry, Fukuoka, Japan. Teeth that presented with restorations, caries lesions, and an undetectable cementoenamel junction (CEJ) were excluded. Teeth were categorized by tooth group (central incisors, lateral incisors, canines, premolars) according to their anatomical characteristics and further divided into worn and unworn subgroups after undergoing scaling and ultrasonic cleaning. The criterion for this selection was presence of a marked incisal wear facet along with well-defined dentin exposure (Fig 1). Tangential light was used to show the incisal edge when viewing the central incisors. All premolars were considered as unworn, since all specimens displayed unworn buccal cusps. Standardized photographs of the buccal surface were made using a digital camera

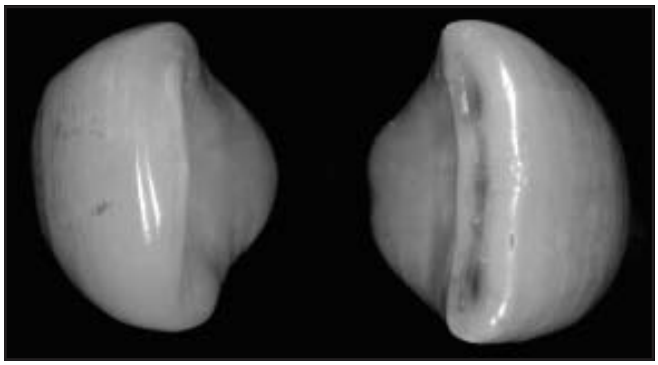

Fig 1 *Unworn central incisor with its incisal edge covered 100% by enamel.* (right) *Worn-down central incisor with a marked incisal wear facet along with well-defined dentin exposure on the incisal edge.*

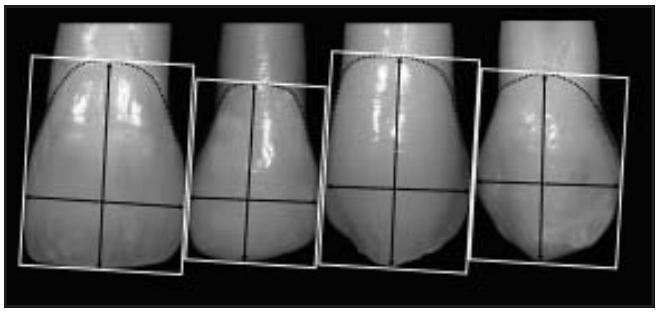

Fig 2 *The CEJ of each individual tooth was identified, followed by the long axis of the tooth. Measurements were performed from the most apical point of the CEJ to the most incisal point of the anatomical crown (parallel to the long axis of the tooth). A line was drawn perpendicular to the long axis of the tooth at the level of the widest mesiodistal dimension for each individual tooth.*

(Canon EOS 30D) with a 100-mm macro and MR-14EX Macro Ring Lite (Canon) attached to a photographic stand (RT-1, Kaiser). Teeth were positioned visually according to their main axis and recorded at original magnification ×1.5, resulting in 264 digital photographs (resolution maintained at 2,336 × 3,504 pixels and 8-bit grayscale, generating 3.6-megabyte files). An image-processing program (Image J; Java-based image processing program developed at the National Institutes of Health) was used to measure *(1)* the widest mesiodistal portion (perpendicular to the long axis of the tooth) and *(2)* the longest apicocoronal distance (parallel to the long axis, between the most apical point of the CEJ and the most incisal point of the anatomical crown) (Fig 2). A special calibration tool built in the Image J software was used to convert all distances into millimeters. Data were then transferred to a spreadsheet program for mathematic arrangement, including the calculation of the width/length ratio.

Statistical analysis was carried out to compare the four tooth groups. A one-way analysis of variance was used to compare the mean values of width, length, and width/length ratio for the seven different subgroups. Multiple least significant difference range tests (confidence level, 99%) were then applied to determine which means differed statistically from others.

Table 1 **Mean (SD) and range of the width, length, and width/length ratio of the four tooth types of the maxillary dentition**

		Width (mm)		Length (mm)		Width/length ratio (mm)	
	n	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Central incisors							
Unworn	35	8.63 (0.56)	7.80–9.70	11.93 (0.81)	10.08–13.24	0.72 (0.04)	0.65–0.81
Worn	56	8.90 (0.49)	7.90–10.48	11.38 (0.63)	10.20–12.91	0.78 (0.04)	0.70–0.88
Lateral incisors							
Unworn	47	6.99 (0.52)	5.52–8.34	10.52 (0.75)	8.72–12.79	0.67 (0.05)	0.57–0.77
Worn	29	7.25 (0.40)	6.48–7.99	9.72 (0.63)	8.59–11.15	0.75 (0.06)	0.63–0.83
Canines							
Unworn	32	7.91 (0.63)	6.64–9.00	11.83 (0.83)	10.36–13.99	0.67 (0.06)	0.57–0.77
Worn	22	8.10 (0.59)	7.07–9.60	10.86 (1.07)	9.14–13.23	0.75 (0.05)	0.64–0.86
Premolars	43	7.56 (0.46)	6.70–8.71	8.68 (0.68)	7.62–10.16	0.87 (0.06)	0.76–0.97

SD = standard deviation.

Results

The mean, standard deviation, and range of the width, length, and width/length ratio are presented in Table 1. In each situation, analysis of variance outcomes required multiple range tests to identify homogenous groups (Tables 2 to 4).

Within the same tooth group, there was no influence of the incisal wear on the mean crown width. The widest crowns were those of central incisors (unworn, 8.63; worn, 8.90 mm), followed by canines (unworn, 7.91; worn, 8.10 mm) and lateral incisors (unworn, 6.99; worn, 7.25 mm). Premolars (7.56 mm) had similar widths to canines and worn lateral incisors. Crown length was logically influenced by incisal wear, with worn teeth showing significantly lower values compared with unworn.

Three homogenous groups were found. The longest crowns were that of unworn central incisors (11.93 mm) followed by unworn canines (11.83 mm) and worn central incisors (11.38 mm). The shortest crowns were those of premolars (8.68 mm). Width/length ratios also showed significant differences. Ratio values were found to decrease as follows: premolars (87%), worn central incisors (78%), worn canines (75%), worn lateral incisors (75%), unworn central incisors (72%), and unworn canines and unworn lateral incisors (both 67%).

Table 2 Results of statistical analysis for width

	Mean (mm)	Homogenous groups*
Lateral incisors: unworn	6.99	
Lateral incisors: worn	7.25	
Premolars	7.56	
Canines: unworn	7.91	
Canines: worn	8.10	
Central incisors: unworn	8.63	
Central incisors: worn	8.90	

$P < .001$.
*Homogenous groups determined by multiple range tests (confidence level, 99%).

Table 3 Results of statistical analysis for length

	Mean (mm)	Homogenous groups*
Premolars	8.68	
Lateral incisors: worn	9.72	
Lateral incisors: unworn	10.52	
Canines: worn	10.86	
Central incisors: worn	11.38	
Canines: unworn	11.83	
Central incisors: unworn	11.93	

$P < .001$.
*Homogenous groups determined by multiple range tests (confidence level, 99%).

Table 4 Results of statistical analysis for width/length ratio

	Mean (%)	Homogenous groups*
Lateral incisors: unworn	67	
Canines: unworn	67	
Central incisors: unworn	72	
Lateral incisors: worn	75	
Canines: worn	75	
Central incisors: worn	78	
Premolars	87	–

$P < .001$.
*Homogenous groups determined by multiple range tests (confidence interval, 99%).

Discussion

The study of natural tooth proportions in the esthetic zone was reported in several publications as presenting a periodontal and restorative purpose.[2,3,9–13] However, it is only recently that the crown width/length ratio has been considered a critical factor for evaluation of the maxillary anterior teeth.[5–8] Among the aforementioned parameters, measurements of width/length ratios of normal clinical crowns seem to represent the most stable reference. A homogenous ratio (81%) was found by Sterrett et al[5] for the three anterior maxillary tooth

groups by measuring clinical crowns of normal white subjects with stone casts and excluding teeth with incisal wear as well as premolars. Because of limited ethnic diversity, only data from the Caucasian group were analyzed. A similar study was conducted in the University of Geneva in Switzerland using digital images of extracted maxillary teeth of white subjects, measuring the width, length, and width/length ratios for the anatomical crowns of unworn and worn maxillary incisors, canines, and premolars. Rosenstiel et al[14] evaluated dentists' preferred maxillary anterior tooth proportions and found that the majority chose smile proportions that resulted in central incisors that were closest to the 75% to 78% width/length ratios. However, most data presented by these investigations are based on Caucasian subjects.

Additional factors such as ethnicity should be taken into consideration to lead a more comprehensive observation. It should be pointed out that previous publications of tooth size and tooth morphology in various populations have shown differences both within and between ethnic groups.[15–17] A study by Bailit[18] in 1975 stressed the importance of clinicians taking into consideration these minor variations in dental traits among population types. These differences could influence the prosthodontic restoration of an esthetic smile.

In the past, the crown width/length ratio that is currently a key factor in achieving an esthetic outcome in the maxillary anterior dentition has not been presented in tooth morphology sources for the Asian population. Thus, it is indispensable to investigate the tooth dimension and ratio in each individual population to establish conclusive esthetic parameters for a specific ethnicity.

Using the data shown in the present study, the following ranking for crown width can be established for the Asian population studied (Table 2): central incisors > canines > premolars/lateral incisors. Within the same tooth group, these measurements were not influenced logically by the degree of incisal wear.

Regarding the general ranking of crown length for all specimens, the following was established for the Asian population studied (Table 3): unworn central incisors > unworn canines > worn central incisors > worn canines > lateral incisors > premolars. The ranking for width/length ratio for the specimens studied (Table 4) emphasizes the difference between unworn teeth, with mean ratios between 67% and 72%, and worn teeth, with mean ratios between 75% and 78%.

Width measurements of extracted teeth can be extremely precise because of the proximal clearance (absence of neighboring teeth); the precision of clinical measurements, including those made on casts, can be jeopardized, especially with overlapping teeth. Length measurements were confined apically by the CEJ, which normally sets the position and structure of the soft tissues.[19,20] However, the relationship between the CEJ and gingival level can show variations within and above normal range,[19] sometimes exposing part of the root and sometimes covering the enamel, an example of which would be incomplete passive eruption.[21] In this context, it seems appropriate to use the CEJ and not the free gingival margin as a reference for the establishment of "natural" guidelines. Accordingly, mean crown lengths in the study from Magne et al[6] were approximately 1 mm longer compared with clinical measurements by Sterrett et al.[5]

Additional factors such as ethnicity should be taken into consideration to lead to more comprehensive guidelines when treating and restoring patients that present with excess gingival display or loss of dental structure because of different circumstances.

A frequent clinical situation is the presence of incomplete passive eruption, as illustrated in Fig 3. The presence of short clinical crowns or excessive gingival display is a common complaint of patients with high esthetic demands. Figure 3e demonstrates an anatomical crown with exposed CEJ and a 78% width/length ratio for the maxillary central incisors, consistent with the range found on previously measured teeth. Osteoplasty and ostectomy were performed to locate the bone crest 2 mm apical to the CEJ to create space for the dentogingival junction over the root surface and the formation of a healthy sulcus over the enamel, preventing the formation of recession defects. This will create a

Fig 3a *A 27-year-old Asian woman was referred to the Postdoctoral Periodontal clinic at Tufts University School of Dental Medicine, Boston, Massachusetts, for esthetic crown lengthening because of altered passive eruption.*

Fig 3b *Frontal view of the maxillary anterior sextant where the alterations of crown width/length ratio can be observed. The correct location of the CEJ helps to identify the original outline of the anatomical crowns in respect to the future gingival margin.*

Fig 3c *Using a Bard Parker no. 15 blade, a submarginal incision was performed to achieve a natural gingival margin and proper tooth contours.*

Fig 3d *Full-thickness flap reflected exposing the supporting bone. Note the presence of excess osseous tissue.*

Fig 3e *Ostectomy and osteoplasty were performed to establish a space of 2 mm for the establishment of the dentogingival junction. A width/length ratio of 78% was measured for the anatomical crown from the incisal edge to the pristine CEJ.*

Fig 3f *Modified papilla preservation suture with 5-0 Monocryl sutures (Ethicon) was used to stabilize and reposition the flap.*

Fig 3g *Clinical view 11 months postoperative showing the natural contour of the teeth and natural display of gingival tissue. A width/length ratio of 84% was observed as the clinical crown proportion, which differs from the anatomical crown proportion seen in Fig 3e because of the formation of a healthy sulcus over the enamel.*

Fig 3h *Facial frontal view at 11 months postoperative.*

shorter clinical crown after healing of an approximate 84% width/length ratio, as observed in Fig 3g. Knowing the adequate mathematic equations of crown width/length ratio will facilitate the periodontist to establish the natural shape of the teeth and gingival contours, as well as in other clinical scenarios when patients have suffered many years of excessive abrasion and attrition, presence of diastemata, amorphous teeth, or a combination of circumstances. All these factors will affect the patient's smile. Thus, more comprehensive treatments are needed involving a combination of periodontal surgery and restorative procedures.

Facial esthetics has been related to a combination of natural proportions of size and shape. The central incisors are the dominant teeth of the smile; thus, respecting their natural size, shape, and contours should be considered when planning treatment that will involve the maxillary anterior dentition.

Interethnic comparisons regarding the width/length ratios of the maxillary teeth have not been performed previously. Therefore, further investigation to examine the correlation between Asian and Caucasian subjects is necessary, as Balit[18] also stresses the importance of consideration for variation among different ethnic populations.

Conclusions

This study investigated the anatomical crowns of the four anterior maxillary tooth groups in Asian subjects (central incisors, lateral incisors, canines, and first premolars) with respect to width, length, and width/length ratios between unworn and worn teeth for a select group of tooth specimens. Within the limitations of this investigation, the following conclusions were drawn:

- There was no influence of incisal wear on the average value of width within the same tooth group. Premolars had a similar width as lateral incisors.
- The length value was influenced by incisal wear.
- Width/length ratios showed significant differences among different groups.
- The Asian population–related measurement presented in this study may serve as a diagnostic tool in treatment planning rehabilitations in the anterior maxilla.

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References

1. Dunn WJ, Murchison DF, Broome JC. Esthetics: Patients' perceptions of dental attractiveness. J Prosthodont 1996;5: 166–171.
2. Ward DH. Proportional smile design using the recurring esthetic dental (red) proportion. Dent Clin North Am 2001; 45:143–154.
3. Black GV. Descriptive Anatomy of the Human Teeth. Philadelphia: S.S. White Dental Manufacturing, 1902.
4. Olsson M, Lindhe J. Periodontal characteristics in individuals with varying form of the upper central incisors. J Clin Periodontol 1991;18:78–82.
5. Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, Russell CM. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. J Clin Periodontol 1999;26:153–157.
6. Magne P, Gallucci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn maxillary teeth in white subjects. J Prosthet Dent 2003;89: 453–461.
7. Chu SJ. A biometric approach to predictable treatment of clinical crown discrepancies. Pract Proced Aesthet Dent 2007;19:401–409.
8. Chu SJ. Range and mean distribution frequency of individual tooth width of the maxillary anterior dentition. Pract Proced Aesthet Dent 2007;19:209–215.
9. Lombardi RE. The principles of visual perception and their clinical application to denture esthetics. J Prosthet Dent 1973; 29:358–382.
10. Levin EI. Dental esthetics and the golden proportion. J Prosthet Dent 1978;40: 244–252.
11. Snow SR. Esthetic smile analysis of maxillary anterior tooth width: The golden percentage. J Esthet Dent 1999;11:177–184.
12. Preston JD. The golden proportion revisited. J Esthet Dent 1993;5:247–251.
13. Albers HA. Esthetic treatment planning. Adept Report 1992;3:45–52.
14. Rosenstiel SF, Ward DH, Rashid RG. Dentists' preferences of anterior tooth proportion—A web-based study. J Prosthodont 2000;3:123–136.
15. Lee GTR. Ethnic variations in teeth morphology. Prac Brit Paedod Soc 1977;7: 23–27.
16. 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.
17. Younes SA, al-Shammery AR, el-Angbawi MF. Anatomic measurements of teeth in two different racial groups from the Middle East. Egypt Dent J 1988;34:371–391.
18. Bailit HL. Dental variations among populations: An anthropologic view. Dent Clin North Am 1975;19:125–139.
19. Gargiulo A, Wentz F, Orban B. Dimensions and relations of the dentogingival junction in humans. J Periodontol 1961;32: 261–267.
20. Ash M. Physiologic form of the teeth and the periodontium. In: Ash M (ed). Wheeler's Dental Anatomy, Physiology and Occlusion, ed 7. Philadelphia: WB Saunders, 1992:102–127.
21. Coslet JG, Vanarsdall R, Weisgold A. Diagnosis and classification of delayed passive eruption of the dentogingival junction in the adult. Alpha Omegan 1977; 70:24–28.