Emergence Angles of the Cementoenamel Junction in Natural Maxillary Anterior Teeth

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ABSTRACT

Statement of the Problem: Fabrication of normal crown contour to maintain gingival health is difficult in the absence of emergence angle data.

Purpose: The aim of this study was to measure the geometric values of the emergence angles on the cementoenamel junction (CEJ) for natural maxillary anterior teeth.

Material and Methods: This study collected 148 natural permanent maxillary anterior teeth (74 central incisors, 59 lateral incisors, and 15 canines) with intact cervixes for this study. The teeth were scanned with a three-dimensional (3D) scanner to construct 3D models. This study measured the emergence angles of the cervical CEJ on the zenith of labial, palatal, mesial, and distal, for each tooth.

Results: Measurements made on 148 maxillary anterior teeth showed the emergence angle to be within a narrow range from 11.30° to 15.26°, irrespective of the tooth location. There were no statistically significant differences between any two groups ($p > 0.05$).

Conclusions: On the basis of measurements taken from natural teeth, we conclude that the emergence angles of the CEJ in natural maxillary anterior teeth should be 15° from the root surface.

CLINICAL SIGNIFICANCE

The information presented in this article may be useful in helping to create dental restorations with optional emergence angles over the CEJ in natural maxillary anterior teeth. Prior to the treatment the dentist should consider not only the fit of the crown, but also the emergence angles and contours of the soft tissues surrounding the involved teeth.

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INTRODUCTION

In dental care, esthetic consideration plays a pivotal role in the planning of treatment options. In cases of restoration of anterior teeth, where such demands are high, subgingival cast restoration margins are frequently used. When making restorations of clinical crowns, the fundamentals of tooth form at the cervical third of crowns or roots must be considered. Failure to maintain proper emergence profile for tissue supporting contour is one of the factors that can subsequently lead to marginal inflammation of the restorations.[1–3]

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Therefore, taking the time to develop a proper emergence profile in the final restoration will help reduce plaque retentive areas, thereby reducing any occurrence of iatrogenic inflammation.[3–6]

The nature of the role of crown contour in health has been accepted as part of a mutually protective mechanism among the components of the masticatory system wherein the teeth, through the individual contours and collective alignment, protected the gingival tissues and hence the attachment apparatus.[7]

The term "emergence profile" was first proposed by Stein and Kuwata,[5] and is commonly used now. The Glossary of Prosthodontic Terms[8] defines "emergence profile" as "the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues." The emergence angle (EA) is the angle formed by the junction of a line through the long axis of the tooth, and a tangent drawn to the coronal of the tooth as it emerges from the sulcus.[1] The EA is the subgingival cervical start related to the profile, and is different from the "emergence profile."[9,10] Wheeler[11,12] proposes that insufficient contours result in gingival recession from the direct traumatic effect of the apically displaced bolus on the gingiva, and that overcontour may result in an area of accumulation and stagnation in proximity to the gingival margin. Sackett[7] demonstrated that alternation of normal crown form by overcontouring the buccal, axial third of a tooth may be a factor that predisposes the subjacent gingival tissues to inflammatory disease. The EA is the most crucial link between the proper subgingival contour and dentogingival complex health.

Evidence-based studies[9,13] examining the precise geometric value of the EA are rare in the existing literature. This study aims to analyze the EA of maxillary anterior teeth on labial, palatal, mesial, and distal proximal aspects.

MATERIALS AND METHODS

This study collected maxillary permanent anterior teeth extracted from dental patients for reasons such as periodontal failure, endodontic failure, or strategic extraction. After careful surface cleansing to remove the cervical depositions, this study examined the teeth with a laboratory magnifier. A criterion of several features was used in the selection of teeth for the study: the apical third of the roots had to be intact; the cervical area had to be intact and free of caries lesion, cervical abrasion, erosion, fracture, or any restorations and other defects. A total of 148 maxillary permanent anterior teeth were selected using this criterion. These included 74 central incisors, 59 lateral incisors, and 15 canines (Figure 1).

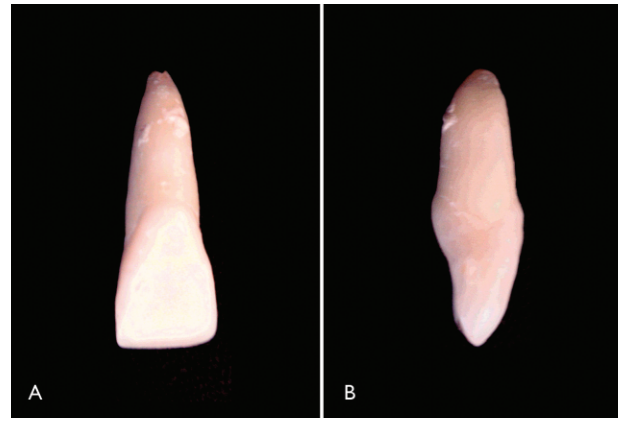

FIGURE 1. One of the selected central incisors. A, Labial view. B, Lateral view.

This study then scanned these selected teeth by a three-dimensional (3D) scanner (3D Scanner ortoTop-HE, Bruckmann, Münster, Germany) to analyze their shape and appearance. The collected digital data was then used to construct 3D geological models by means of a dedicated 3D modeling program (3D Geomagic Studio 8, Geomagic, North Carolina, USA). Figure 2A displays the 3D model constructed from the data obtained from a central incisor, which is shown in Figure 1. The 3D model was constructed using a polygonal mesh model, and represents the tooth in 3D using a collection of points in 3D space that are connected by various geometric entities such as triangles, lines, and curved surfaces. In the example of the selected central incisor tooth shown in Figure 2A, 39,510 triangles were used to build its 3D model (Figure 2B).

To construct the standard labiopalatal plane of the tooth, several measurements were taken: the midpoint along the width of the crown incisal third, and the midpoint along the width of the root apical third on labial view; the midpoint along the cervical width on palatal view. To construct the standard mesiodistal plane of the tooth, these measurements were taken: the incisal edge of the crown and the midpoint along the width of the root apical third on mesial view; and the middle width of the cervical on distal view (Figure 3). The intersecting line between these two standard planes was used to define the long axis of the tooth.

The lateral emergence profile of the tooth was projected onto the plane that was formed by the zenith curvature of the cementoenamel junction (CEJ) and its long axis (Figure 4). The EA was calculated as the angle formed between the tangent and the line extending from the root surface on these two-dimensional planes (Figure 5). In this manner, we determined the EA of the labial, palatal, mesial, and distal view for each maxillary anterior tooth individually.

RESULTS

The mean and standard deviation of measured EAs of the collected maxillary permanent anterior teeth were

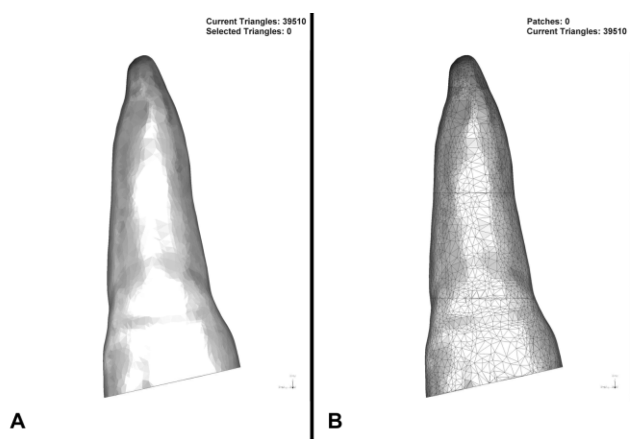

FIGURE 2. The three-dimensional (3D) model constructed for the selected central incisor (labial view). A, 3D model. B, Polygonal mesh model (the incisal edge portion was omitted).

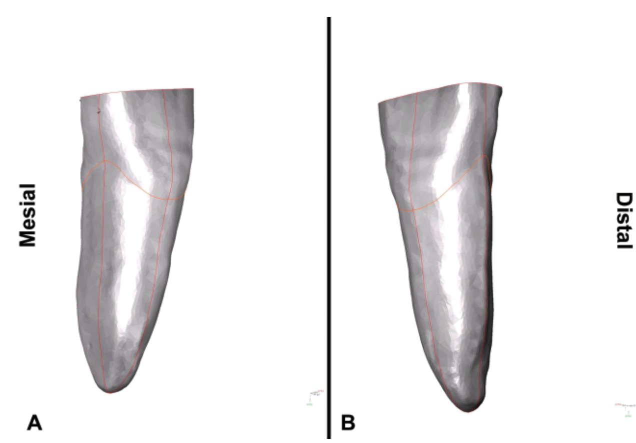

FIGURE 3. The standard labiopalatal plane and mesiodistal plane (shown as a red line). A, Mesiolabial view. B, Distolabial view.

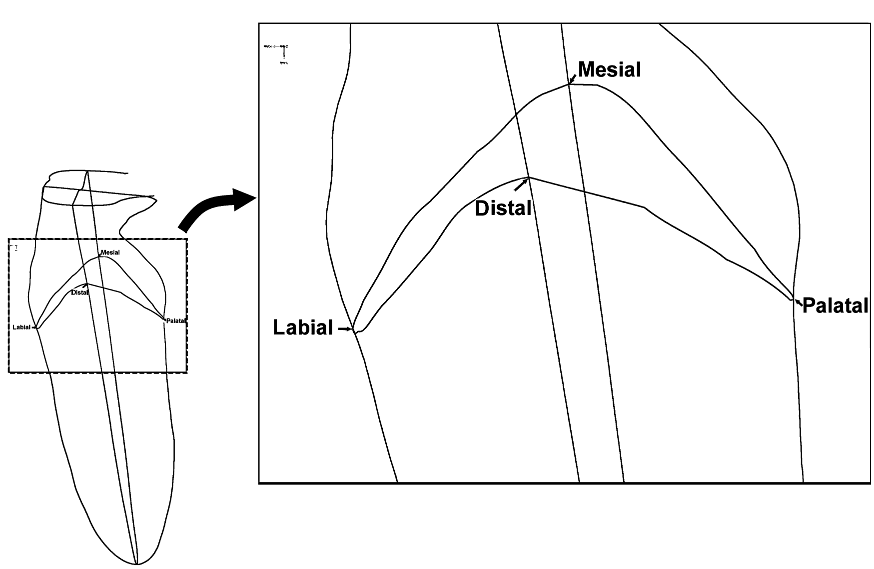

FIGURE 4. The projected lateral emergence profile on the plane formed by the zenith of curvature of cementoenamel junction and the long axis of the tooth.

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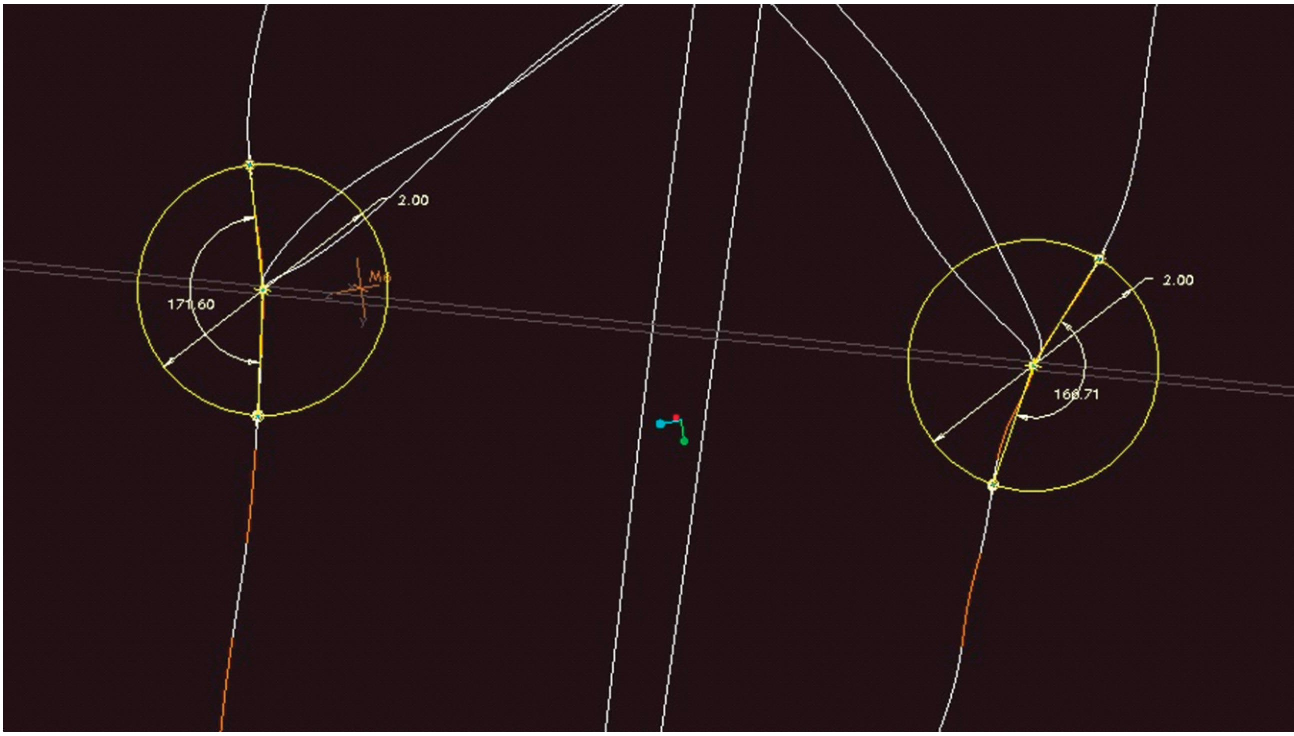

FIGURE 5. The emergence angle was calculated as the angle formed between the tangent and the line extending from the root surface.

TABLE 1. Mean and standard deviation (SD) of the emergence angles of the maxillary anterior teeth (unit: degree)

Tooth	*N*	Labial		Palatal		Mesial		Distal	
		Mean ± SD	^Min–Max	Mean ± SD	Min–Max	Mean ± SD	Min–Max	Mean ± SD	Min–Max
Central I	74	15.26 ± 5.64	5.17–30.91	11.97 ± 5.10	0.51–28.46	13.29 ± 4.61	3.62–16.12	14.49 ± 5.27	5.21–27.55
Lateral I	59	12.11 ± 4.58	3.45–25.43	11.84 ± 4.52	2.75–21.07	11.30 ± 3.59	2.20–19.34	12.40 ± 4.83	4.33–24.83
Canine	15	11.65 ± 5.25	3.30–19.92	12.70 ± 4.42	3.69–22.31	11.96 ± 3.06	6.61–15.13	12.54 ± 5.10	4.44–21.83
Total	148	13.65 ± 5.42	3.30–30.91	11.99 ± 4.79	0.51–28.46	12.37 ± 4.17	2.20–19.34	13.47 ± 5.15	4.33–27.55

I = Incisor; Max = maximum; Min = minimum; ^Min–Max = range.

calculated and are listed in Table 1. The mean and standard deviation of EAs of total maxillary anterior teeth were: labial, 13.65° ± 5.42°; palatal, 11.99° ± 4.679°; mesial, 12.37° ± 4.17°; and distal, 13.47° ± 5.15°. The mean EAs of central incisors were: labial, 15.26° ± 5.64°; palatal, 11.97° ± 5.10°; mesial, 13.29° ± 4.61°; and distal, 14.49° ± 5.27°; those of lateral incisors were: labial, 12.11° ± 4.58°; palatal, 11.84° ± 4.52°; mesial, 11.30° ± 3.59°; and distal, 12.40° ± 4.83°; and those of canine were: labial, 11.65° ± 5.25°; palatal, 12.70° ± 4.42°; mesial, 11.96° ± 3.06°; and distal, 12.54° ± 5.10°, respectively. There were no statistically significant differences ($p > 0.05$) between the groups.

DISCUSSION

The resolution of the 3D scanner (3D Scanner ortoTop-HE) was 1,384 × 1,036 pixels (optionally: 6.6 megapixels), and 1 pixel on the scanner represented ~1.5 to 2.0 μm of the tooth scanned. Based on this

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scaling, almost no three points of the tooth were in a line. A single line was defined as the difference coordinate of three points within 2 pixels.

It is difficult to precisely define the long axis of a tooth because the geography of the crown and root for each tooth is asymmetric. The selected standard labiopalatal plane and standard mesiodistal plane was usually reliable. The long axis was the intersecting line between the two standard planes. However, these two planes did not always lie perpendicular to each other.

Under the scanning electron microscope, the enamel and cementum of the CEJ show different types of tissue interrelations.[14] The EA is typically observed under low magnification for clinical convenience. The EAs of the cervical CEJ in this study were measured between the tangent and the line extending from the root surface. This definition is different from that of the angle between the tangent and the long axis of the tooth, which is the measurement used in previous studies.[1,8] The long axis of the tooth is an imaginary line devised for clinical purposes and is often difficult to verify and define. Thus, the angle between the tangent and the line extending from the root surface can be considered as a better measurement in comparison, and is also convenient for clinical application. The measurement radius was 0.5 mm from the CEJ (Figure 5). When taking measurements for the 148 teeth examined in this study, we found that from all viewpoints the emergence profile for each tooth is almost straight. After an almost straight profile for 0.5 mm, the surface contours then have a gradual curvature with ripples. This straight emergence profile observed here corroborates with the photographic observations made by several previous studies.[2–5]

There were no significant differences between the measured EAs for the collected maxillary anterior teeth at any of the gingival zenith positions (Table 1). The mean EA ranged from 11.30° to 15.26°. The standard deviations of the measured EA varied from 3.06° to 5.64°. Thus, the EA lies between a narrow range of 11° to 15°. This measured EA corroborates with the 15° found by Croll and colleagues,[13] and also with the observations by Yotnuengnit and colleagues[9] (labial, 9.93°; palatal, 14.35°). Moreover, our measurements are close to the 9.76° (80.24°) observed for the mandibular second premolars by Wu and Xu.[15]

Ehrlich and Hochman[16] report that healthy gingiva may tolerate slight variations in crown contour, thus providing a more reasonable approach to the relationship of crown contour and gingival health, both for the dentist and for the laboratory technician. Our study did not find the tolerance of crown contour in healthy gingiva because the samples collected were mostly from the periodontal failure. We also found the larger emergence angle in samples of endodontic failure or strategic extraction. But the small number of samples cannot conclude the finding. However, we believe the EA lies between a narrow range of 11° to 15°, should be a safe value in periodontal involved or healthy gingiva.

Rosenberg and colleagues[1] suggest that the free gingival architectural forms have an affinity relationship to the dimensions of subgingival contours. The EA is thought to be influenced by the underlying form of the osseous structures.[1] Our study, however, failed to find an association between these parameters. One of the limitations of this study was its small sample size. Further, variables like tooth position (maxillary/mandibular; anterior/posterior), dentition (permanent/deciduous), gender, and race differences are other potential confounding factors that could affect the measurements taken. A large scale study is needed to validate the measurements taken here.

Based on our findings, we recommend that for proper crown formation the maxillary anterior artificial crown should follow an EA of 15°. There should also be a 0.5-mm straight emergence profile to maintain healthy gingival tissues and cervices. This conclusion is in agreement with Kois.[17]

The circular band of connective tissue fibers of the marginal gingiva is best observed in horizontal sections from healthy submucosa underlying the epithelium of the margin of the gum. It is composed of many connective tissue cells with their closely interwoven collagenous fibers, forming a compact well-differentiated group. A large majority of these are

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not attached to bone or cementum, but form an encircling band within the gingival margin.[18] The arrangement of the fibers serve a significant role in maintaining the tone of the marginal gingiva, and its close adherence to the neck of the tooth.[19] The free gingiva is held more firmly against a slight EA (such as 15°) to the crown by the elastic supra-alveolar connective tissue fibers. The suprabony connective tissue surrounding the implant is made up of circumferential fibers that run parallel to the implant surface.[20,21] The peri-implant soft tissue lacks the interwoven encircling band fibers and epithelial attachments; so the emergence profile of an implant abutment needs to be different from a natural tooth and should be more convex than a natural tooth. This angle of convexity needs to be determined by further examination.

Whatever the specific size of a particular manufacturer's implant, it is unlikely to correspond accurately to the size or shape of a natural tooth at the gingival level. The final esthetic result will be compromised without the appropriate shape, size, and location of the implant restoration that emerges from the soft tissue.[22] The development of a "ball on a stick" restoration can be avoided through considering the proper emergence profile in three dimensions.[23] Emergence profile is also related to implant placement. The vertical length of the subgingival portion of the restoration is particularly important because guided gingival growth is indirectly proportional to the subemergence depth of the implant.[24] The need for cervical overcontouring or ridge lapping and the restoration can emerge from the implant gradually by placing the implant at least 3 mm apical to the CEJ of the adjacent natural teeth (measured from the midfacial aspects of these teeth).[25] If the implant is placed deeper than 3 mm, the ideal emergence profile can be created easier by screw-retained implant-supported restoration. If the angle of implant placement is larger than the long axis of the adjacent teeth for more than 25°, it is also suggested that clinician can easily get an ideal emergence profile with screw-retained implant-supported restoration. A lingually placed shallow implant will require excessive buccal contour; meanwhile, a buccally placed implant will require undercontour. However, an acrylic resin provisional crown is fabricated and contoured with a definite cervical margin prominence that satisfyies functional and esthetic demands.

Clinically, there are several methods in place to assist the development of the optimal subgingival cervical contour for artificial crowns. One such measure is the model simulation method.[26–31] This method preserves the soft tissue landmarks on laboratory die models with removable, pliable simulated gingival contours. This facilitates esthetic contouring of the restoration in the dental laboratory. Although gingival replica can assist in the reproduction of a restoration's gingival contour and emergence profile, this method is not free from shortcomings. These include the simulation material distortion and the soft tissue displacement. Also, the anatomical information for the free gingiva cannot be determined accurately and this can result in morphological and positional deformation.

The other method is achieved by using provisional restorations.[30,31] The clinician uses provisional restorations to establish and maintain the patient's gingival health during the provisional treatment phase to confirm the correct emergence profile and accurate margination. Long-term follow-up is necessary in these cases to monitor tissue reactions with frequent adjustments.

The third method is checking the restoration as try-in procedures. The emergence profile of restorations can be checked clinically with a silicone-disclosing medium, such as Fit Checker (GC America, Alsip, IL, USA), and adjusted to a correct contour without marginal gingival bleaching within 10 seconds.[6,32]

Clinically, the included angle of periodontal probe is about ~10° to 15°. Therefore, it is suggested that the dentist/dental technician use a periodontal probe to be the reference tool of recreated ~11° to 15° EA.[33] At present, our search team had developed a group of waxing instruments which ~11° to 15° would be easily emerged based on the study and we are applying for patent on this research.

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The restorative EA may be dependent upon tooth position in the arch. However, if the EAs of teeth are provided, the technician can make fixed prostheses with optimal contours. Giving vague guidelines for the subgingival axial contours to the dental technician often results in tissue impingement of the axial walls and poor accessibility for oral hygiene. The root topography can be captured in the conventional impression with conservative tissue retraction procedures. The use of a defined angle to a fixed prosthesis can then assure predictable marginal fidelity.

CONCLUSIONS

This study aimed to measure the emergence profile of the CEJ in natural maxillary anterior teeth. The results support the concept that the emergence profile is straight within the range 0.5 mm from the CEJ. Measurements of the EAs for 148 teeth show the angle to be within a narrow range from 11.30° to 15.26°, irrespective of the tooth location. Interpretation of the results must be made with caution, and larger studies are warranted to investigate the effects of other factors.

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REFERENCES

1. Rosenberg MM, Kay HB, Keough BE, Holt RL. Periodontal and prosthetic management for advanced cases. Chicago (IL): Quintessence; 1988.
2. Croll BM. Emergence profiles in natural tooth contour. Part I: photographic observations. J Prosthet Dent 1989;62:4–10.
3. Weisgold AS. Contours of the full crown restoration. Alpha Omegan 1977;7:77–89.
4. Wagman SS. The role of coronal contour in gingival health. J Prosthet Dent 1977;37:280–7.
5. Stein RS, Kuwata M. A dentist and a dental technologist analyze current ceramo-metal procedures. Dent Clin North Am 1977;21:729–49.
6. Kois J. “The gingiva is red around my crowns”—A differential diagnosis. Dent Econ 1993;83:101–2.
7. Sackett BP, Gildenhuys RR. The effect of axial crown overcontour on adolescents. J Periodontol 1976;47:320–3.
8. The Glossary of Prosthodontic Terms 8th ed. J Prosthet Dent 2005;94:35.
9. Yotnuengnit B, Yotnuengnit P, Laohapand P, Athipanyakom S. Emergence angles in natural anterior teeth: influence on periodontal status. Quintessence Int 2008;39:e126–33.
10. Sundh B, Köhler B. An in vivo study of the impact of different emergence profiles of procera titanium crowns on quantity and quality of plaque. Int J Prosthodont 2002;15:457–60.
11. Wheeler RC. Restoration of gingival or cervical margins in full crowns. Dent Cosm 1931;73:238.
12. Wheeler RC. Complete crown form and the periodontium. J Prosthet Dent 1961;11:722–34.
13. Croll BM. Emergence profiles in natural tooth contour. Part II: clinical considerations. J Prosthet Dent 1990;63:374–9.
14. Neuvald L, Consolaro A. Cementoenamel junction: microscopic analysis and external cervical resorption. J Endod 2000;26:503–8.
15. Wu YM, Xu J. Geometric relationship of axial crown contour and gingival contour of normal second mandibular premolars. Chin J Stomatol 2000;35:274–6.
16. Hochman N, Yaffe A, Ehrlich J. Crown contour variation in gingival health. Compendium 1983;4:360–2.
17. Kois J. The restorative-periodontal interface: biological parameters. Periodontol 2000 1996;11:29–38.
18. Arnim SS, Hagerman DA. The connective tissue fibers of the marginal gingival. J Am Dent Assoc 1953;47:271–81.
19. Wagmen SS. Tissue management for full cast veneer crowns. J Prosthet Dent 1965;15:106–17.
20. Bergiundh T, Lindhe J, Ericsson I, et al. The soft tissue barrier at implants and teeth. Clin Oral Implants Res 1991;2:81–90.
21. Abrahamsson I, Bergiundh T, Wennstrom J, et al. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. Clin Oral Implants Res 1996;7:212–9.
22. David N, Winston WL. Chee development of implant soft tissue emergence profile: a technique. J Prosthet Dent 1994;71:364–8.

 DOI 10.1111/j.1708-8240.2011.00471.x

23. Daniel CTM, Mark S. Method for developing an optimal emergence profile using heat-polymerized provisional restorations for single-tooth implant-supported restorations. J Prosthet Dent 2004;91:289–92.
24. Stein JM, Nevins M. The relationship of the guided gingival frame to the provisional crown for a single-implant restoration. Compend Contin Educ Dent 1996;17:1175–82.
25. Donald FR. Esthetic and functional considerations for implant restoration of the partially edentulous patient. J Prosthet Dent 1993;70:433–7.
26. Martin D. Soft tissue, master cast. Int J Periodontics Restorative Dent 1982;4:35–43.
27. Williamson RT, Kinderknecht KE. Soft tissue cast aids in establishing interproximal contours for restorations. J Prosthet Dent 1993;69:630–1.
28. Breeding LC, Dixon DL. Transfer of gingival contours to a master cast. J Prosthet Dent 1996;75:341–3.
29. Bassiouny MA, Yearwood LL. Establishing the gingival emergence profile restorations by using a resilient gingival replica. J Prosthet Dent 1996;76:386–9.
30. Liebenberg WH. Multiple porcelain veneers: a temporization innovation—the peripheral seal technique. J Can Dent Assoc 1996;62:70–8.
31. Smukler H, Chaibi M. Periodontal and dental considerations in clinical crown extension: a rational basis for treatment. Int J Periodontics Restorative Dent 1997;17:465–77.
32. Minami M, Yamazaki M. Requirement of crown contouring resides in the gingival support. Pract Prosthodont 2001;34:638–57.
33. Burney MC. Emergence profiles in natural tooth contour. Part II: clinical considerations. J Prosthet Dent 1990;63:374–9.

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