Esthetic Paradigms in the Interdisciplinary Management of Maxillary Anterior Dentition—A Review

VISHNU RAJ, BDS, MSFS, MS*

ABSTRACT

This article reviews some commonly used esthetic proportions and paradigms in dentistry. Establishing optimal anterior esthetics frequently entails restorative, orthodontic, and periodontal treatment. Several guidelines have been purported to facilitate an esthetic outcome during the rehabilitation of the maxillary anterior teeth. The golden proportion, recurring esthetic dental proportion, tooth width : height ratios, vertical positioning of the maxillary lateral incisor, and the apparent contact dimension are examples of some such guidelines. Evaluation of these esthetic paradigms including their validity, esthetic significance, perception by laypeople, and the range of tolerance to alterations are very important considerations.

CLINICAL SIGNIFICANCE

This review presents a comprehensive analysis of some selected esthetic dental paradigms and recommendations for their application in the interdisciplinary management of anterior dental esthetics.

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The effect of an esthetic smile cannot be overemphasized and may have far-reaching ramifications in the personal and professional arena. An esthetic smile has been described as one in which the size, shape, position, and color of the teeth are in harmony, proportion, and relative symmetry to each other and the elements that frame them.[1] Mesiodistal and vertical tooth proportions constitute a major determinant of dental esthetics and symmetry. Generating esthetic tooth proportions during the restoration or replacement of the maxillary anterior dentition continues to present significant challenges to the restorative dentist, periodontist, and orthodontist. Depending on the situation, alteration of existing tooth dimensions may involve osseous and orthognathic surgery, orthodontic space distribution, intrusion or extrusion, enameloplasty, and prosthodontic rehabilitation including alteration of the occlusal vertical dimension. Several authors have proposed theoretical guidelines that purport to help establish esthetic proportions during restoration of the dentition. However, the validity of these guidelines remains dubitable. In this era of evidence-based decision making, clinical decisions need to be corroborated with the best available data. This review will attempt to describe some commonly used esthetic proportions in dentistry and the validity of their application.

THE GOLDEN PROPORTION

The golden proportion (GP) as a concept was first used in ancient Greek architecture. The basic premise is that for two related objects to appear natural and harmonious, the larger to the smaller should form a ratio of 1.6 and 181:1.[2] In dentistry, GP represents a 62% regression from the mesial to the distal, with the implication that a 62% progressive reduction in the

*Private Practice, Austin, TX, USA

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perceived mesiodistal widths of the maxillary anterior teeth is considered to be esthetically pleasing. As stated by Levin, when viewed from the facial, "The width of the central incisor should be in GP to the width of the lateral incisor, and the width of the lateral incisor should be golden to the canine and the canine width should be golden to the first premolar" (Figure 1).[3] Lombardi proposed that dental and facial esthetics were optimized if features, such as the central to lateral width and lateral to canine width, were repeated in proportion when the patient is viewed from the front.[4]

In order to evaluate the prevalence of the GP in the natural dentition, Preston measured the perceived widths of the maxillary central and lateral incisors on 58 imaged casts. He found that only 17% of the casts (10) had a perceived central : lateral incisor width ratio in the range of 1.59 and 1.65:1. The mean perceived central : lateral incisor width ratio was 1.51:1. Preston also failed to find any diagnostic cast with a perceived maxillary lateral : canine width ratio within the range of the GP.[5]

Gillen and colleagues in 1994 conducted a study to determine the average dimensions of the six maxillary anterior teeth and to evaluate the relationships between intertooth and intratooth dimensions using dental casts from 54 volunteers.[2] The authors found that GP did not correlate with any of the calculated ratios. However, the GP is only relevant to perceived tooth proportions as evaluated from the frontal, and it is not valid when applied to actual tooth proportions. With respect to the actual and perceived widths, however, there appears to be a difference between diagnostic models and images. Hasanreisoglu and colleagues compared the mesiodistal width of the maxillary anterior teeth of 100 volunteer dental students measured on casts to the perceived widths measured on the corresponding images. They found that the actual and perceived dimensions of the anterior teeth when viewed from the facial differed because of the curvature of the arch and angulation of the teeth in relation to the frontal plane of the photograph.[6]

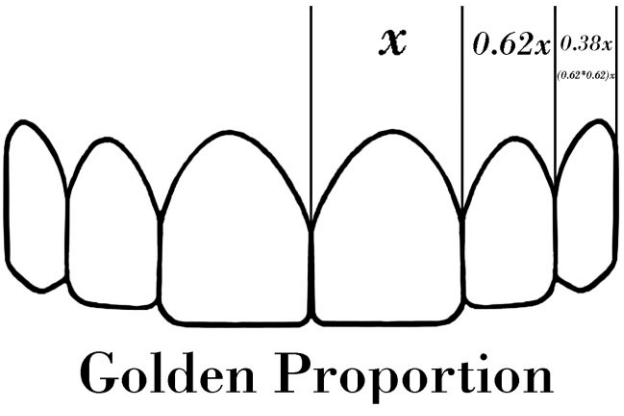

FIGURE 1. Graphic representation of the golden proportion (Courtesy of Ward[8]).

Although several studies have assessed the GP, the influence of tooth height on the perceived esthetics of GP is an important factor. Rosenstiel and colleagues used computer-manipulated images of the six maxillary anterior teeth, which were assigned to five groups based on tooth height (very short, short, normal height, tall, and very tall). For each group, four images were generated by manipulating the relative mesiodistal widths of the central incisors, lateral incisors, and canines according to the following proportions—62% (or "GP"), 70%, 80%, and normal or unaltered. The four images for each group were evaluated in random order by dentists who were asked to rank them from best to worst. GP was considered to be the best option only for very tall teeth (Figure 2). For normal height or short teeth, GP was considered to be the worst choice presumably because its use made the central incisors look unnaturally squat (Figure 2).[7] In another survey-based study of dentists' preferred maxillary anterior tooth proportions, GP was not the most preferred esthetic proportion.[8]

Another important factor to consider when evaluating tooth proportions is the perception of laypeople toward variations in tooth proportions. In a landmark study, Kokich and colleagues evaluated the esthetic preferences of laypeople and dentists to altered dental esthetics and established threshold values beyond which deviations from the optimal would not be perceived by the majority of laypeople.[9] Kokich and colleagues reported that although dentists could perceive a 3-mm narrowing of the maxillary lateral incisor, laypeople did

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FIGURE 2. The application of the golden proportion to very short and very tall teeth (Rosenstiel and colleagues[7]).

not notice a significant change until the lateral incisor was narrowed by 4 mm.[9]

In a survey-based study designed to evaluate the esthetic preferences of laypeople, the vast majority considered the GP to be less attractive.[10] A study by Ong and colleagues assessed the relative importance of various dental features contributing to overall dental attractiveness. Photographs of 60 subjects were evaluated by 12 laypeople who rated the subjects' dental appearance on a 5-point Likert attractiveness scale. The authors concluded that GP was not found to be a decisive factor in determining dental attractiveness.[11] However, this study also assessed other factors influencing dental attractiveness, and it is not entirely clear how the authors would obviate the influence of these other parameters when evaluating the esthetics of the existing tooth proportions. In addition, it is unclear if and how many subjects in the study exhibited smiles that were consistent with the GP.

Among the maxillary anterior teeth, the lateral incisor shows a large degree of variability in tooth width and height, and thus the potential to present an esthetic liability. Bukhary and colleagues evaluated the influence of varying the dimensions of the maxillary lateral incisor on the perception of smile esthetics. A photograph of a female smile was digitally altered in 5% increments to produce maxillary lateral incisor widths ranging from 52% to 77% of the width of the adjacent central incisor. The images were ranked from "most attractive" to "least attractive" by 41 hypodontia patients, 46 nonhypodontia "controls," and 30 dentists. The images reflecting 67% lateral : central width proportions were considered to be the most attractive, and GP was not preferred by the majority of evaluators.[12]

An important aspect validating the use of GP is the degree of prevalence of a GP in individuals considered to exhibit an esthetic smile. Mahshid and colleagues studied the existence of GP in 157 subjects deemed to possess an esthetic smile. Scanned images of the subjects' smile were used to measure the apparent mesiodistal widths of the maxillary anterior teeth using an image measurement program. The authors did not find a GP between the perceived widths of the maxillary anterior teeth. The mean perceived lateral : central incisor ratio was 0.67, and the mean perceived canine : lateral incisor ratio was 0.84.[13] A weakness of the study, however, was the somewhat subjective selection of the sample. Use of a large number of individuals with varying tooth form, arch dimension, and less-than-ideal arrangements may produce conflicting results.[14]

A study by Basting and colleagues found that only 19% of smiles exhibiting the GP were classified as agreeable by a computer. However, the authors used a range of 51.1% to 69.9% to denote the GP. This range of apparent mesiodistal widths is excessively large, with the extremes clearly unrepresentative of the GP, and thus does not allow for any useful interpretation of the results.[15] Another study by de Castro and colleagues that used a digital analysis technique to assess the prevalence of the GP in subjects considered to possess an agreeable smile found only 7.1% of these smiles exhibiting the GP.[16]

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Although GP has been widely proposed as a guideline to design smiles, the actual prevalence of the use of the GP in cases of rehabilitation of the maxillary anterior dentition remains unknown. Pini and colleagues assessed the existence of GP in 48 subjects with missing maxillary lateral incisors who were treated with either canine substitution or with implant-supported restorations. The authors reported that GP was not evident in the majority of subjects evaluated.[17] Therefore, based on all the aforementioned research, it is very clear that GP is not generally evident in the natural or the restored dentition, nor is it considered esthetically pleasing by the majority of dentists or laypeople, unless it is applied to the evaluation of excessively long teeth. Thus, the GP is not suitable for use as a general esthetic paradigm for evaluation of the maxillary anterior teeth.

THE RECURRING ESTHETIC DENTAL PROPORTION

The recurring esthetic dental (RED) proportion was a concept proposed by Ward. The RED proportion states that the proportion of the successive widths of the maxillary teeth as viewed from the front should remain constant progressing distally (Figure 3).[18] When viewed from the front, the width of each successive tooth depreciates by the same proportion relative to the tooth mesial to it. Although the actual proportion may differ

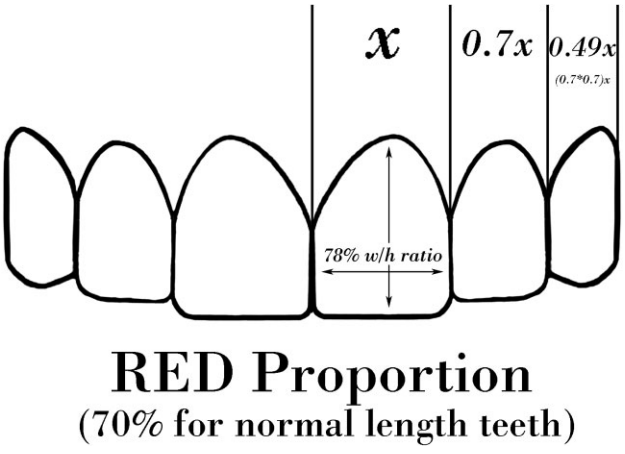

FIGURE 3. Graphic representation of the recurring esthetic dental (RED) proportion (Ward[8]).

(e.g., 70%, 75%, 80%, etc.) because of differences in tooth height and other factors, the selected RED proportion must be applied consistently to the specific smile.

Rosenstiel and colleagues used computer-manipulated images of the six maxillary anterior teeth, which were assigned to five groups based on differing tooth height (very short to very tall), and for each group, the mesiodistal tooth proportion was manipulated to reflect a successive decrement of 62% (or "GP"), 70%, 80%, and "normal" or unaltered, relative to the tooth mesial to it. The four images for each group were randomly evaluated by dentists who were then asked to rank them from best to worst. When viewing short teeth, dentists preferred a RED proportion of 80%. However, for teeth of normal height, there was no clear-cut choice with dentists being divided between the 70%, 80%, and unaltered RED proportions.[7] A confounding factor in this study design was the inadvertent change in the width : height ratio consequent to manipulating the widths while maintaining a constant tooth height. Thus, it is hard to delineate whether the evaluation of the manipulated images were indicative of the effect of change in intertooth mesiodistal proportion or if the judges were instead responding to the change in the intratooth width : height ratio.

In another study by Ward, 301 North American dentists were surveyed to determine their preferences of imaged smiles exhibiting different anterior tooth width proportions and the primary proportion influencing their decision. Fifty-seven percent of dentists surveyed preferred the smiles with the 70% RED proportion when evaluating teeth of normal height (Figure 4).[8] The height of the teeth was maintained a constant in this study.[8] Ker and colleagues created a survey using an interactive digital slider bar to produce a visually continuous scale of images. These images were evaluated by 243 laypeople who could move the slider bar to select the ideal for each smile characteristic presented and identify the range of acceptability for the variables. Maxillary lateral incisor width was altered in 0.18-mm increments. The evaluators found the ideal lateral incisor mesiodistal crown width to be 72% the mesiodistal width of the central incisor. Acceptable

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FIGURE 4. Smile representing the preferred 70% recurring esthetic dental proportion (Ward[8]).

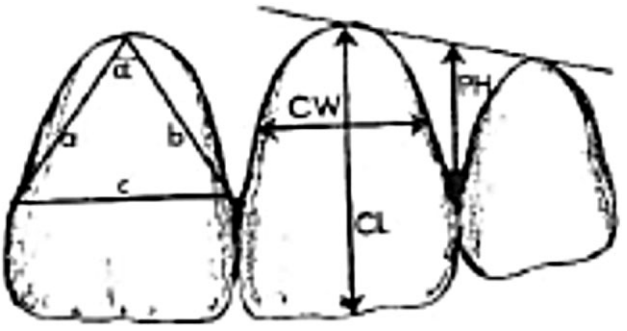

FIGURE 5. Schematic illustration of the width and height measurements (Olsson and colleagues[20]).

lateral incisor crown widths ranged from 53% to 76% the width of the maxillary central incisor.[19]

WIDTH-TO-HEIGHT (W : H) RATIO

The W : H ratio of individual teeth, specifically the maxillary central incisors, is a very important intratooth proportion with significant influence on the balance and esthetics of a smile. Olson and colleagues evaluated the W : H ratio of the maxillary anterior teeth in 108 volunteers and reported W : H ratios ranging from 0.66 to 0.76.[20] However, this study did not exclude subjects with incisal wear, gingival recession, and altered passive eruption. In addition, tooth width was assessed at the junction of the middle and cervical vertical thirds of the tooth (Figure 5). This may not represent the widest mesiodistal portion of the tooth, especially with triangular-shaped teeth. Sterrett and colleagues evaluated tooth height, width, and the W : H ratio of unworn maxillary anterior teeth in 71 subjects and reported a mean W : H ratio of 0.81.[21] Magne and colleagues estimated the W : H ratio on 146 extracted teeth including teeth with and without incisal wear.[22] Unworn central incisors exhibited an average W : H ratio of 0.78, and unworn canines and lateral incisors exhibited an average W : H ratio of 0.73.

On average, Magne and colleagues reported anterior tooth height of unworn teeth to be about 1 mm longer than that reported by Sterrett and colleagues. This may be attributable to their use of the cementoenamel junction (CEJ) as the apical point (anatomic crown height) to measure tooth height, as opposed to the use of the gingival margin (clinical crown height) by Sterrett and colleagues.[21] The relationship between the CEJ and gingival level can show variations within and above the normal range, thus leading to variations in tooth height measurements.[23] A study by Wolfart and colleagues evaluated smiling images that were digitally altered to reflect varying W : H ratios of the maxillary central incisors while keeping the proportions between the widths of the central to lateral and lateral to canine constant. The images were evaluated by 179 laypeople, 24 dentists, and 24 medical students. The judges found W : H ratios of the central incisors between 75% and 85% to be the most esthetic.[24]

Ker and colleagues created a survey by using an interactive digital slider bar to produce a visually continuous scale of images evaluated by 243 laypeople. The raters could move the slider bar to select the ideal for each smile characteristic presented and identify the range of acceptability for the variables. Maxillary anterior tooth height was altered in 0.18-mm increments. The authors concluded that a central incisor crown W : H ratio of 0.73 was considered the most attractive. However, the authors mentioned that the heights of all the maxillary anterior teeth were altered, thus making it difficult to determine if the preferred choice of proportion could solely be attributed to the change in W : H ratio of the maxillary central incisors.[19]

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A recent study by Cooper and colleagues digitally manipulated an image of a posed smile to create three images, which reflected maxillary central incisors with normal form, tooth wear, and delayed apical migration. For the normal tooth form group, maxillary central incisor height was altered by 0.5-mm increments to reflect W : H ratios between 66% and 96%. For the tooth wear group and delayed apical migration group, maxillary central incisor height was altered by 0.5-mm decrements to reflect W : H ratios between 78% and 96%. Tooth height reduction for the delayed apical migration group was represented by 0.5-mm increments of increased gingival display, whereas the tooth wear group displayed no change in gingival display as tooth height was reduced. Images in each set were ranked in order of most to least attractive by 96 evaluators (32 patients, 32 technicians, and 32 dentists). The authors reported a W : H ratio of 0.82 as the most attractive for normal central incisors with a definite trend toward the extremes of very long or very short teeth being less attractive (Figure 6). However, although the authors suggest that all else except central incisor height was kept constant, based on the images, it appears that the height of all the maxillary anterior teeth were also manipulated as the central incisor height was altered. Therefore, it is difficult to delineate if the evaluators' preferences were influenced by alteration of the W : H ratio of all the maxillary anterior teeth or if instead it was just the maxillary central incisor W : H ratio that influenced their choice.[25]

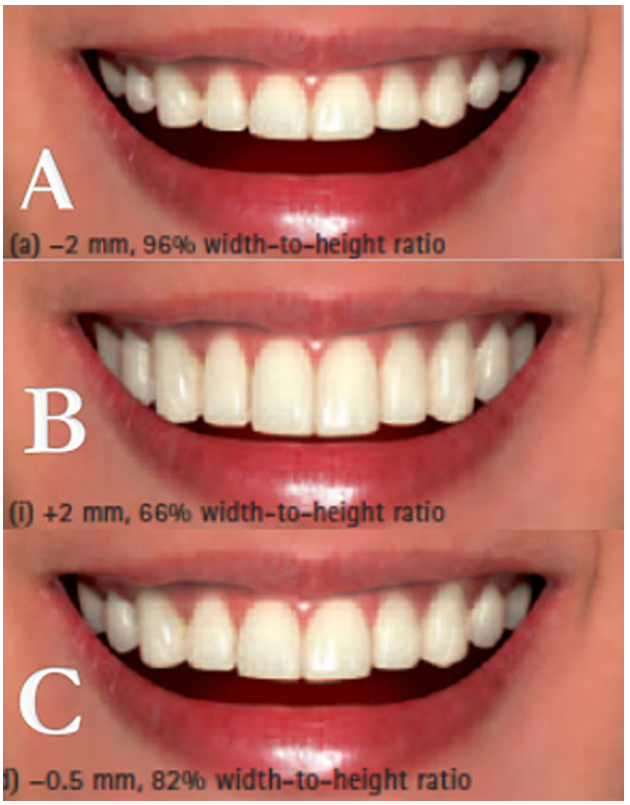

FIGURE 6. Width-to-height ratios of the maxillary central incisors representing: A, short; B, tall; and C, preferred (Cooper and colleagues[25]).

VERTICAL POSITION OF THE MAXILLARY LATERAL INCISOR

In an esthetic smile, it has been suggested that the maxillary central incisors and canines be positioned approximately in level with each other, with the incisal edge of the lateral incisors positioned approximately 1 to 1.5 mm superior (Figure 7).[26] This lateral incisor offset is often reflected in orthodontic bracket placement guides.[27,28] However, the esthetic impact of variations in the vertical position of the maxillary lateral incisor remains unclear. In a study by Bukhary and colleagues, a photograph of a female smile displaying only the lips and teeth was digitally modified to

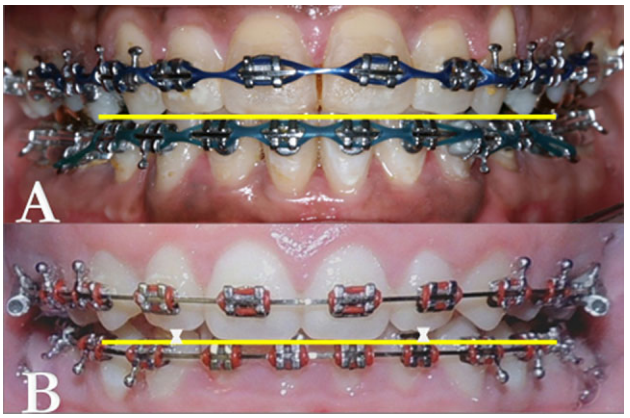

FIGURE 7. A, Minimal lateral incisor vertical offset. B, One mm lateral incisor offset.

produce five images with the lateral incisor 0.5, 1, 1.5, 2, and 2.5 mm shorter than the adjacent central incisor.[12] The height was manipulated by maintaining the gingival margin constant and varying the incisal edge. A maxillary lateral incisor position that was 1 to

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1.5 mm shorter than the central incisor was the most preferred. A study by King and colleagues evaluated the preferences for vertical maxillary lateral incisor position among orthodontists, general dentists, and laypeople. The judges in this study preferred the maxillary lateral incisors to be set about 0.5 mm above the incisal plane and not level with the central incisors and canine.[29] The differing preferences between the two studies may be attributable to the gender of the models used and the nationality of the judges.

THE APPARENT CONTACT DIMENSION

Although there are multiple paradigms that purport to represent optimal maxillary anterior mesiodistal intertooth proportions, the research on ideal vertical intertooth proportions is very scant. One such paradigm, the apparent contact dimension or the ACD, is an important indicator of maxillary anterior vertical tooth proportions. ACD, previously referred to as the "connector zone," is defined as the area where the teeth appear to touch when viewed from the facial aspect at 90 degrees to each interproximal area (Figure 8).[30]

In an esthetic smile, the ACD between the maxillary anterior has been purported to exhibit a proportional relationship relative to the height of the central incisors.[31] This relationship referred to as the 50:40:30 rule defines the ideal ACD between the central incisors as 50% of the height of the central incisors, the ideal ACD between a maxillary lateral incisor and central incisor as 40% of the height of a central incisor, and the ideal ACD between a lateral incisor and a canine as 30% of the height of a central incisor.[31] Proportions of the ACD between the maxillary anterior teeth has a significant influence on tooth shape and the perception of tooth height.

FIGURE 8. The apparent contact dimension (Raj and colleagues[30]).

Raj and colleagues measured the average ACD proportions using diagnostic models of orthodontically treated ($N = 40$) and nontreated ($N = 27$) subjects who were deemed to possess excellent occlusion. Relative to the height of the ipsilateral central incisor, the authors reported ACD proportions of 49%, 38%, and 27% between the central incisors, central and lateral incisors, and the lateral incisor and canine, respectively.[30] A pilot study helped validate the excellent correlation between intraoral ACD measurements versus measurements obtained from diagnostic models. This was the first study to validate the existence of these ACD proportions among subjects with excellent occlusion. In another study, Stappert and colleagues measured the ACD in 20 healthy subjects and reported ACD proportions of 41:32:20% between the maxillary anterior teeth.[32] However, it does not appear as if the ACD was measured at 90 degrees relative to each contact area. Although esthetics is not always perceived at 90 degrees to each interdental area, a standard orientation is necessary to facilitate ACD measurement accuracy and reproducibility.[30] In addition, the authors chose to express ACD proportions relative to the height of the individual teeth instead of the height of the central incisor as reported by other researchers.[30,31,33] Besides, because the ACD is a shared proportion between two adjacent teeth, it is unclear which tooth height was used to establish the reported ACD proportions of 41:32:20%.

The esthetic import of variations in ACD proportions, as perceived by laypeople, is a very important factor to consider during treatment planning any periodontal surgery, orthodontic finishing, or prosthodontic restoration/replacement in the maxillary anterior region. A study by Foulger and colleagues used an image of a smile in which the ACD proportions of the maxillary anterior were digitally manipulated to reflect

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five different ACD proportions between the maxillary anterior teeth.[33] Tooth height and width were maintained constant, and all ACD proportions were measured relative to the height of the central incisor. From central incisor to canine, the ratios studied were: Ideal (50:40:30), Reversed (30:40:50), Equal (50:50:50), Ideal++ (50:30:10), and Reversed++ (10:30:50). The images were ranked in order of attractiveness from "Most Attractive" to "Least Attractive" by 35 dentists, 35 dental technicians, and 35 patients.[33] The authors found that the group representing 50% of the height of the central incisor applied equally between the maxillary anterior teeth (50:50:50) was considered the most esthetic ACD proportion (Figure 9). The group representing ACD proportions of 10:30:50 was found to be the least attractive (Figure 9).[33] However, the authors did not assess the ACD at a standardized orientation as reported by previous investigators.[30] Therefore, owing to the shape of the dental arch, this could lead to progressive measurement errors further from the midline. Nonetheless, it is unlikely that the ACD between the central and lateral incisor would be affected as much. Therefore, within the limitations of this study, it does appear that a 50% ACD proportion (relative to the height of the central incisor) equally applied between the central incisors and the central and lateral incisors was considered attractive by the majority of evaluators. The esthetics of this 50:50 central/lateral incisor ACD proportion could arguably be influenced by lateral incisor height, thus potentially detracting from optimal esthetics when applied to shorter lateral incisors.

FIGURE 9. Apparent contact dimension proportions. A, 50:40:30%; B, 50:50:50%; and C, 10:30:50% the height of the maxillary central incisor (Foulger and colleagues[33]).

As with other esthetic paradigms, it is important to establish the actual prevalence of the specific ACD proportions that are used in the rehabilitation of the maxillary anterior dentition. Pini and colleagues compared ACD proportions in patients with missing lateral incisors treated either with implant-supported restorations or with canine substitution relative to a control group. For the maxillary anterior teeth of the implant-supported group, the authors reported ACD proportions of approximately 57:55:48% of the height of a central incisor.[34] This increase in ACD dimension evident on either side of the maxillary lateral incisor represents an elongated and more apically extended proximal contact area usually seen as a consequence of attempting to compensate for incomplete gingival papillary fill around implant crowns.[35,36] An interproximal area dominated by tooth contact (as reflected by the increased ACD) may not be as esthetic as one where tooth contact and papilla exhibit more equitable proportions.

CONCLUSIONS

Dental attractiveness encompasses an interaction between a range of dimensions and proportions for several of the variables assessed. During the esthetic evaluation of the maxillary anterior teeth, it is important to remember that although a range of factors may connote optimal esthetics, it is nonetheless beneficial to consider the individual characteristics of all the interacting components that contribute to it.

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Some conclusions that may be drawn from this review are:

1 Although the GP has been purported to be an esthetic proportion for several decades, the plethora of evidence does not support its routine use, except perhaps during the restoration of excessively tall teeth
2 Intertooth mesiodistal RED proportions of 70% to 80% applied across the maxillary anterior teeth are considered to be the most esthetic
3 The optimal W : H ratio for maxillary central incisors ranges from 0.75 to 0.8
4 Maxillary lateral incisors positioned 0.5 to 1 mm above the maxillary incisal plane are considered to be the most attractive
5 Within the context of normal tooth height and optimal embrasure form, ACD proportions of 50:40:30 (relative to the height of a maxillary central incisor) applied across the maxillary anterior teeth appear to represent optimal intertooth vertical tooth proportions

These factors play an important role in the interdisciplinary management of anterior dental esthetics and can serve as a useful guideline to the treating clinician. Further research on the specific hierarchy of these esthetic dental proportions and their clinical applications would be very useful.

DISCLOSURE

The author does not have any financial interest in any of the companies whose products are included in this article.

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Reprint requests: Vishnu Raj, BDS, MSFS, MS, 127 E Riverside Drive, Austin, TX 78704, USA; Tel.: 919-259-2360;
email: rajv@livemail.uthscsa.edu

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