Geometric and Mathematical Proportions and their Relations to Maxillary Anterior Teeth

Mohammed Ali Fayyad, PhD; Kifah Dafi Jamani, PhD;
Jamal Aqrabawi, DSc

Abstract

Aim: One of the critical aspects of esthetic dentistry is creating geometric or mathematical proportions to relate the successive widths of the anterior teeth. The golden proportion, the recurring esthetic dental (RED) proportion, and the golden percentage are theories introduced in this field. The aim of this study was to investigate the existence of the golden proportion, RED proportion, and the golden percentage between the widths of the maxillary anterior teeth in individuals with natural dentition.

Methods and Materials: Standardized frontal images of 376 dental student smiles were captured. The images were transferred to a personal computer, the widths of the maxillary anterior teeth were measured, and calculations were made according to each of the above mentioned theories. The data were statistically analyzed using paired student T-test (level of significance P<0.05).

Results: The golden proportion was found to be accurate between the width of the right central and lateral incisors in 31.3% of men and 27.1% of women. The values of the RED proportion were not constant, and the farther the one moves distally from the midline the higher the values. Furthermore, the results revealed the golden percentage was rather constant in terms of relative tooth width. The width of the central incisor

represents 23%, the lateral incisor 15%, and the canine 12% of the width of the six maxillary anterior teeth as viewed from the front.

Conclusions: Both the golden proportion and the RED proportion are unsuitable methods to relate the successive widths of the maxillary anterior teeth. However, the golden percentage theory seems to be applicable to relate the successive widths of the maxillary anterior teeth if percentages are adjusted taking into consideration the ethnicity of the population.

Keywords: Esthetic dentistry, golden proportion, recurring esthetic dental (RED) proportion, golden percentage

Introduction

In the search to create esthetically pleasing restorations, several authors have suggested the use of geometric or mathematic proportions to describe the relationship between maxillary anterior teeth across the midline. Lombardi[1] was the first to suggest the application of the golden proportion in dentistry. He stated the golden proportion was" too strong" for use in determining tooth size. In addition, he described the use of a "repeated ratio" in the maxillary anterior teeth which implies in an optimized dentofacial composition the lateral to central incisor width and the canine to lateral incisor width are repeated in proportion. Levin[2] suggested the golden proportion to relate the successive width of the anterior teeth as viewed from the labial aspect. He stated the width of the central incisor should be in "golden proportion" to the width of the lateral incisor and the lateral incisor be in golden proportion to the width of the canine. In addition, he devised a grid with the spaces in golden proportion and advocated the use of this grid to evaluate and develop harmonious proportions of teeth. However, in a more recent
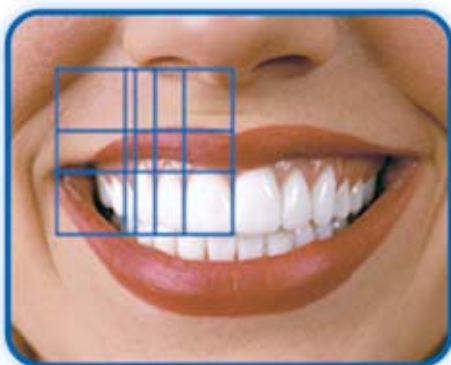
study it was reported the golden proportion did not exist between the widths of the maxillary anterior teeth in individuals who have an esthetic smile.[3] Ward[4] suggested the recurring esthetic dental (RED) proportion as a result of his study in which he described the RED proportion as the proportion of the successive width of the teeth remaining constant when progressing distally from the midline. Snow[5] considered a bilateral analysis of apparent individual tooth width as a percentage of the total apparent width of the six anterior teeth. He proposed the golden percentage wherein the proportional width of each tooth should be: canine 10%, lateral 15%, central 25%, central 25%, lateral 15%, and canine 10% of the total distance across the anterior segment in order to achieve an esthetically pleasing smile.

Preston[6] studied the relationship of the golden proportion to the perspective dimension of the maxillary dentition anteroposteriorly. He found only 17% of the samples studied actually had a golden proportion between the perceived width of the maxillary central and lateral incisors.

Gillen et al.,[7] in their study to determine the average dimension of the six maxillary anterior teeth in a targeted population, concluded the golden proportion was not found to correlate with any of the calculated ratios. However, Al-Wazan[8] suggested the use of intercanthal distance as a preliminary method for determining the width of the maxillary anterior teeth.

Rosenstiel et al.[9] performed a web-based study using computer-manipulated images of the six maxillary anterior teeth. Manipulation was

carried out for the relative proportion of the central incisors, lateral incisors, and canines according to the proportions 62% (or "golden proportion"), 70%, 80%, and "normal" or not further altered. Dentists were asked via e-mail to visit the web page and complete a survey. They reported dentists preferred the 80% proportion when viewing short or very short teeth and the golden proportion when viewing very tall teeth. The purpose of this study was to investigate the existence of the golden proportion, RED proportion, and the golden percentage between the widths of the maxillary anterior teeth in individuals with natural dentition.

Methods and Materials

Subject Selection
The sample size for this study consisted of 376 dental students, 193 men and 183 women, ranging in age from 20 to 23 years. The selection criteria required the subjects to have all of their natural anterior teeth, no history of orthodontic treatment or tooth size alteration, and be of Arabic origin.

Image Capture
A standardized frontal image of each subject's face was taken using a digital camera (Epson Photo PC 3000Z, Seiko Epson Corporation, Nagano-ken, Japan). The subject's head was positioned so the Frankfort horizontal plane was parallel to the floor and the mid-sagittal plane of the head was aligned with the center of the

camera lens. The camera was positioned and adjusted so as to obtain a sharp image of the face from the tip of the nose to the tip of the chin. In this position the focal plane was 450 mm from the soft tissue with the camera lens focused on the lips. The subject was asked to smile, and the image was captured during the smile. The images were downloaded on to a personal computer. All measurements were performed utilizing the Coral DRAW version 10 software (Coral Corporation, Ottawa, Ontario, Canada), and all measurements were performed by one investigator. To improve upon image accuracy, a zoom function of the program was used to allow more precise measurement from pixel to pixel (Figure 1).

Measurements
The golden proportion for each subject was measured as follows: the width of the central incisor was multiplied by 62% and compared with the width of the adjacent lateral incisor. Similar values mean the width of the central incisor is in golden proportion to the width of the lateral incisor. In comparing the width of the lateral incisor multiplied by 62% with the width of the adjacent canine it can be determined if the width of the lateral incisor is in golden proportion to the width of canine.

The RED proportion was calculated by dividing the width of each lateral incisor by the width of the adjacent central incisor and multiplying by 100. Similarly, the width of each canine was divided by the width of the adjacent lateral incisor
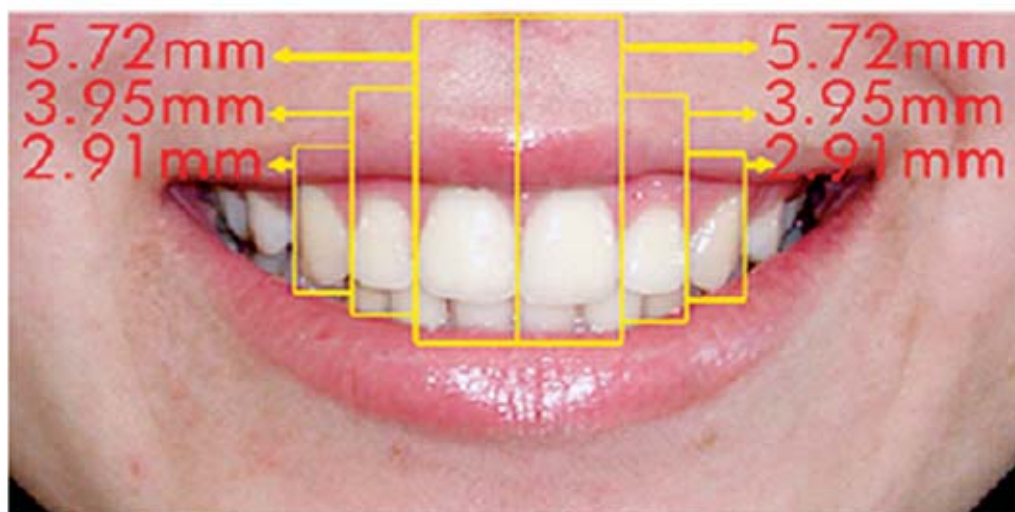

Figure 1. Photograph showing the method of measurements.

and multiplied by 100. If the resultant values are constant, it means the central incisor, lateral incisor, and canine are in RED proportion.

The golden percentage was calculated by dividing the width of each central incisor, lateral incisor, and canine by the total width of all six maxillary anterior teeth, multiplied by 100 in order to obtain the golden percentage for each tooth. If the values from canine to canine were 10%, 15%, 25%, 25%, 15%, and 10%, it means the six maxillary anterior teeth are in golden percentage. The data was statistically analyzed using the paired student T-test P< 0.05.

Results

The data collected from the 376 subjects revealed the existence of a statistically significant difference between the width of the left and right central incisors and a statistically significant difference between left and right lateral incisors. However, no statistically significant differences were observed between left and right canines in female subjects. For males, the data revealed there are no statistically significant differences between the widths of the left and right centrals, the left and right laterals, and the left and right canine.

The data revealed 31.3% of males and 27.1% of females have the widths of their right central incisors in golden proportion to the width of their right lateral incisors (Figures 2 and 3).

However, 13.1% of male subjects and 11.8% of female subjects have the widths of their right lateral incisors in golden proportion to the widths of their right canines (Figures 4 and 5).

Moreover, the data shows 38.2% of the male subjects and 30.5% of the female subjects have the widths of their left central incisors in golden proportion to the widths of the left lateral incisors (Figures 6 and 7), while 14.7% of males and 15.2% of females have the widths of the left lateral incisors in golden proportion to the widths of their left canines (Figures 8 and 9).

The mean value and standard deviation for the RED proportions for males and females are listed in Table 1. The values show the RED proportion is not constant when progressing distally as suggested by Ward[4] and the more distal the higher the values. Paired sample T-test showed there was a statistically significant difference between the RED proportion of men and women (P=.008) subjects in all teeth except for the relation between left canine and left lateral incisors (P=.354) in both groups. The mean value and standard deviation for the golden percentage for men and women are listed in Table 2. Figures 10 and 11 show the relationship between the golden percentage suggested by Snow[5] and the actual percentage for each anterior tooth for men and women, respectively.
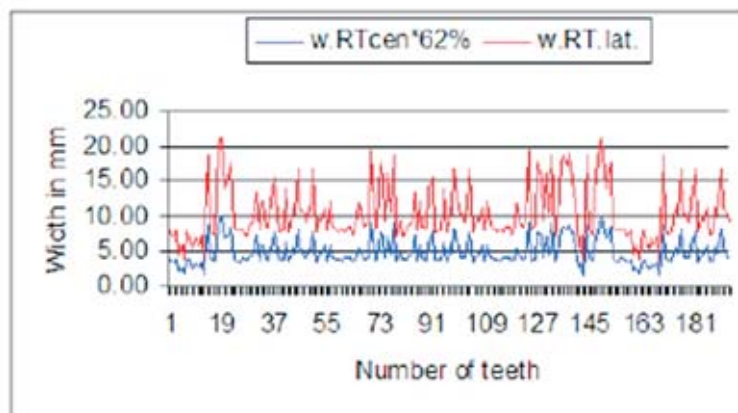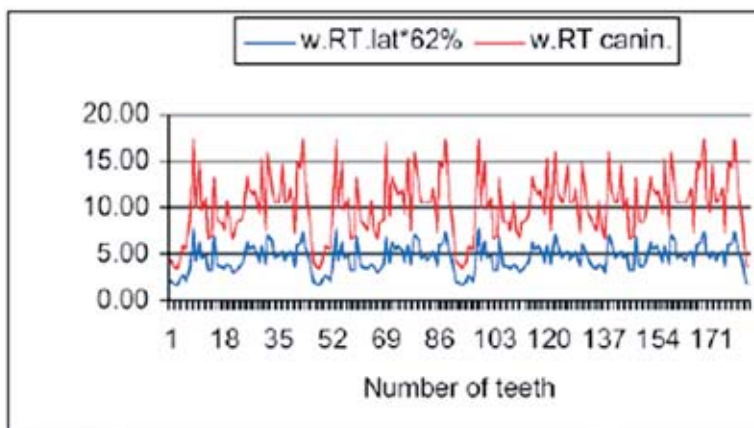

Figure 2. Golden proportion relationship of (right central incisor x 62%, blue line) to the right lateral incisor (red line) in male subjects (overlapping of red and blue lines represent the teeth in golden proportion).
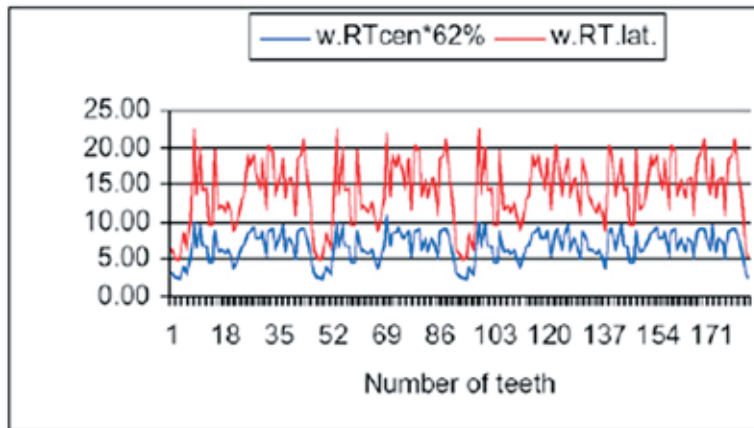
Figure 3. Golden proportion relationship of (right central incisor x 62%, blue line) to the right lateral incisor (red line) in female subjects (overlapping of red and blue lines represent the teeth in golden proportion).
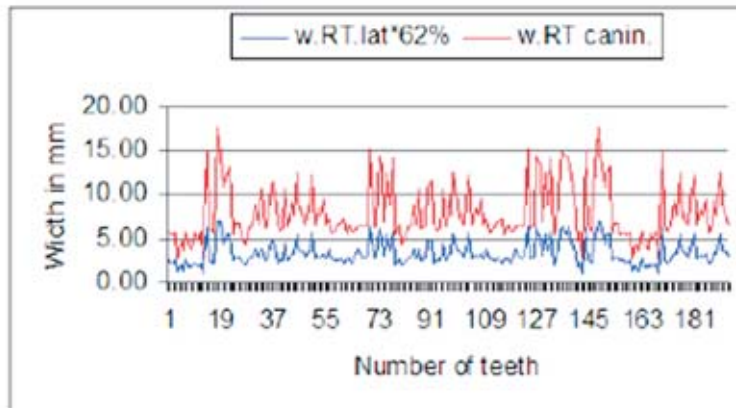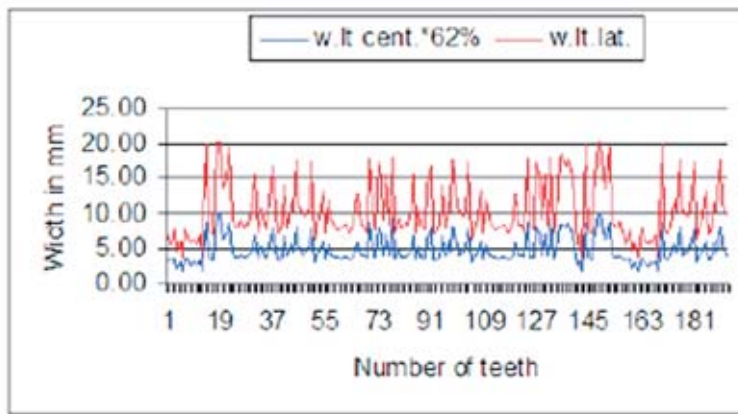

Figure 4. Golden proportion relationship of (right lateral incisor x 62%, blue line) to the right lateral incisor (red line) in male subjects (overlapping of red and blue lines represent the teeth in golden proportion).
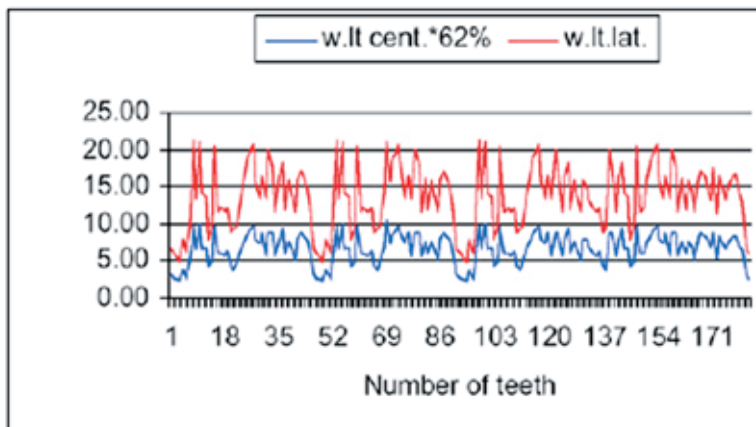

Figure 5. Golden proportion relationship of (right lateral incisor x 62%, blue line) to the right canine (red line) in female subjects (overlapping of red and blue lines represent the teeth in golden proportion).
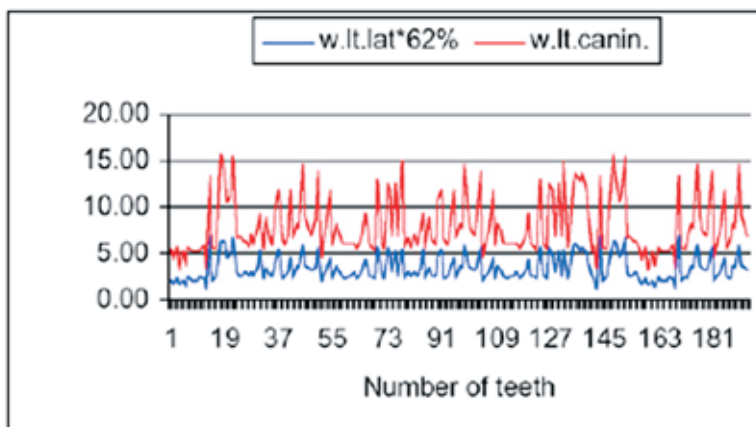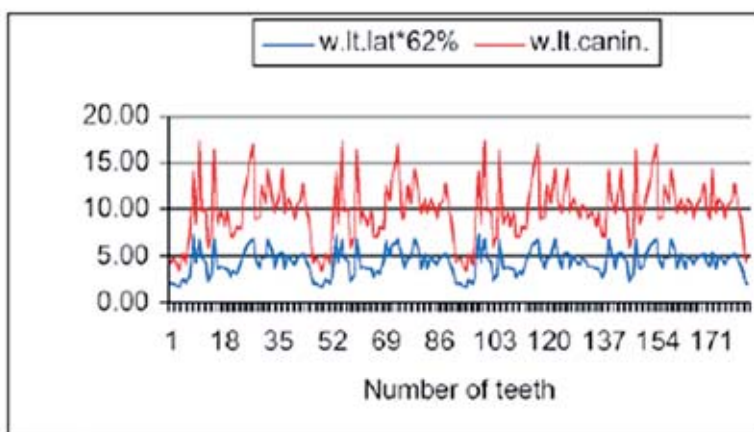
Figure 6. Golden proportion relationship of (left central incisor x 62%, blue line) to the left lateral incisor (red line) in male subjects (overlapping of red and blue lines represent the teeth in golden proportion).

Figure 7. Golden proportion relationship of (left central incisor x 62%, blue line) to the right lateral incisor (red line) in female subjects (overlapping of red and blue lines represent the teeth in golden proportion).

Figure 8. Golden proportion relationship of (left lateral incisor x 62%, blue line) to the right lateral incisor (red line) in male subjects (overlapping of red and blue lines represent the teeth in golden proportion golden proportion).

Figure 9. Golden proportion relationship of (left lateral incisor x 62%, red line) to the left canine (blue line) in female subjects (overlapping of red and blue lines represent the teeth in golden proportion).

**Table 1. The mean value and standard deviation of the RED proportion for male and female subjects.**

Variable	Number	Minimum	Maximum	SD
Right lateral / Right central (Female)	183	51.00	81.00	6.74
Right canine / Right lateral (Female)	183	49.00	92.00	8.07
Left lateral / Left central (Female)	183	54.00	110.00	12.50
Left canine / Left lateral (Female)	183	47.00	110.00	15.09
Right lateral / Right central (Male)	193	47.00	86.00	7.10
Right canine / Right lateral (Male)	193	39.00	100.00	11.46
Left lateral / Left central (Male)	193	49.00	82.00	5.92
Left canine / Left lateral (Male)	193	46.00	100.00	10.26

Table 2. The mean value and standard deviation of the golden percentage for male and female subjects.

Variable	Number	Minimum	Maximum	Mean	SD
Right Canine-Female	183	8.00	15.00	11.89	1.64
Right Lateral-Female	183	11.00	17.00	15.24	1.32
Right Central-Female	183	21.00	26.00	23.00	1.13
Left Central-Female	183	20.00	26.00	22.80	1.25
Left Lateral-Female	183	12.00	17.00	14.64	1.41
Left Canine-Female	183	8.00	15.00	11.69	1.74
Right Canine-Male	193	6.00	14.00	11.66	1.55
Right Lateral-Male	193	12.00	17.00	15.09	1.00
Right Central-Male	193	20.00	26.00	22.68	1.31
Left Central-Male	193	13.00	26.00	22.60	1.34
Left Lateral-Male	193	10.00	16.00	14.59	1.07
Left Canine-Male	193	8.00	14.00	11.87	1.40
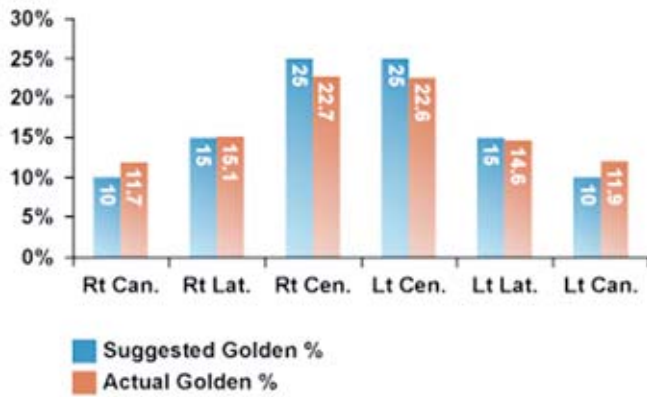
Figure 10. The relationship between the suggested golden percentage and that found in this study for male subjects.
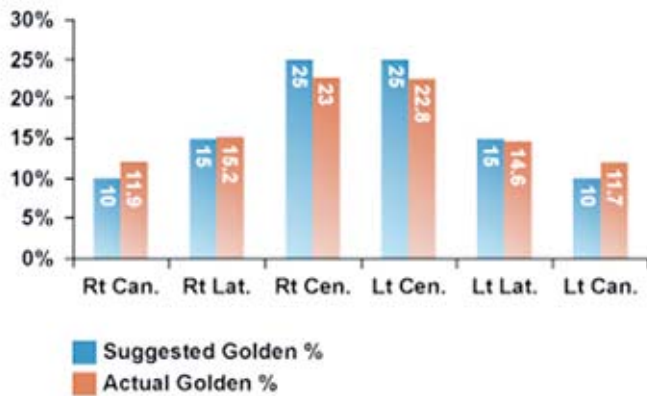
Figure 11. Relationship between the suggested golden percentage and that found in this study for female subjects.

Discussion

It is important to determine a mathematical or geometrical relationship between teeth in order to achieve an esthetic restorative result. It would be helpful if statistically reliable relationships existed to support existing relationship theories. However, the results of this investigation found no reliable relationships in the average natural dentition. These findings are supported by other investigations.[3,6,7]

Gillen et al.[7] found no correlation exists between tooth dimension and golden proportion. Although in their study the values of tooth width were not measured from frontal view as the theory implies.

The results of the present investigation revealed the highest value for golden proportion was 38.2% between the left central incisor and the

left lateral incisor for men subjects. These values are higher than those reported by Preston[7] who found that golden proportion existed in the relationship between the maxillary central and lateral incisors in only 17% of the casts of patients studied from frontal view. The difference in results may be attributed to several factors, the least of which are differences in research methodology as well as the differences in the ethnicities of the subjects. The present study utilized data from Arab subjects, while Preston's sample consisted of American subjects. This might also explain differences in Preston's conclusions regarding the absence of golden proportion between lateral incisor and canine widths, while in the present study the highest value for golden proportion existed between the left lateral incisor and left canine of women subjects (15.2%).
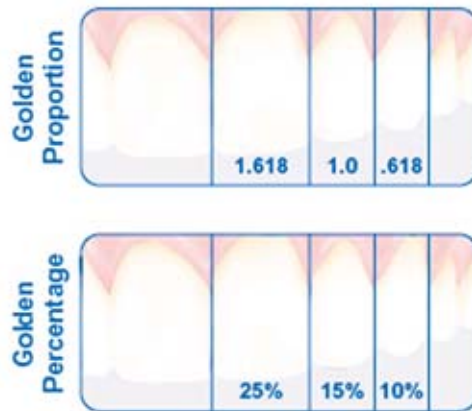
With respect to the RED proportion, the results of this investigation showed the ratio of the width of the maxillary lateral incisors to the width of the central incisors fall between 67.28% (female right lateral incisors to the right central incisors) and 78.36% (female left lateral incisors to the left central incisors). These findings are in close agreement with previous studies[3,6,7] that evaluated the ratio of the width of the maxillary lateral to the central incisors in sample patients and reported a mean proportion of 66% to 78%.

In the present study the ratio between central and lateral incisors and between lateral incisors and canines are not constant as suggested by Ward.[4] Hence, there is no evidence in this study to support the RED proportion theory as applied to the natural dentition. As for using the golden

percentage theory to correlate the six anterior teeth, the result of the present investigation suggests the mean values for golden percentage for women's central incisors has a range of 22.8-23.0%, while that for men is 22.6%. These figures are slightly lower than those suggested by Snow[5] who estimated a value of 25% for central incisors. However, the mean values of golden percentage for lateral incisors ranged from 14.6-15.2% for women and 14.59-15.09% for men.

These figures can be considered to be in agreement with those suggested by Snow[5] who recommended a value of 15% as the golden percentage for lateral incisors. With respect to the golden percentage of canines, the results of this study showed mean values of 11.69-11.89% for female canines and 11.66-11.87% for males. These figures are slightly higher than those suggested by Snow[5] who recommended a golden percentage value of 10% for canines. In general, it appears the width of central incisors is slightly smaller and the width of canines is slightly larger than those suggested by the golden percentage theory. A value of 23% for centrals, 15% for laterals, and 12% for canines can be adopted as these percentages are more applicable to natural dentition.

Conclusions

In light of the results of this investigation the following conclusions can be derived:

1. The golden proportion was not found to exist between perceived maxillary anterior teeth on natural dentition.
2. The RED proportion was not found to exist between the six maxillary anterior teeth.
3. The values suggested in the golden percentage were not applicable on the subjects of this study. However, a slight modification of these percentages can be adopted taking into consideration the ethnicity differences of the subjects in this study the values obtained were 12%, 15%, 23%, 23%, 15%, and 12%.
4. Gender has no statistically significant effect when the golden proportion, the golden percentage, and the RED were applied.
5. In order to establish objectively quantifiable width ratio between maxillary anterior teeth, ethnic differences should be considered to determine exactly what percentages are truly golden.

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About the Authors

Mohammed Ali Fayyad, PhD

Dr. Ali Fayyad is a Professor and Chairman of the Department of Conservative Dentistry and Prosthodontics and the Director of the Graduate Prosthodontics Program in the Faculty of Dentistry at the University of Jordan in Amman, Jordan.

e-mail: dr-zoubi@ju.edu.jo

Kifah Dafi Jamani, PhD

Dr. Jamani is an Associate Professor in the Department of Conservative Dentistry and Prosthodontics. She is the former Vice Dean for Graduate Studies and Scientific Research in the Faculty of Dentistry at the University of Jordan in Amman, Jordan.

e-mail: kifah@ ju.edu.jo

Jamal Aqrabawi, DSc

Dr. Aqrabawi is an Associate Professor of Endodontics in the Department of Conservative Dentistry and Prosthodontics of the Faculty of Dentistry at the University of Jordan in Amman, Jordan. He is a former Assistant Professor at Boston University in Boston, MA, USA.

e-mail: Jamal58@go.com.jo