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Analysis of Golden Proportion, Recurring Esthetic Dental Proportion and Golden Percentage in Adult Saudi Arabian Population

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ABSTRACT

Objectives: The objective of the current study was to analyze the proportions of maxillary anterior teeth with respect to golden proportion (GP), recurring esthetic dental proportion (RED), in addition to width/height (W/H) and golden percentage ratios in adult Saudi population.

Materials and Methods: Maxillary gypsum casts obtained from 200 adults were photographed using standardized frontal digital imaging. The apparent and actual anterior teeth dimensions were measured using Image J software and digital calipers, respectively, for the calculation of existence of GP, RED, W/H ratio and golden percentage ratio. Calculated ratios of the apparent widths of the teeth were statistically analyzed using descriptive analysis and compared with their respective esthetic proportion values using a one sample t-test at $\alpha < 0.05$.

Results: The anterior teeth exhibited significantly greater width and length in males than in females ($P < 0.05$). The proportions of the maxillary incisors deviated significantly from the GP (62%), except for the left lateral incisor/left central incisor ratio in males. Additionally, these proportions differed significantly from the RED (70%) and golden percentage. Moreover, the W/H ratio of the maxillary central incisor has statistically exceeded the established optimal value of 80%.

Conclusions: The GP was exclusively observed in maxillary left lateral incisor/left central incisor, and only in males. All other measured proportions diverged significantly from GP and RED. Furthermore, the W/H ratio for maxillary central incisor significantly differed from the ideal 80%, in both genders.

Keywords: Golden proportion, Recurrent dental proportion, Golden percentage, Width/length ration, Maxillary anterior teeth, Saudi Arabian adults.

1. Introduction

The prime importance of dental esthetics cannot be neglected or overemphasized, because smile is consistently portrayed as the most expressive and striking facial feature. Proportion, harmony and

symmetry are considered the pillars of an appropriately designed smile (1). It is thus deemed crucial to evaluate the mesiodistal and vertical tooth proportions prior to designing an appealing esthetic smile.

Maxillary anterior teeth size and proportions may play

essential roles in a balanced esthetically pleasing smile. Hence, several guidelines based on teeth size and proportions were proposed to enhance dental esthetics including the golden proportion (GP) (2), the recurring esthetic dental proportion (RED) (3), width-to-height (W/H) ratio of individual teeth (4), the apparent contact dimension (5) and more recently, the gauge proportion (6).

Golden proportion assumes a distally successive decrease in visible width of maxillary anterior teeth with a ratio of 62% for each tooth compared to its mesial neighboring tooth when viewed from front, and suggests that this repetitive proportion would enhance the dental and facial esthetics (7). Multiple studies have documented the infrequent occurrence of the GP in maxillary anterior teeth across numerous populations, including Malaysians, Portuguese, Nepalese, Indian, Turkish, Pakistani, Jordanian and Spanish populations (8-16). Nevertheless, its occurrence was documented in Irish dental students, specifically between their lateral and central incisor teeth (17), corroborated further by similar findings amongst both Kurdish and Arab Iraqi dental students (18). Although the effect of ethnicity on the existence of GP was not conclusively evident (8,19), the variations in lateral incisor dimensions between Arabs and Kurds suggested that GP can be useful in planning esthetic restorations or replacement of maxillary anterior teeth, but only after taking racial and ethnic factors into consideration (18).

The RED proportion is another accepted esthetic standard for esthetic rations between maxillary anterior teeth. It was advocated that a proportion of 70%, proceeding distally, is esthetically agreeable (20). However, published data has demonstrated that dentists preferred smiles with RED of 80% for extremely short teeth, 62% for extremely long teeth and 70% for teeth with normal height (21). The literature presents conflicting results on RED proportion. One report suggested proportioning maxillary anterior teeth to conform to RED proportions (22), while, another study found RED proportions to exist only in Nepalese females who are of Mongolian origin (10), highlighting the significant role of ethnicity in determining teeth size and proportions. However, a study of an Indian population found no distinct relationships between golden proportion and RED and smiles perceived as esthetic (11).

Golden percentage is another esthetic paradigm that was introduced based on mathematical proportions

obtained by dividing the width of anterior maxillary tooth by the combined widths of all the six maxillary anterior teeth when perceived from frontal view. Accordingly, the proportions considered esthetically pleasing suggest that the width of maxillary central incisor is 25% of the combined width of maxillary anterior teeth; lateral incisor 15%; and canine 10% (19). This was also proposed as a guideline to design maxillary anterior teeth alignment. However, in a recent systemic review that included 12 studies from Asia, 2 from Europe, and 2 from the United Kingdom, concluded that golden percentage values were not found, where the mean predicted dental percentage was either larger or smaller than the successive widths of maxillary natural anterior teeth. Hence, the authors recommended that dental ratios should be set on a racial and ethnic basis for a given population (23).

Regarding width and height ratio, it has been assumed that 0.75 to 0.80 is the most widely favored (24-26), with one specific study proposing that the height and width coronal ratio of maxillary anterior teeth should not exceed 78% (6). Differences between males and females are also frequently cited (26-30). Additionally, to enhance esthetic, lateral incisor is recommended to be positioned 0.5 to 1 mm above the incisal plane (20).

Studying the esthetic beliefs and standards in a particular population cannot be underscored if the uniqueness of different cultures and ethnicities is to be respected. Furthermore, this can be of prime importance in establishing esthetic guidelines to practitioners to help provide the best esthetic oral care most suitable to a particular population adjusted for racial modifying factors, as previously recommended (15).

To the best of our knowledge, limited studies investigated the relationship between maxillary anterior teeth and different esthetic proportions in young Saudi Arabian adults (28,29). This study, therefore, aimed to mathematically evaluate maxillary anterior teeth within this population, in relation to GP, golden percentage, and the W/H ratio of central incisor teeth. As frequently referenced, these proportions do not occur frequently, thus cross-ethnic differences could be anticipated. Hence, the resultant data could serve as a guide to esthetic dentists providing esthetic dental rehabilitation to this specific population.

The tested null hypotheses were that there are no differences between proportions of maxillary anterior

teeth of Saudi Arabian adults and 1) GP value of 62%, 2) RED value of 70%, 3) golden percentage, 4) would have a W/H ratio of 80% and 5) no difference in maxillary anterior teeth width and height between males and females.

2. Materials and Methods

This study is a quantitative, observational and cross-sectional descriptive investigation. Dental students at King Saud bin Abdulaziz University for Health Sciences were invited to participate in the current study. Sample size calculation was conducted using G-power software applied for the one sample t-test statistical design of this study. Assuming a small effect size of 0.2, a minimum sample size of 156 subjects was needed to guarantee a statistical power of 80% (31).

A total of 200 dental students (100 males and 100 females) who met the set inclusion criteria were recruited. Students who are of Saudi origin, 18-24 years of age, with complete intact set of maxillary and mandibular anterior teeth, no previous orthodontic treatment, with no signs of crown fracture or incisal wear, no restorations that change the original tooth dimension, no sign of positive eruption or congenital anomaly, no sign of intrusions or extrusions, severe maxillary canting, malformations or developmental anomalies, and had no prosthetic reconstruction, implants or history of periodontal disease were recruited in the study. Students who do not meet the aforementioned inclusion criteria in addition to those with spacing, or history of allergy to irreversible hydrocolloid impression material were excluded.

The study protocol was conducted after obtaining the approval of the institutional Ethics and Review Board. The study was explicitly explained to the recruited subjects. After obtaining the informed consent, full maxillary impressions were made with irreversible hydrocolloid impression material (Hydrogum Thixotropic, Zhermack, Italy) using plastic stock tray (Impression Trays, Dentaurum, Ispringen, Germany). The tray was sprayed with a thin layer of adhesive and allowed to dry out for 5 minutes before loading with impression material. After removal from the mouth, impression was washed copiously with tap water for at least 30 seconds, disinfected, and visually inspected for any imperfections. Impressions were then numbered using a unique code for each subject, and then immediately poured in dental stone. The impressions

were gently removed 3-4 hours after casting. The resultant casts were trimmed, air dried, numbered and allowed to bench dry for 24 hours, then stored in special cardboard boxes.

Casts collected were used to perform the measurements that included the length and width of all maxillary anterior teeth using digital calipers (Kreator KRT705004, Lier, Belgium). The length of the clinical crown was measured from the most apical point to the incisal edge parallel to the long axis of the tooth. Width was measured between the mesial and distal contact points along a line perpendicular to the longitudinal axis of the tooth. All measurements were made by a single operator. An average of 3 readings was obtained for each measurement. The actual width and length measurements were used to evaluate W/H ratios.

Frontal view digital photographs were taken for all the casts, following a standardized protocol. The frontal view was captured with a camera that was mounted directly perpendicular to the plane formed by the labial aspects of the central incisors, with the mid incisal point located in the image midpoint (Figure 1).

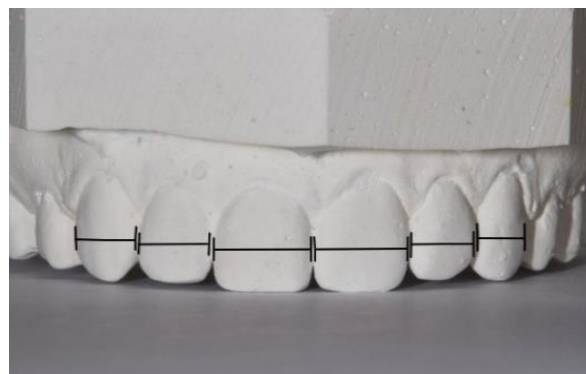


Figure 1: Apparent mesiodistal width of anterior teeth from frontal view

All photographs were taken under a standard light source with a constant focal distance of 60 cm using a digital camera (Canon 60D) set with f 1/2.8 and Sigma macro lens 105 mm connected with wired macro ring flash light. The apparent width of maxillary anterior teeth was calculated by an ImageJ software (National Institutes of Health) (32).

The collected data were used to measure different ratios including GP, golden percentage and W/H ratio.

Statistical analysis has been performed with statistical software (SPSS, version 25). Descriptive statistics have been conducted for all data. Paired t-test

was used to compare between the measurements of right and left maxillary anterior teeth. Independent t-test has been performed to detect any gender differences, and one sample t-test was employed to compare the W/H ratios of central incisor to the ration of 80% and the relationship of the measurements obtained with GP of 62%, RED of 70% and golden percentage. All tests were set at a 0.05 level of significance.

3. Results

The mean widths and heights of all maxillary anterior teeth are presented in Table 1. Both width and height were significantly greater in males than in

females (P<.001), and were greatest in right lateral incisor tooth, in both height (Males, 9.18; Females, 7.95) and width (Males, 8.65; Females, 6.64) dimensions.

The results of the one-sample t-test indicated that the ratio of apparent width of maxillary lateral incisors to central incisors and that of canines to lateral incisors were significantly different from the GP in both genders (Table 2). The only exception was the ratio of apparent width of left lateral incisor to left central incisor in males, where the ratio was not statistically different from the GP (P>.05). The other ratios on the right and left sides were comparable in males and females.

Table 1: Width and height of maxillary anterior teeth

Tooth	Females		Males		P
	Mean	SD	Mean	SD	
Height					
RCI	9.55	0.81	10.19	0.75	<.001
LCI	9.59	0.82	10.14	0.75	<.001
RLI	7.95	0.78	9.18	0.41	<.001
LLI	7.99	0.80	8.64	0.73	<.001
RC	8.89	0.78	9.53	0.78	<.001
LC	8.94	0.87	9.43	0.80	<.001
Width					
RCI	8.71	0.57	9.17	0.40	<.001
LCI	8.63	0.57	9.17	0.44	<.001
RLI	6.64	0.58	8.65	0.75	<.001
LLI	6.69	0.62	7.24	0.33	<.001
RC	7.52	0.52	8.36	0.39	<.001
LC	7.56	0.52	8.28	0.36	<.001

RCI: Right central incisor; LCI: Left central incisor; RLI: Right lateral incisor; LLI: Left lateral incisor; RC: Right canine; LC: Left canine.

Table 2: Golden proportions assessment in both genders

Proportion	Right		95% Confidence interval	p	Left		95% Confidence interval	P
	Mean	SD			Mean	SD		
Females								
LI/CI	.66	.09	.018-.056	<.001	.66	.09	.023-.057	<.001
C/LI	.81	.13	.160-.216	<.001	.79	.12	.147-.195	<.001
Males								
LI/CI	.66	.09	.022-.060	<.001	.62	.06	-.015-.010	.71
C/LI	.72	.13	.081-.134	<.001	.73	.090	.090--.137	<.001

CI: Central incisor; LI: Lateral incisor; C: Canine.

Recurring esthetic dental proportion has not been found between adjacent anterior teeth in both genders and sides (Table 3). All RED values obtained were

statistically different from 70%, the criterion standard of RED.

Table 3: Recurrent esthetic dental ratios in both genders and sides

Proportion	Right			p	Left			P
	Mean	SD	95% Confidence interval		Mean	SD	95% Confidence interval	
Females								
LI/CI	.66	.09	-.061- .024	<.001	.66	.09	-.057- .024	<.001
C/LI	.81	.13	.080-.136	<.001	.79	.12	.067- .115	<.001
Males								
LI/CI	.66	.09	-.039- .058	<.001	.62	.06	-.095- .069	<.001
C/LI	.72	.13	.001-.054	.04	.73	.09	.010- .057	<.001

CI: Central incisor; LI: Lateral incisor; C: Canine.

The W/H ratio of the central incisor, lateral incisor and canine teeth in both sides was statistically different from the predicted ideal 80% ratio, in both males and females (Table 4). The W/H ratio of the central incisor

specifically was significantly the highest compared to the predicted W/H ratio in both genders (males 91%, females 92%). However, no differences were detected between right and left side ratios.

Table 4: Width/height ratio analysis of maxillary anterior teeth

W/H ratio	Right			p	Left			P
	Mean	SD	95% Confidence interval		Mean	SD	95% Confidence interval	
Females								
CI	.92	.08	.101-.131	<.001	.92	.07	.089-.118	<.001
LI	.84	.08	.024-.055	<.001	.84	.09	.024-.059	<.001
C	.86 ^a	.07	.041-.069	<.001	.85 ^a	.09	.036-.068	<.001
Males								
CI	.91	.08	.097-.121	<.001	.91	.08	.096-.127	<.001
LI	.83	.07	.019-.049	<.001	.84	.08	.024-.054	<.001
C	.88 ^b	.06	.071-.098	<.001	.88 ^b	.07	.069-.098	<.001

CI: Central incisor; LI: Lateral incisor; C: Canine.

* Values at the same column with different superscript letters are significantly different.

Based on one-sample t-test analysis, golden percentage existed only in right and left lateral incisor teeth in females. However, other teeth deviated

significantly from the considered ideal golden percentage. Moreover, there were no differences between the right and left sides in both genders (Table 5).

Table 5: Golden percentage analysis of maxillary anterior teeth in both genders and sides

Proportion	Right			p	Left			P
	Mean	SD	95% Confidence interval		Mean	SD	95% Confidence interval	
Females								
CI	.22	.015	.018-.056	<.001	.23	.014	.024-.018	<.001
LI	.15	.014	.003-.002	0.59	.15	0.014	.0005-.005	.12
C	.12	.015	.017-.023	<.001	.12	.013	.0156-.0127	<.001
Males								
CI	.24	.015	.014-.008	<.001	.24	.012	.0142-.009	<.001
LI	.16	.017	.003-.009	<.001	.14	.012	.005-.001	<.01
C	.11	.015	.009-.015	<.001	.11	.014	.004-.009	<.001

CI: Central incisor; LI: Lateral incisor; C: Canine.

4. Discussion

Dental esthetics depends on different anthropometric relationships and ratios among teeth. These geometrical relationships form the basis for the acknowledged esthetic theories and can be employed to optimize esthetic dental treatment outcomes. In contemporary esthetic dentistry, the micro esthetics of anterior teeth, such as dental morphology, inclination of the teeth, gingival color, gingival zenith, contact points, plays a detrimental role in defining facial attractiveness (13).

Esthetic parameters, such as GP, RED ratios and W/H ratio, have been accordingly explored in different populations to reveal the existence of these parameters (8-18). Relationship between those factors in addition to potential racial differences could be useful to clinicians.

GP, RED, W/H ratio and golden percentage are all parameters proposed as harmonious and esthetic standards in the literature. The purpose of this study was to measure the occurrence of these parameters amongst young Saudi population. The current findings indicated that differences according to gender exist, where the width and height of all maxillary anterior teeth were significantly greater in males than in females. These results are in accordance with data published in previous studies (4,6).

Agreeing with most of the existing literature, the results indicated that GP was not frequently found between maxillary lateral incisors and central incisors and between canines and lateral incisors in both genders (8-18). Thus, the first null hypothesis was partially rejected. This study, however, confirmed previous findings relevant to Saudi population, where the apparent dimensions of maxillary anterior teeth significantly deviated from the GP (21-22). However, only the left lateral incisor/left central incisor ratio in males occurred within the GP guidelines. Surprisingly, this may suggest that the tooth proportions were not symmetrical in male dental students. That can be attributed to narrower left lateral incisor tooth in males than right lateral incisor or asymmetrical alignment that caused unequal apparent dimensions. These findings partially coincided with proportions measured in Irish (20), and in Kurdish and Arab Iraqi dental students (18). Nevertheless, the later studies reported existence of GP in both sides and genders. Racial differences in the alignment, positioning, shape of the maxillary arch, lack of symmetry across the midline and dimensions of maxillary anterior teeth are all potential explanations for

differences with previous literature. Additionally, methodological inconsistencies and inter-operator variabilities could also be assumed attributable reasons for discrepancies with prior literature.

The RED proportion, set at 70%, is generally considered more esthetically pleasing than the 62% GP (3). Despite this, the present study found that the perceived widths of the maxillary anterior teeth did not follow the RED proportion in either males or females, and this was consistent on both the right and left sides. As a result, the second null hypothesis, which predicted that the teeth would conform to the RED proportion, was rejected. Though disagreed with another report that demonstrated the existence of RED proportions in Nepalese females who are of Mongolian origin (10), current findings coincided with data reported in several previous studies carried out on different populations (9,11,12). It is also worth noticing that the RED between right canine and right lateral incisor in male students (72%) was approximate to 70%, the criterion standard of RED, though it was statistically different. Generally, RED proportions were not predominant in the successive widths of maxillary anterior teeth among different geographic regions and ethnicities, and thus were not considered the only standard for restoring esthetic smiles (33).

According to the present investigation, the mean value for the golden percentage for the right side is 22:15:12, whereas it is for the left side 23:15:12. The data recorded for the central incisors and canines slightly differ from the ideal golden percentage that estimated the value of 25% for central incisors and 10% for canines (22). Approximate findings were reported for Jordanians, which are of the Arab ethnicity, similar to Saudi Arabian individuals (14,15).

Generally, these findings corroborated with previous conclusions that considered GP as a better starting point for tooth shape and size compared to other esthetic proportions (30). However, the percentage for the right and left lateral incisors in females was 15%; this finding is in agreement with the percentage thought to be ideal for lateral incisors (19). Moreover, GP values on the right and left sides were not different in both males and females. The third null hypothesis was therefore partially rejected.

A W/H ratio between 0.75 and 0.80 was reported in literature as the most favorable ratio (24). The fourth null hypothesis was rejected, as amongst the studied

population, although a similar W/H ratio of the central, lateral incisor and canine has been shown on the right and left sides, the ideal W/H ratio of 80% was not noted. The W/H ratio of the central incisor exceeds the predicted W/H ratio in both genders. These outcomes concurred with results obtained for Iraqi Arab dental students, but disagreed with findings for Kurdish Iraqi students (18). This result also agreed with studies conducted on Turkish, European, Jordanian and Malaysian populations (8,12,16,24,25,30,34). This finding was confirmed by a recent meta-analysis of the W/H ratios of the maxillary central, lateral, and canine teeth which concluded that the differences between populations were not significant (35).

The criterion standard of W/H ratio of 80%, had, however, been suggested to be used with only apparently long and not normal or short teeth (21). The fifth null hypothesis was obviously rejected, as males have significantly wider and longer maxillary anterior teeth compared to females. The differences in W/H ratios were significant between both genders, except for the canines in both sides where females had greater W/H ratios than males. This sexual dimorphism has been reported in previous studies (4,24,25,26,30). However, W/H ratio of anterior teeth was greater than values described in previous literature, which indicated that Saudi adults may have wider maxillary anterior teeth than their equivalents in other populations. Apparently, maxillary arches in Saudi adults are probably wider anteriorly. Such observation emphasizes the racial differences in tooth size and morphology as well as in arch morphology (28).

Combining the information derived from the study, esthetic standards can be a useful tool for diagnosis and treatment planning for natural looking and esthetically pleasing restorations for maxillary anterior teeth. Evidence-based objective quantification of esthetic proportions can serve as a starting point for guided treatment planning. This analysis can also identify esthetic problems and act as a blueprint for designing esthetic restorations that enhance natural, harmonious and balanced smile design and improve patient satisfaction.

It should be acknowledged that the sample consists

of dental students, which may not represent the general Saudi population in terms of age, gender and anatomical variations thereby presenting a selection bias. Hence, future studies may be warranted to include different geographical regions within the same country, as well as different age groups, and compare between different ethnicities to improve generalizability.

Despite the rigid treatment of esthetic parameters, the harmony between dental-periodontal-facial apparatus might be more important than rigid constant values. Thus, further data to analyze teeth measurements in accordance with other facial measurements could be a significant contribution to existing literature. Moreover, a larger sample size may be needed before producing these results to the general population. Another important area for future research could be the exploration of the perceptibility of differences between the ideal and existing proportions in a clinical setting and how they might affect esthetic outcomes, as large deviations can be still acceptable and viewed as harmonious and functional.

5. Conclusions

Within the limitations of the current clinical study, the following conclusions were drawn:

- 1- The GP has been found for LL/LC ratio in males only.
- 2- There are no RED proportions in the maxillary anterior teeth.
- 3- The W/H ratio did not conform to the optimum ratio of 80%.
- 4- Males have wider and longer maxillary anterior teeth compared to females.
- 5- The proportions measured did not follow the golden percentage of 25:15:10, except for the percentage for the L/R lateral incisors in females.

Conflict of Interests

The authors have no conflict of interests to declare.

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