Background: Maxillary anterior teeth are important in achieving optimum aesthetics. Different methods are used to calculate their dimension: as golden standard (GS) to measure Width/Height (W/H) of anterior teeth and Golden Proportion (GP) to measure their perceived widths. Researchers had reported on GS and GP in different populations. Objectives: The aim of the present study is to evaluate the occurrence of GS and GP of maxillary anterior teeth among the Saudi population in Makkah. Materials and Methods: A total of 384 participants (2304 teeth) were included in this study; photographs were taken by using a digital camera at a fixed distance and saved on a personal computer; the perceived mesio-distal widths and occluso-gingival heights of the maxillary anterior teeth were measured; GS was calculated from W/H of upper central incisors (W11/H11 and W21/H21); and GP was calculated from width of canines/laterals (W13/W12 and W23/W22) and laterals/centrals (W12/W11 and W22/W21). The normal range of GS was considered between 75% and 85%, whereas the normal range of GP was considered between 55% and 65%. Data were analyzed by using suitable statistical tests, and p-value ≤ 0.05 was considered statistically significant. Both GS and GP were compared in relation to gender, race, and shape of the face. Results: There were 43% of GS ratios, 14% of GP of canines/laterals, and 34% of GP ratios of laterals/centrals that were within the normal range. There were no significant differences between GS of males and females (p=0.512) as well as among different races (0.137), whereas there were significant differences among different face shapes (p=0.001). For GP of canines/laterals, there were significant differences between males and females (p=0.000), different races (p=0.000), and different face shapes (p=0.001). For GP of laterals/centrals; there were no significant differences between males and females (p=0.216) whereas there were significant differences among different races (p=0.000) and different face shapes (p=0.007). Conclusion: The GS was 85% among the Saudi population in Makkah and it was more prevalent than other golden measures. The GP was 77.5 for canines/laterals and 65.8 for laterals/centrals, and their frequencies were very low. Personal characteristics and dento-facial specifications should be considered to obtain maximum aesthetics.

Keywords: Anterior teeth, aesthetics, golden proportion, golden standard

Received: 16-12-20
Revised: 05-01-21
Accepted: 06-02-21
Published: 10-06-21

Introduction

Dimensions of anterior teeth are important during prosthodontics treatment planning to achieve ideal

Access this article online

Quick Response Code:

Website: www.jispcd.org

DOI: 10.4103/jispcd.JISPCD_432_20

How to cite this article: Abdallah MF, Alamoudi OH, Ali AM, Marzogi RA, Bafaraj MA, Elkwatehy WM. Golden standard and golden proportion of maxillary anterior teeth among Saudi population in Makkah. J Int Soc Prevent Communit Dent 2021;11:294-306.

Address for correspondence: Assoc. Prof. Wahdan Mohammed Abdelghany Elkwatehy, Department of Pediatric, Dental Public Health and Preventive Dentistry, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.

E-mail: elkwatehywahdan@gmail.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com
aesthetic results. Many guidelines were introduced to achieve maximum aesthetics in the maxillary anterior region as GP. Lombardi was the first to introduce the GP; Lombardi and Levin\(^2\) stated that the width of the upper central incisor can be measured by using GP to the width of the upper lateral incisor; also, the width of the upper lateral incisor can be calculated by the width of the canine, respectively, by using the GP. As per the GP rule, “Visible mesio-distal width of upper canine is approximately sixty two percent (0.618) of upper lateral incisor and the visible width of upper lateral incisor is approximately sixty two percent (0.618) of upper central incisor.” Many studies were carried out to assess GP in different populations. Aldegheishem et al\(^4\) studied GP in the Saudi population living in Riyadh; they found a significant difference between W/H and GP, except in the case of the upper right lateral incisor in male samples, where no significant width comparison was available for upper anterior teeth to the ideal GP of 0.618–1.618. Swelem and Al-Rafah\(^8\) found highly significant differences between ideal GP and the calculated golden ratio in the Jeddah population in Saudi Arabia and the males in their study had a broader perceived mesio-distal width of upper anterior teeth than the females. Also, Mahajan V. found that GP did not present in most cases of the Himachal Pradesh population in north India. Similarly, Hegde and Malhotra\(^7\) found that GP was not prevalent in the south Indian population where the ratio of central incisor and lateral incisor on both sides was 1.23 and 1.18, respectively. Al-marzouk et al\(^8\) evaluated GP and GS of maxillary central incisors in three different races living in Malaysia. They found no significant differences between the studied races for GP and GS. The ratio of upper lateral to central incisors was 73.8% in China, 71% in India, and 77% in Malaysia; however, the canine to lateral ratio was 75% in China, 79% in Malaysia, and 80% in India. Many other researchers studied GP in different populations.

The concept of “recurring aesthetic dental proportion” (RED) was introduced in 2001 by Ward,\(^9\) who suggested that dentists can use their own proportion in a constant ratio proceeding distally according to the relationship between teeth and facial proportion. In the year 2007, he reported that most dentists in North America are using the RED concept to create aesthetic smiles.\(^9\)

However, Ali Fayyad et al\(^{11}\) and Murthy and Ramani\(^{12}\) found that the RED proportion was unsuccessful when applied to upper anterior dentition.

GS value is “the relation between width and height of maxillary anterior teeth”; it had been studied for different populations of different origins.\(^{13-24}\) The optimum W/H proportion of upper central incisors should be approximately 80%\(^{25}\); increasing the W/H ratio will lead to squarer looking teeth, whereas decreasing it will give a longer tooth appearance.\(^{26}\) Williams\(^{27}\) and Cesário\(^{28}\) proved that a great correlation exists between the face shape and dimensions of the anterior teeth. However, Sellen et al.\(^{29}\) mentioned that there is not necessarily any relationship between face shape and anterior teeth, and accurate aesthetic analysis must be taken into consideration to establish the final dimensions of the teeth to be restored.

Due to limited available research that evaluated GP and GS in the KSA population and special characteristics of the Makkah population as there are diverse population, their origin was from different races, the aim of the current study was to investigate the GP and GS in Makkah population and to evaluate whether there is a consistent relationships of GP and GS values with the gender, race, and face shape.

**Materials and Methods**

**Study design and ethical approval**

This cross-sectional study was carried out at the Faculty of Dentistry, Umm Al-Qura University, Makkah city. Acceptance was obtained from the ethical committee (IRB number: 147-19). All participants signed a consent form after illustration of the study objectives.

**Subjects and sample size calculation**

This study was carried out for the Makkah population who had been seeking dental treatment at UQUDENT teaching hospital and accepted to participate in the study. Sample size was determined according to the formula used for the whole population (No. = \(Z^2\) (pq)/\(e^2\)), where \(q = 1 – p\), with a 95% level of confidence and sample error ±5%; we considered \(q = 0.5\) to obtain maximum sample size. The sample for this study consists of 384 (196 males and 188 females) Saudi nationals.

**Subjects’ inclusion criteria**

Certain criteria were met in all participants; these criteria were; (1) Makkah origin and resident, (2) No significant gingivitis or periodontitis, (3) No missed teeth in both arches (except the third molar), (4) No anterior defects or restorations, (5) No anterior crowding or history of orthodontic treatment, (6) No developmental anomalies such as hypoplasia, dense indent, or peg-shaped laterals.
DATA COLLECTION

The participants were asked face to face about their origin and age. Face shape was divided into six forms: (1) Round: Face has equal width and length; (2) Oval: Forehead is wide and bones of the cheeks are wide, whereas there is tapering toward chin; (3) Long: Face height is obvious and there is tapering toward chin; (4) Heart: Also, face tapers toward chin, which is pointy; (5) Square: Width of the forehead, bones of the cheeks, and jawline are equal, and jawline is bony and square; (6) Diamond: Bony face with high angles and widest part is at the temple.

A frontal photograph of the mouth was taken while the participant was smiling to expose all anterior teeth. All photographs were taken while the participant was sitting in an upright position at a dental chair; a special head holder device was used to stabilize the participant’s head position by supporting chin and forehead and the standardization of the distance between the camera and teeth was 50 cm [Figure 1].

Photos were taken in standard daylight while maxillary teeth were parallel to the floor by using a digital camera (Canon EOS D700, Canon Inc, Ota, Tokyo, Japan). The photos were transferred to a personal computer and opened by using Photoshop program (Adobe Photoshop CS 6, Adobe system Inc. San Jose, CA, USA) [Figure 2]. Special calibration tools were used in the program to change pixels to mm. Anterior teeth width (W) was measured from mesial to distal surfaces of upper anterior teeth, whereas height (H) was measured from the cervical margin to the incisal edge on a line to the long access of the tooth as described by Hasanreisoglu et al.\textsuperscript{[15]} and Janiszewska-Olszowska et al.\textsuperscript{[30]} The following values were recorded: (1) Width of upper centrals, laterals, and canines (W11, W21, W12, W22, W13, W23) was recorded. (2) Calculating the W/H ratio of upper right and left centrals (W11/H11, W21/H21) to determine GS. (3) Calculating the ratio between canines and laterals (W13/W12, W23/W22), laterals and centrals (W12/W11, W22/W21) to determine GP. All readings and calculations were checked thrice.

The normal range of GS was considered between 75% and 85%, whereas the normal range of GP was considered between 55% and 65%.

STATISTICAL ANALYSIS

Data were collected and analyzed by using statistical program (SPSS, version 22, IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp). Quantitative data were interpreted as mean ± SD. Independent t-test was used to compare between males and females. One-way ANOVA and post hoc Tukey tests were used to compare among different races and different face shapes. Qualitative data were presented as frequency, and a comparison was done by the Chi-square test. The level of significance was considered statistically significant at \( P \leq 0.05 \).

RESULTS

This study was carried out on 384 participants (196 males + 188 females) with a mean age of 23.47 ± 2.78 years. The sample contained 165 Saudis, 84 Middle Easterners, 57 South Asians, 30 Eastern Asians, 29 Caucasians, and 19 Africans. In relation to face shape, there were 55 square, 98 rounded, 100 oval, 67 long, 26 heart, and 38 diamond face shapes [Table 1].

Regarding GS, there were no significant differences between males and females (\( P = 0.512 \)) as well as different races (0.137) whereas there were significant differences among different face shapes (\( P = 0.001 \)). The differences were between oval faces and long, heart, and diamond faces [Table 1]. All GS measures were within the normal range except for African and Eastern Asian races as well as between square and oval face shapes, which were above the normal range [Table 1 and Figure 3].
Regarding the GP of canines/laterals, there were significant differences between males and females ($P = 0.000$), different races ($P = 0.000$), and different face shapes ($P = 0.001$). In relation to race, the differences were between Caucasian and Saudi, Middle East, South Asian, and African; they were also between South Asian and Eastern Asian. In relation to face shape; the differences were between oval and square, rounded and...
diamond face shapes. All GP measures obtained from canines/laterals were above the normal range regardless of gender, race, and face shape [Table 2 and Figure 4]. For the GP of laterals/centrals, there were no significant differences between males and females ($P = 0.216$). On the other hand, there were significant differences

| Variables       | W13/W12, mean ± SD | W23/W22, mean ± SD | Total, mean ± SD |
|-----------------|---------------------|---------------------|-----------------|
| Gender          |                     |                     |                 |
| Male            | 0.798 ± 0.135       | 0.812 ± 0.152       | 0.805 ± 0.144   |
| Female          | 0.745 ± 0.118       | 0.743 ± 0.131       | 0.744 ± 0.125   |
| $p$             | 0.000               | 0.000               | 0.000           |
| Race            |                     |                     |                 |
| Saudi           | 0.772 ± 0.113       | 0.761 ± 0.125$A$    | 0.766 ± 0.119$A$|
| Middle Easterner| 0.767 ± 0.152       | 0.783 ± 0.135$B$    | 0.755 ± 0.144$B$|
| South Asian     | 0.735 ± 0.136$A$    | 0.747 ± 0.136$C$    | 0.741 ± 0.136$DE$|
| Eastern Asian   | 0.793 ± 0.093       | 0.833 ± 0.234       | 0.813 ± 0.178$E$|
| Caucasian       | 0.844 ± 0.134$A$    | 0.874 ± 0.144$ABCD$ | 0.859 ± 0.139$ABCD$|
| African         | 0.762 ± 0.138       | 0.761 ± 0.154$D$    | 0.761 ± 0.145$C$|
| $p_l$           | 0.010               | 0.000               | 0.000           |
| Race            |                     |                     |                 |
| Square          | 0.771 ± 0.116       | 0.807 ± 0.184$A$    | 0.788 ± 0.154$A$|
| Round           | 0.783 ± 0.154       | 0.799 ± 0.155$B$    | 0.792 ± 0.155$B$|
| Oval            | 0.746 ± 0.126       | 0.733 ± 0.113$C$    | 0.739 ± 0.120$CDE$|
| Long            | 0.776 ± 0.099       | 0.775 ± 0.136       | 0.776 ± 0.119   |
| Heart           | 0.772 ± 0.173       | 0.788 ± 0.177       | 0.780 ± 0.174   |
| Diamond         | 0.803 ± 0.085       | 0.795 ± 0.112       | 0.799 ± 0.099$A$|
| $p_l$           | 0.213               | 0.012               | 0.001           |
| Total of the sample | 0.772 ± 0.130     | 0.778 ± 0.146       | 0.775 ± 0.138   |

No. = number, $p = P$-value calculated by unpaired Student $t$-test. $p_l = P$ value calculated by one-way ANOVA test. $A–E$, $*$,$**$,$***$Similar letters/symbols mean significant difference between corresponding groups in the same column according to Tukey’s test, $P \leq 0.05$ = statistically significant value.

Figure 4: The mean of GP (W13/12 and W23/22) in relation to gender, race, and face shape.
among different races ($P = 0.000$) and different face shapes ($P = 0.007$). In relation to race, the differences were between Eastern Asian and Saudi, Middle Eastern and Caucasian, and also between African and Saudi, Middle Eastern and Caucasian. In relation to face shape, the differences were between oval and heart face shape. The GP measures obtained from laterals/centrals were close to the normal range, except

| Variables | W12/W11, mean ± SD | W22/W21, mean ± SD | Total mean ± SD |
|-----------|---------------------|---------------------|-----------------|
| Gender    | Male                | Female              | p               |
|           | 0.661 ± 0.069       | 0.655 ± 0.083       | 0.654 ± 0.081   |
|           | 0.322               | 0.449               | 0.216           |
| Race      | Saudi               | Middle Easterner    | Caucasian       |
|           | 0.653 ± 0.079       | 0.650 ± 0.069       | 0.652 ± 0.074   |
|           | 0.653 ± 0.079       | 0.652 ± 0.074       | 0.652 ± 0.074   |
|           | 0.653 ± 0.079       | 0.652 ± 0.074       | 0.652 ± 0.074   |
|           | 0.653 ± 0.079       | 0.652 ± 0.074       | 0.652 ± 0.074   |
|           | 0.653 ± 0.079       | 0.652 ± 0.074       | 0.652 ± 0.074   |
|           | 0.653 ± 0.079       | 0.652 ± 0.074       | 0.652 ± 0.074   |
|   p1      | 0.002               | 0.007               | 0.949           |
| Race      | South Asian         | Eastern Asian       | African         |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|           | 0.662 ± 0.068       | 0.666 ± 0.069       | 0.656 ± 0.085   |
|   p1      | 0.080               | 0.244               | 0.007           |
| Face shape| Square              | Round               | Heart           |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|           | 0.667 ± 0.058       | 0.662 ± 0.056       | 0.662 ± 0.056   |
|   p1      | 0.002               | 0.007               | 0.007           |

$p = P$ value calculated by unpaired Student $t$-test. $p1 = P$-value calculated by one-way ANOVA test

$A$, $D$, $E$ – Similar letters/symbols mean significant difference between corresponding groups in the same column according to Tukey’s test, $P \leq 0.05$ = statistically significant value

![Figure 5: The mean of GP (W12/11 and W22/21) in relation to gender, race, and face shape](image-url)
for South Asians, Eastern Asians, and Africans; apart from this, square, heart, and diamond face shapes were above the normal range [Table 3 and Figure 5].

Regarding the frequency of GS, there were no significant differences between male and female participants ($P = 0.523$), different races ($P = 0.066$), and different face shapes ($P = 0.144$) [Table 4].

### Table 4: Frequency of golden standard in relation to gender, race, and face shape

| Variables          | W11/H11 | W21/H21 | Total  |
|--------------------|---------|---------|--------|
| **Gender**         |         |         |        |
| Male               | With G.S. | 82      | 85     | 167    |
|                    | Above G.S. | 93      | 90     | 183    |
|                    | Below G.S. | 21      | 21     | 42     |
| Female             | With G.S. | 82      | 81     | 163    |
|                    | Above G.S. | 82      | 82     | 164    |
|                    | Below G.S. | 24      | 25     | 49     |
| **P**              |         | 0.696   | 0.723  | 0.523  |
| **Race**           |         |         |        |
| Saudi              | With G.S. | 77      | 79     | 156    |
|                    | Above G.S. | 70      | 66     | 136    |
|                    | Below G.S. | 18      | 20     | 38     |
| Middle Easterner   | With G.S. | 35      | 37     | 72     |
|                    | Above G.S. | 40      | 38     | 78     |
|                    | Below G.S. | 9       | 9      | 18     |
| South Asian        | With G.S. | 21      | 16     | 37     |
|                    | Above G.S. | 29      | 31     | 60     |
|                    | Below G.S. | 7       | 10     | 17     |
| Eastern Asian      | With G.S. | 15      | 14     | 29     |
|                    | Above G.S. | 13      | 14     | 27     |
|                    | Below G.S. | 2       | 2      | 4      |
| Caucasian          | With G.S. | 11      | 16     | 27     |
|                    | Above G.S. | 11      | 11     | 22     |
|                    | Below G.S. | 7       | 2      | 9      |
| African            | With G.S. | 5       | 4      | 9      |
|                    | Above G.S. | 12      | 12     | 24     |
|                    | Below G.S. | 2       | 3      | 5      |
| **P**              |         | 0.444   | 0.173  | 0.066  |
| **Face shape**     |         |         |        |
| Square             | With G.S. | 24      | 25     | 49     |
|                    | Above G.S. | 25      | 26     | 51     |
|                    | Below G.S. | 6       | 4      | 10     |
| Round              | With G.S. | 33      | 39     | 72     |
|                    | Above G.S. | 52      | 48     | 100    |
|                    | Below G.S. | 13      | 11     | 24     |
| Oval               | With G.S. | 44      | 46     | 90     |
|                    | Above G.S. | 47      | 48     | 95     |
|                    | Below G.S. | 9       | 6      | 15     |
| Long               | With G.S. | 29      | 31     | 60     |
|                    | Above G.S. | 29      | 24     | 53     |
|                    | Below G.S. | 9       | 12     | 21     |
| Heart              | With G.S. | 13      | 11     | 24     |
|                    | Above G.S. | 9       | 10     | 19     |
|                    | Below G.S. | 4       | 5      | 9      |
| Diamond            | With G.S. | 21      | 14     | 35     |
|                    | Above G.S. | 13      | 16     | 29     |
|                    | Below G.S. | 4       | 8      | 12     |
| **P**              |         | 0.617   | 0.225  | 0.144  |
| **Total of the sample** | With G.S. | 164     | 166    | 330 (43%) |
|                    | Above G.S. | 175     | 172    | 347 (45.2) |
|                    | Below G.S. | 45      | 46     | 91 (11.8) |

$\ p = P\ value\ calculated\ by\ \chi^2\ test$
For the GP frequency of canines/laterals, there were significant differences between males and females (0.000), different races ($P = 0.017$), and different face shapes ($P = 0.009$) [Table 5 and Figure 6].

For the GP frequency of laterals/centrals, there were no significant differences between males and females (0.233). On the other hand, there were significant differences among different races ($P = 0.005$) and different face shapes ($P = 0.016$) [Table 5 and Figure 7].

For the total sample, the mean GS was $0.850 \pm 0.093$ with 43% of the measurements being within the normal range. The mean GP of canines/laterals was $0.775 \pm 0.138$ and for laterals/centrals it was $0.658 \pm 0.075$ with 14% and 34% of the measurements being within the normal GP range [Tables 1–3 and Figure 8].

**Discussion**

Patients' speech as well as their aesthetics will be improved and this will be reflected in their public communications, which will, in turn, improve their quality of life. The GS and GP are important mathematical calculations used by prosthodontists, orthodontists, or lab technicians to design restorations and set up teeth in the most aesthetic positions. They are affected by different variables such as gender, facial characteristics, races, and geographical location. An aesthetic smile was not one of the factors of selection for the participants; rather we chose a natural smile, as previous studies reported that GS and GP were not affected by aesthetic smiles.

For each case, frontal standardized photographs were taken at a fixed distance by using a digital camera; then, they were analyzed by a computer program. This method has many advantages, such as accurate and repeatable measurements, simplicity, and the ability to manipulate (as magnification) the photographs by using the computer program.

The upper central incisors greatly affect a patient’s smile; their W/H ratio plays an important role in aesthetic appearance. When W/H equals 0.62 or 62%, the central incisor is identified to be in GS. However the most attractive aesthetic appearance can be achieved when W/H equals 75–85%. If W/H values are decreased, they will result in a tall narrow tooth; if they are increased, they will lead to a short broad tooth. The results of the present study concluded that the Saudi population in Makkah have more square central incisors ($0.850 \pm 0.093$); most of the different races (Saudi, Middle East, South Asian, and Caucasian) have a more attractive appearance than Eastern Asians and Africans, and rounded, long, heart, and diamond faces are more attractive than square and oval faces.

---

**Figure 6:** The percentage of GP (W13/12 and W23/22 in relation to gender, race, and face shape.
The results of the current study indicated nonsignificant difference in mean GS values between right and left upper central incisors; there were no significant differences between male and female groups. Similar results were reported by different researchers.\cite{13,25} Also, there were no significant differences between different face shape groups. On the other hand, the differences among different races were statistically significant [Table 1]. The percent of measurements within the normal GS range was comparable for males

| Variables       | W13/W12 | W23/W22 | Total | W12/W11 | W22/W21 | Total |
|-----------------|---------|---------|-------|---------|---------|-------|
| Gender          |         |         |       |         |         |       |
| Male            | 22      | 22      | 44    | 70      | 65      | 135   |
| Above G.P.      | 170     | 172     | 342   | 115     | 120     | 235   |
| Below G.P.      | 4       | 2       | 6     | 11      | 11      | 22    |
| Female          | 28      | 36      | 64    | 64      | 63      | 127   |
| Above G.P.      | 149     | 142     | 291   | 105     | 111     | 216   |
| Below G.P.      | 11      | 10      | 21    | 19      | 14      | 33    |
| Race            |         |         |       |         |         |       |
| Saudi           | 23      | 24      | 47    | 62      | 58      | 120   |
| Above G.P.      | 138     | 133     | 271   | 85      | 94      | 179   |
| Below G.P.      | 4       | 8       | 12    | 18      | 13      | 31    |
| Middle Easterner | 15     | 12      | 27    | 28      | 29      | 57    |
| Above G.P.      | 67      | 72      | 139   | 48      | 48      | 96    |
| Below G.P.      | 2       | 0       | 2     | 8       | 7       | 15    |
| South Asian     | 8       | 12      | 20    | 22      | 17      | 39    |
| Above G.P.      | 43      | 43      | 86    | 34      | 38      | 72    |
| Below G.P.      | 6       | 2       | 8     | 1       | 2       | 3     |
| Eastern Asian   | 0       | 4       | 4     | 6       | 5       | 11    |
| Above G.P.      | 29      | 26      | 52    | 22      | 24      | 46    |
| Below G.P.      | 1       | 0       | 1     | 2       | 1       | 3     |
| Caucasian       | 3       | 2       | 5     | 13      | 13      | 26    |
| Above G.P.      | 26      | 27      | 53    | 15      | 14      | 29    |
| Below G.P.      | 0       | 0       | 0     | 1       | 2       | 3     |
| African         | 1       | 4       | 5     | 3       | 6       | 9     |
| Above G.P.      | 16      | 13      | 29    | 16      | 13      | 29    |
| Below G.P.      | 2       | 2       | 4     | 0       | 0       | 0     |
| Face shape      |         |         |       |         |         |       |
| Square          | 4       | 5       | 9     | 15      | 15      | 30    |
| Above G.P.      | 49      | 49      | 98    | 37      | 39      | 76    |
| Below G.P.      | 2       | 1       | 3     | 3       | 1       | 4     |
| Round           | 13      | 15      | 28    | 41      | 37      | 78    |
| Above G.P.      | 78      | 81      | 159   | 48      | 54      | 102   |
| Below G.P.      | 7       | 2       | 9     | 7       | 7       | 16    |
| Oval            | 17      | 16      | 33    | 38      | 38      | 76    |
| Above G.P.      | 79      | 80      | 159   | 50      | 54      | 104   |
| Below G.P.      | 4       | 4       | 8     | 12      | 8       | 20    |
| Long            | 8       | 15      | 23    | 26      | 21      | 47    |
| Above G.P.      | 59      | 49      | 108   | 39      | 41      | 80    |
| Below G.P.      | 0       | 3       | 3     | 2       | 5       | 7     |
| Heart           | 7       | 5       | 12    | 7       | 7       | 14    |
| Above G.P.      | 17      | 19      | 36    | 18      | 18      | 36    |
| Below G.P.      | 2       | 2       | 4     | 1       | 1       | 2     |
| Diamond         | 1       | 2       | 3     | 7       | 10      | 17    |
| Above G.P.      | 37      | 36      | 73    | 28      | 25      | 53    |
| Below G.P.      | 0       | 0       | 0     | 3       | 3       | 6     |
| Total of the sample |      |       |     |         |         |       |
| With G.P.      | 50      | 58      | 108 (14%) | 134     | 128     | 262 (34%) |
| Above G.P.      | 319     | 314     | 633 (82.4) | 220     | 231     | 451 (58.7) |
| Below G.P.      | 15      | 12      | 27 (3.5) | 30      | 25      | 55 (7.2)  |

\( p = P \text{ value calculated by } \chi^2 \text{ test, } P \leq 0.05 = \text{ statistically significant value.} \)
and females (42.6% vs 43.3%). Eastern Asian has the highest GS percentage (48.3%) followed by Saudi (47.3%), Caucasian (46.5%), Middle East (42.9%), and South Asian (32.5%) and the least was the African (23.7%) [Figure 9].

In the current study, the W/H of upper centrals was close to the ideal 75–85% ratio, as the calculated ratios ranged from 82% to 88%. This range was comparable with previous studies that gave ranges from 76% to 86%. Hasanreisoglu et al. [15] found it to be 82%, Wolfart et al. [25] reported it to be 82%, and Parnia et al. [33] stated that it was 83%. The present results were not in agreement with those of Al-Marzok et al. [8] who found a great variation between the recorded and ideal W/H of anterior teeth, explaining that different complex factors may affect GS. Rosenstiel et al. [14] suggested that GS can be used only with apparently long teeth and not normal or short ones.

The present results showed a very low prevalence of the ideal GP value (61.8%) among all participants from Makkah. The GP of canines/laterals and laterals/centrals was found only in nine (2.34% all participants) out of 384, fulfilling the ideal (1.618:1:0.618) rule. Similar results

Figure 7: The percentage of GP (W12/11 and W22/21 in relation to gender, race, and face shape

Figure 8: Pie chart showing the percentage of measurements within, above, and below the golden range
were obtained by other researchers\cite{5,8,10-12,31,33} studying different populations with age ranges such as that of the present study. Thus, GP might not be considered in dental treatment as many articles found that it did not exist. These results contrast previous studies carried out on Iraqi,\cite{13} Pakistani,\cite{34} and Indian participants.\cite{35} Also, the present results disagreed with the results reported by Kanaparthy et al.,\cite{36} who showed that GP is present between canines and laterals ratio in both male and female Saudi participants; these differences may be due to different methodologies and measurement methods. The current study and other research\cite{19,33} have proved that there is no golden ratio present but the ideal GS using W/H of maxillary central incisors is a dominating factor in aesthetic appearance.

When the GP was broadened in the present study to be 55% to 65% rather than a fixed value of approximately 62%, valuable results were obtained where 14% (11.2% males and 17% females) of the examined canine to lateral ratio was found to be within this new range [Figures 6 and 8]. Also, 34% (34.4% males and 33.8% females) of the lateral to central ratio was found to be within this range [Figures 7 and 8].

In relation to the GP frequency of canines/laterals, females have a higher percent than males (17% vs 11.2%); the South Asians have the highest GP percentage (17.5%) followed by Middle Easterners (16%), Saudis (14.2%), Africans (13.2%), Caucasians (8.6%) and the least were the Eastern Asians (7%). This result may be due to the higher hairline in the south Asian race, as stated by Packiriswamy et al.\cite{37}

The heart face has the highest GP percentage (23.1%), followed by long (17.2%), oval (16.5%), rounded (14.3%), square (8.2%) and the least was the diamond face shape (3.9%), as shown in Figure 6.

In relation to the GP frequency of laterals/centrals, males and females have a comparable percentage (34.4% vs 33.8%); Caucasians have the highest GP percentage (44.8%), followed by Saudis (36.4%), South Asians (34.2%), Middle Easterners (33.9%), Africans (23.7%) and the least were the Eastern Asians (18.3%). The rounded face has the highest GP percentage (39.8%), followed by oval (38%), long (35.1%), square (27.3%), heart (26.9%) and the least is the diamond face shape (22.4%), as shown in Figure 7.

So, optimum aesthetics can be achieved by applying local measurements and racial characteristics rather than blindly calculating GP values, as stated by Forster et al.\cite{19} The results of the current study indicated that for the Saudi population in Makkah, the aesthetic proportion can be generalized as a canine to lateral ratio of 77.5% and a lateral to central ratio of 65.8%.

![Figure 9: The percentage of GS in relation to gender, race, and face shape](image-url)
and they considered ideal ratios for all races and face shapes.

The GS and GP of the total participants in the present study were different from those obtained in the most recent studies. The GS and GP were significantly different among different face shapes [Tables 1–3]. These findings were in disagreement with the results obtained by Rokaya et al., who concluded that: GS was 90% for upper central incisors; GP was 66% for laterals/centrals, 70% for canines/laterals; and there were no differences among different face shapes in the Nepalese population. Melo et al. reported that the GS was 92.4% for centrals; GP was 61.6% for laterals/centrals and 83.2% for canines/laterals in the Spanish population. These differences may be attributed to the differences of the study population and study methodology. These previous findings support the results of the present study, as these golden ratios cannot be generalized as a standard for the different populations.

The variations in GS and GP may be due to genetic properties that are affected by race; thus, race may affect teeth dimensions, proportions, and face shapes. However, these results may be due to the special characteristics of the Makkah population: Different races had intermarried and stayed there due to the entire Muslim population considering Makkah a holy place.

According to these results, a patient who comes to a dental clinic seeking cosmetic dental rehabilitation should not be treated based on the mathematical calculation of GP values; rather, the patient should be treated based on his/her facial and personal characteristics and preference to obtain an aesthetically attractive smile.

STUDY LIMITATION

There are some limitations of the present study, such as sample size, exclusion criteria, and measurements that were done only on a computer screen without any indirect measurements on the casts or directly on the patient’s mouth.

CONCLUSION AND CLINICAL SIGNIFICANCE

Within the limitations of the current study, the following conclusions can be drawn:

1- The GS (W/H of upper central incisor teeth) was found to be the most prevalent among the Saudi population in Makkah and it was not affected by gender, race, or face shape. However, the frequency of the GP was very low and it differed among different races and face shapes.

2- The GS for the Saudi population was 85% (ranged from 82% to 88%); the GP was 65.8% (ranged from 64.5% to 69.6%) for the laterals/centrals ratio and 77.5 (ranged from 73.9% to 85.9%) for the canines/laterals ratio.

3- Although dentists should follow aesthetic principles during prosthodontics treatment, the GP should not be a regular mathematical calculated value, but personal characteristics and dento-facial specifications should be considered to obtain maximum aesthetics of anterior teeth.

ACKNOWLEDGMENT

The authors want to thank Dr. Lama Ali, Dr. Ruba Alamoudi, Dr. Anoud Alsulami, Dr. Mrooj Sindi, and Dr. Arwa Almatrafi for their efforts in data collection.

FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

AUTHORS’ CONTRIBUTIONS

All authors contributed equally, this included study design and conception, data retrieval and analysis as well as writing and reviewing the final paper.

ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT

The study was approved by the Institutional Review Board (IRB), College of Dentistry, Umm AlQura University (registration number: 147-19) and all the procedures have been performed as per the ethical guidelines laid down by Declaration of Helsinki (2000).

PATIENT DECLARATION OF CONSENT

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/ have given his/ her/ their consent for his/ her/ their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

DATA AVAILABILITY STATEMENT

The collected data that support the findings of this study are available from the corresponding author upon request.

REFERENCES

1. Sarver DM. Principles of cosmetic dentistry in orthodontics: Part 1. Shape and proportionality of anterior teeth. Am J Orthod Dentofacial Orthop 2004;126:749-53.

2. Lombardi ME, Levin EI. Dental esthetics and the golden proportion. J Prostheth Dent 1978;40:244-52.
3. Snow SR. Esthetic smile analysis of maxillary anterior tooth width: The golden percentage. J Esthet Dent 1999;11:177-84.
4. Aldegheishem A, Azam A, Al-Madi E, Abu-Khalaf L, Bani Ali B, Anweig L. Golden proportion evaluation in maxillary anterior teeth amongst saudi population in Riyadh. Audi Dent J 2019;31:322-9.
5. Swelem AA, Al-Rafah EM. Evaluation of “golden proportion” in Saudi individuals with natural smiles. Saudi Dent J 2019;31:277-83.
6. Mahajan V, Nagpal A, Gupta R, Vaidya S, Jabeen F, Thakur K. Comparative evaluation of golden proportion, recurring esthetic dental proportion and golden percentage in Himachal demographic. J Adv Med Med Res 2019;29:1-7.
7. Hegde M, Malhotra S. Evaluation of golden proportion between maxillary anterior teeth of South Indian population. Dent Open J 2016;2:137-41.
8. Al-Marzok MJ, Majeed KR, Ibrahim IK. Evaluation of maxillary anterior teeth and their relation to the golden proportion in Malaysian population. BMC Oral Health 2013;13:9.
9. Ward DH. Proportional smile design using the recurring esthetic dental (red) proportion. Dent Clin North Am 2001;45:143-54.
10. Ward DH. A study of dentists preferred maxillary anterior tooth width proportions: Comparing the recurring esthetic dental proportion to other mathematical and naturally occurring proportions. J Esthet Restor Dent 2007;19:324-39.
11. Ali Fayyad M, Jamani KD, Agrabawi J. Geometric and mathematical proportions and their relations to maxillary anterior teeth. J Contemp Dent Pract 2006;7:62-70.
12. Murthy BV, Ramani N. Evaluation of natural smile: Golden proportion, RED or golden percentage. J Conserv Dent 2008;11:16-21.
13. Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, Russell CM. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. J Clin Periodontol 1999;26:153-7.
14. Rosenstiel SF, Ward DH, Rashid RG. Dentists’ preferences of anterior tooth proportion—a web-based study. J Prosthodont 2000;9:123-36.
15. Hasanreisoglu U, Berksun S, Aras K, Arslan I. An analysis of maxillary anterior teeth: Facial and dental proportions. J Prosthet Dent 2005;94:530-8.
16. Marcuschamer E, Tsukiyama T, Griffin TJ, Arguello E, Gallucci GO. Magne P. Anatomical crown width/length ratios of worn and unworn maxillary teeth in Asian subjects. Int J Periodontics Restorative Dent 2011;31:495-503.
17. Chander NG, Kumar VV, Rangarajan V. Golden proportion assessment between maxillary and mandibular teeth on Indian population. J Adv Prosthodont 2012;4:72-5.
18. Tsukiyama T, Marcuschamer E, Griffin TJ, Arguello E, Magne P, Gallucci GO. Comparison of the anatomic crown width/length ratios of unworn and worn maxillary teeth in Asian and white subjects. J Prosthet Dent 2012;107:11-6.
19. Forster A, Velez R, Antal M, Nagy K. Width ratios in the anterior maxillary region in a Hungarian population: Addition to the golden proportion debate. J Prosthet Dent 2013;109:211-5.
20. Meshramkar R, Patankar A, Lekha K, Nadiger R. A study to evaluate the prevalence of golden proportion and RED proportion in aesthetically pleasing smiles. Eur J Prosthodont Restor Dent 2013;21:29-33.
21. Calçada D, Correia A, Araújo F. Anthropometric analysis of anterior maxillary teeth with digital photography - a study in a Portuguese sample. Int J Esthet Dent 2014;9:370-80.
22. Jin MX, Hong MH, Lee KJ, Lee KB. Does the maxillary anterior ratio in Korean adults follow the golden proportion? J Adv Prosthodont 2016;8:125-30.
23. Al-Kaisy N, Garib BT. Analysis of the golden proportion and width/height ratios of maxillary anterior teeth in Arab and Kurdish populations. J Prostheth Dent 2018;119:981-6.
24. Bishara SE, Jakobsen JR, Abdallah EM, Fernandez Garcia A. Comparisons of mesiodistal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico and the United States. Am J Orthod Dentofac Orthop 1989;96:416-22.
25. Wolfart S, QuaaS AC, Freitag S, Kropp P, Gerber WD, Kern M. Subjective and objective perception of upper incisors. J Oral Rehabil 2006;33:489-95.
26. Peixoto LM, Louro RL, Gomes AA, de Nascimento APC. Photographic analysis of aesthetic dental proportions. Rev Gaucha Odontol 2012;60:13-7.
27. Williams JL. The temperamental selection of artificial teeth, a fallacy. Dent Digest 1914;20:63-75.
28. Cesario VA Jr, Latta GH Jr. Relationship between the mesiodistal width of the maxillary central incisor and interpupillary distance. J Prostheth Dent 1984;52:641-3.
29. Sellen PN, Jagger DC, Harrison A. Computer-generated study of the correlation between tooth, face, arch forms, and palatal contour. J Prostheth Dent 1998;80:163-8.
30. Janiszewskas-Olszowska J, Stepin M, Syrynska M. Spacing in deciduous dentition of polish children in relation to tooth size and dental arch dimensions. Arch Oral Biol 2009;54:397-402.
31. Mahshid K, Khoshvaght A, Varshosaz M, Vallac N. Evaluation of “golden proportion” in individuals with an esthetic smile. J Esthet Restor Dent 2004;16:185-92; discussion 193.
32. Brisman AS. Esthetics: A comparison of dentists’ and patients’ concepts. J Am Dent Assoc 1980;100:345-52.
33. Parnia F, Hafezeqoran A, Mahboub F, Moslehifard E, Koodaryan R, Moteyagheni R, et al. Proportions of maxillary anterior teeth relative to each other and to golden standard in tabriz dental faculty students. J Dent Res Dent Clin Dent Rehabil 2012;60:13-7.
34. Al-Kaisy N, Garib BT. Analysis of the golden proportion and width/height ratios of maxillary anterior teeth in Arab and Kurdish populations. J Prostheth Dent 2018;119:981-6.
35. Bani Ali B, Anweigi L. Golden proportion evaluation in South Asian population. J Prostheth Dent 2013;109:211-5.
36. Al-Kaisy N, Garib BT. Analysis of the golden proportion and width/height ratios of maxillary anterior teeth in Arab and Kurdish populations. J Prostheth Dent 2018;119:981-6.
37. Packiriswamy V, Kumar P, Rao M. Identification of facial shape by applying golden ratio to the facial measurements: An interracial study in Malaysian population. N Am J Med Sci 2012;4:624-9.
38. Rokaya D, Humagain M, Amornvit P. Maxillary anterior teeth proportions for creating esthetically pleasing smile in Nepalese patients. J Nepal Health Res Coun 2018;16:362.
39. Umer F, Khan FR, Khan A. Golden proportion in visual dental smile in Pakistani population: A pilot study. Acta Stomatol Croat 2010;44:168-75.
40. Bhatkal MK, Garg S, Mittal S, Dang R, Sukhija U. Esthetic smile analysis in mathematical proportion: A study. Indian J Dent Sci 2015;7:26-9.
41. Kanaparthy A, Kanaparthy R, Boreak N, Aalami R. Evaluation of widths of maxillary anterior teeth and their relation to the golden proportion in the southwestern part of Saudi Arabia. J Res Med Den Sci 2015;7:26-9.