

Evaluation of the Golden Proportion in Patients Visiting the Oral Health Directorate of the Komfo Anokye Teaching Hospital, Kumasi

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Abstract

Background: Aesthetics is a primary consideration for patients seeking dental treatment. The size and shape of the maxillary anterior teeth have significant effects not only on the dental aesthetics, but also on the complete facial aesthetics of a person. To satisfy this expressed need, the “Golden Proportion” is a numerical value that is used as a rule in achieving dental aesthetics. In the last two decades, several studies have questioned the application of this rule in dentistry. **Aim:** The aim of this study is to evaluate the presence of “The Golden Proportion in the maxillary anterior teeth widths of clients visiting the Komfo Anokye Teaching Hospital’s (KATH) Oral Health Directorate, Kumasi”. **Materials and methods:** A total of 100 dentulous subjects comprised of 50 males and 50 females, with ages ranging between 18 and 37 years were chosen using convenience sampling. Their dental casts were evaluated for apparent width by digital calliper. **Results:** The results of the study were expressed in relation to gender and tooth laterality. The results revealed that the golden proportion existed in 14% and 20% for the left and right respectively between the central incisor and the lateral incisor for males, 12% and 16% respectively for the left and right sides of females, 8% and 20% for the left and right sides respectively for males between the lateral incisor and canine and 16% and 20% for the left and right respectively for females. **Conclusion:** Comparison of our results with the established golden value shows differences between 1.618 and from the range that was acquired from this study. The results suggest that the rule of the golden proportion should not be strictly applied when restoring anterior teeth of patients in the dental clinic.

Keywords

Golden Proportion, Dental Cast Analysis, Smile Aesthetics

1. Introduction

Beauty is said to be power, a smile is its sword. The perception of dental esthetics varies significantly among dental professionals, although substantial efforts have been made to establish common standards [1] [2]. Research in the area of aesthetic perception has identified different factors that contribute to a beautiful face [3] like: sexual dimorphism, ethnic background, genetics, and environment [4]. Dental and facial esthetics are said to be optimized if the proportion between widths of maxillary anterior teeth is repeated when viewed from the front [3]. However, each individual is unique and the application of a generalized relationship seems not precise [5].

Various researchers have opined for and against the use of this mathematic proportion in dentistry [6]. Levin observed the golden proportion between the width of central incisor, lateral incisor and the canine [7]. He advocated the use of the golden proportion for establishing tooth size and stated that the width of the central incisor is in golden proportion to the lateral incisor, as is the lateral to canine and the canine to first premolar, when viewed from the front [7]. George and Bhat found that the golden proportion is a reliable predictor for determining the width of the maxillary central incisors in the South Indian population [8]. Preston in a study, measured 58 computer-generated images of dental casts with an image-measurement program and evaluated the frequency of the golden proportion (considered to be in the range of 0.61 - 0.63) in the ratios of the perceived maxillary lateral to central incisors and canine to lateral incisors. He found 17% of his study samples had golden proportion between the width of the maxillary central and lateral incisors [1].

Lombardi however in his research recommended a repeated ratio concept in contrast to golden proportion. Ward introduced the Recurring Esthetic Dental (RED) proportion concept, stating that clinicians may use a proportion of their own choice, as long as it remains consistent, proceeding distally in the arch [6] [9]. Mahshid *et al.* reported that the golden proportion did not exist between the widths of the maxillary anterior teeth and it was substantiated by researches done by Ward, Gillen *et al.* and Rosenstiel *et al.* [10] [11] [12].

In Gillen's cross-sectional descriptive study on the topic "Analysis of Selected Normative Tooth Projections" conducted to determine the average dimensions of the six maxillary teeth in a targeted population and to evaluate the relationships between intertooth dimensions. 54 dental casts of males and females (21 white males, 13 black males, 10 white females and 10 black females) were measured using a digital caliper. Using these measurements, ratios were calculated: length to width, width to width, and length to length. Although the tooth di-

mensions varied somewhat by race and gender, the ratios were quite consistent. However, the golden proportion was not found to correlate with any of the calculated ratios [2] [11].

In a study conducted to determine the best mathematical proportion that exists between the maxillary anterior teeth widths among Jordanian population, a randomly selected 150 (78 male and 72 female) patients were subjected to clinical examination and maxillary teeth impressions. For each subject, a stone cast was placed on a flat surface and grid lines were drawn for the perceived width of the six anterior teeth and measured with a digital caliper. Width dimensions were quantified by geometric proportions, related to each other and compared with golden proportion, recurring esthetic dental proportion (RED) and golden percentage. Data were analyzed statistically using the Chi-square test and t-test (SPSS-V17.0) at 95% confidential interval. Level of significance was set to 0.05. The golden percentage seems to be acceptable for Jordanian population. Study was conducted to determine the best mathematical proportion that exists between the maxillary anterior teeth widths among Jordanian population [13].

A cross-sectional study by Azimi *et al.* was published on February 27, 2016 on the topic “Evaluating Recurring Esthetic Dental Proportion (RED) and Golden Proportion in Natural Dentition” [14]. This descriptive study used sequential sampling and was conducted with 116 subjects (88 women and 28 men) in Shahed Dental School in Iran using photographs, where images of subjects taken were transferred to a computer and digital measurements recorded [14]. Evaluating the existence of the golden proportion by evaluating teeth ratios indicated that the golden proportion in the range of 0.55 - 0.64 existed in 25% of lateral to central incisors and 2.1% of canine to lateral incisor in maxilla [14].

Although the golden proportion has been proposed in the literature by Preston as a useful application for achieving proportion and aesthetics, no one has yet evaluated this proportion in esthetically accepted cases [15]. Preston also stated that this association was the exclusion in nature, rather than the rule, its existence however produced the most aesthetic expression [15]. On the contrary despite the approach to the assessment of the golden proportion, researchers have found that usage of the golden proportion is theoretical and its application is quite challenging.

2. Methodology and Materials

Pythagoras in 530 BC proposed the Pythagoreans’ Golden Number, represented by the Greek symbol, $\phi \left[\phi \left(\frac{1+\sqrt{5}}{2} \right) \right]$. Lombardi however in 1973 was the first who emphasized the importance of order in dental composition, with a recurring ratio noted between all teeth from the central incisor to the first premolar. In its simplest depiction, the golden proportion postulates that if we take the lateral incisor as a factor of 1, then the central incisor would be 1.6. The visible part of that canine, usually the mesial part of the canine in that front photographic

view, would be 0.6. [6] [7]. These ratios are illustrated in pictorial form in **Figure 1**.

Picture showing golden ratio described by Levin [7].

Sampling Technique and Size

The study adopted the convenience sampling technique. Participants were approached at the dental clinic for the administration of the confidentiality form. It was specifically based on all individuals who fell under the definition of our inclusion criteria and were easily accessible during the study. This method was chosen for its simplicity and ease for the researchers. An alginate impression was then taken for a study cast for all the individuals who consented to our study by filling our confidentiality form.

To calculate our sample size, the formula $n = \frac{Z^2(1-p)}{C^2}$ was used, where

n = (5%) estimated sample size.

p = the probability that the desired sample size will not be representative of the study population.

C = level of confidence that the chosen sample will be representative of the population (95%)

$$n = \frac{1.96^2 \times 74(100 - 26)}{(1 - 0.95)^2}$$

$$n = 841.46$$

For a population that is less than 10,000, the following is used

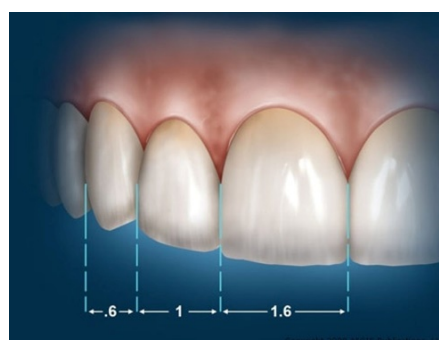
$$nf = \frac{n}{1 + n}$$

where:

nf = desired sample size for a population less than 10,000.

n = estimated size of the population with the characteristics of interest under investigation.

$$nf = \frac{841}{\left(1 + \frac{841}{100}\right)}$$



The "golden ratio"

Figure 1. Picture showing the golden proportion.

$nf = 90$ casts

This was approximated to 100 casts.

The study population used were clients visiting Komfo Anokye Teaching Hospital dental clinic for treatment aged between 18 years to 37 years. These are individuals who have completed their dental growth and with proper occlusal articular balance and also the age group who are more concerned with esthetics. Convenience sampling technique was used in selecting 100 subjects consisting of 50 males and 50 females.

Inclusion Criteria

- All patients aged 18 - 37 years visiting the dental clinic
- All patients who consented to the study procedures.
- Patients with fully erupted permanent Maxillary central incisor (MCI), Maxillary lateral incisor (MLI) and Maxillary canine (MC).
- Maxillary anterior teeth free from caries, interproximal restoration or crown fracture
- Well aligned anterior teeth and an aesthetically acceptable smile.

EXCLUSION CRITERIA

- All persons below age 18 years and above 37 years.
- All persons 18 - 37 years who refused consent to participate in the study.
- Patients with midline diastema.
- Congenital or acquired facial and dental defects.
- History of orthodontic treatment.

Data Collection Method and Instruments

For each participant a maxillary arch impression was taken to form a cast (positive replica) as shown in **Figure 2**. The measurements were performed by placing the cast on a flat surface and grid lines were drawn for the perceived width of the six anterior teeth (**Figure 2**) and measured using an electronic digital caliper presented in **Figure 3**. The accuracy of the measurements was set at ± 0.01 mm. Each tooth was measured three times and the average calculated. For the purpose of this study the golden value was set at 1.6 ± 0.05 .

Concerning the Golden Proportion (GP) or successive tooth-to-tooth width proportion analyses, the apparent widths of each tooth were measured over a Levin's grid registered on a blank card and viewed from the front. Levin argued that successive GP occurs when both the central incisor and lateral incisor, and the lateral incisor and canine relations are in agreement with the golden number, that is, 0.618. In other words, the width of the central incisor is in GP to the width of the lateral incisor, which is also in GP to the width of the canine.

Data Analysis

The data compiled was analyzed using IBM Statistical Package for Social Sciences (SPSS) version 23.0. The drawing of graphs and charts was done using Microsoft Excel and the results were displayed using tables.

Ethical approval was obtained from the School of Medical Sciences-KNUST, Institutional Review Board (IRB).



Figure 2. Picture of dental model on drawn grid as used for measurements in study.



Figure 3. Picture showing electronic calipers used and sample dental cast.

3. Results and Analysis

A total of 100 clients visiting the Oral Health directorate of Komfo Anokye Teaching Hospital participated in this study. The details of results obtained from the data are shown below.

Socio-demographic information

The study included 100 clients as shown in **Table 1**. The age range of participants was 18 - 37 years. The minimum age was 18 years for both males and females. The maximum age was 37 years for males and 36 years for females, as shown in **Table 2**.

Table 2 shows that out of the 100 participants, 50% belonged to the age range 22 - 25 years (males = 22 and females = 28) with an overall mean age of 25.22 years.

Table 3 represents the perceived mean widths of the maxillary anterior teeth (left and right sides) in relation to gender measured from May to September, 2019. There was no significant difference between the left and right maxillary centrals for males and only the left lateral incisors showed no significant gender differences.

The results of the mean ratios of the maxillary centrals to laterals and the maxillary laterals to canines and the percentage of males and females who satisfied the GP (1.6 +/- 0.05) with these ratios are shown in **Table 4** and **Table 5** respectively.

Table 1. Demographic characteristics of study participants (n = 100).

| Demographic characteristics | Number | Percentage (%) |
|-----------------------------|--------|----------------|
| Gender | | |
| Male | 50 | 50 |
| Female | 50 | 50 |

Table 2. Demographic characteristics of study participants in relation to specific age Males (n = 50); Females (n = 50).

| Age range (years) | Frequency (Percentage) | | Total (Percentage) |
|-------------------|------------------------|-----------|--------------------|
| | Males | Females | |
| 18 - 21 | 8 | 7 | 15 |
| 22 - 25 | 22 | 28 | 50 |
| 26 - 29 | 12 | 8 | 20 |
| 30 - 33 | 6 | 4 | 10 |
| 34 - 37 | 2 | 3 | 5 |
| Total | 50 (50.0) | 50 (50.0) | 100 (100.0) |

Table 3. Perceived widths of maxillary anterior teeth in relation to gender.

| Width | Central Incisor | | Lateral Incisor | | Canine Incisor | |
|----------------|-----------------|-----------|-----------------|-----------|----------------|-----------|
| | Right (mm) | Left (mm) | Right (mm) | Left (mm) | Right (mm) | Left (mm) |
| Males (mean) | 8.97 | 8.95 | 5.77 | 6.01 | 3.50 | 3.60 |
| Females (mean) | 8.61 | 8.83 | 5.66 | 6.05 | 3.58 | 3.39 |

Table 4. Representation of the ratios of maxillary central incisor (MCI) to maxillary lateral incisor (MLI) and maxillary lateral incisor (MLI) to maxillary canine (MC) in relation to gender.

| | Right side | | Left side | |
|----------------|--------------|-------------|--------------|-------------|
| | MCI/MLI (mm) | MLI/MC (mm) | MCI/MLI (mm) | MLI/MC (mm) |
| Males | 1.5719 | 1.7610 | 1.5126 | 1.7330 |
| Females | 1.5548 | 1.6117 | 1.4714 | 1.8404 |

Table 5. Golden proportion relationship of right and left sides of the maxillary anterior teeth in male and female subjects.

| PERCENTAGE OF TEETH IN GOLDEN PROPORTION | | | | | | |
|--|------------|------------|--------|-----------|----------|--------|
| Gender | Right side | | | Left side | | |
| | MCI/MLI % | MLIR/MCI % | % Diff | MCI/MLI % | MLI/MC % | % Diff |
| Males (n = 50) | 14.00 | 20.00 | 6.00 | 20.00 | 8.00 | 12.00 |
| Females (n = 50) | 12.00 | 20.00 | 8.00 | 16.00 | 14.00 | 2.00 |
| Total | 26.00 | 40.00 | 14.00 | 36.00 | 22.00 | 14.00 |

4. Discussion

This study was conducted to evaluate the concept of the Golden Proportion that has been used over the years among Caucasians as a determinant of esthetics in the maxillary anterior teeth widths. The sample consisted 100 individuals 50 men and 50 women, aged between 18 and 37 years. These are young people or young adults who have completed their growth and with proper occlusal articular balance and also the age group who are more concerned with esthetics during smile and speech. Their selection however did not take into account the respective shapes of the Upper Central Incisors (rectangular, triangular or square), but rather the presence, proper alignment and integrity of the anterior teeth with no previous history of orthodontic treatment as this could influence the results. Frechner as quoted by Shillingburg *et al.*, 1998, showed that the rectangles whose proportions meet the golden ratio are more pleasing to the sight [16]. Also, the measurement of the teeth was restricted to only the GP as explained by Levin, 1978 that during a smile only 62% of the width of the lateral incisor is displayed by the canines [7]. This, when measured targets the cuspal tips of the canines. Most smile analysts also confirm that during a smile, only up to the canine cusp is visible in the frontal view. Our study thus limited the measurement of the canine tooth to this point. However, our method of study is based on analysis of data obtained from measurements made on the cast although we recognize other similar studies were based either on direct measurements on the patient using a double decimeter or using the Levin's golden rule; or the indirect measurements on analog photography, or a slide projected on a viewer or on the screen of a computer from a digital photograph. This method we adopted in our study could have introduced bias in our results. Nevertheless, we can consider that the volumetric changes of impression materials and casting taking place in every sense of space, the proportions remain constant. In all cases, since it is an analysis of relationships, both measures concerned (numerator and denominator) undergo the same variations, the differences due to the properties of these materials can be neglected.

Results in relation to Gender and Laterality

The results of our study were considered in relation to gender. The results of our study revealed the golden proportion was approximately found to be 14% and 20% for the left and right respectively between the central incisor and the lateral incisor for males and 12% and 16% respectively for the left and right sides of females. For the ratio lateral incisor to canine widths, both males and females had 20% of each population expressing the GP on the right side although on the left side, females expressed more GP with 14% than the males who expressed only 8% GP. These values were statistically significant ($p < 0.05$).

The outcome of our study seems to conflict with some of the results of studies done on GP. In a study by Mahshid *et al.*, using images of subjects for data collection, the existence of the golden proportion was found to be similar in the left and right side and for both sexes [1]. Also in a similar study by Azimi *et al.*, also

using images of subjects for data collection, results from their study revealed no significant gender and laterality difference [14]. However in the study done in Ivorian melanoderms using dental casts, they noted that there were slight differences between the two sexes. However, this finding according to their study was statistically insignificant. They concluded that the golden ratio does not differ according to the sex. Furthermore in a study by Ahmad *et al.*, using dental casts, they recorded no statistical gender differences in the golden percentage ($p > 0.05$) [4]. However, for calculated percentages, it was shown that females recorded more values compared to males. In addition, the right side values were higher than that of left sides, but the differences were statistically insignificant.

Results of Ratio of MCI to MLI and Ratio of MLI to MC

The values from this present study for the ratio of MCI to MLI and the ratio of MLI to MC for both the left and right sides are higher than those reported by Azam *et al.* in 2014, who found that golden proportion existed in the relationship between the maxillary central and lateral incisors in only 1.0% and 2% of the perceived canine to lateral incisor ratio on the right side and 6% on the left side using images of subjects for data collection [17].

Our results also seem to be different from the results obtained by Preston who evaluated his results from study casts of subjects and found GP to exist in only 17% maxillary lateral to central and 0% canine to lateral. This difference could have resulted from the wider range of GP we used in our study. Azimi *et al.*, in their study analyzed data from images, with results inconsistent with this study [14]. The results from their study revealed GP to exist in 25% of lateral to central incisors and 2.1% of canine to lateral incisor in maxilla in the range of 0.55 - 0.64 [14].

In a study conducted to determine the best mathematical proportion that exists between the maxillary anterior teeth widths among Jordanian population, evaluation of our results against this study showed dissimilarities as their results revealed that golden proportion for the widths of central incisors to that of lateral incisors existed in 22% which is higher than the results of our study for both gender and even when viewed as a whole [13]. They found GP to be in 11% for the widths of lateral incisors to that of canines which is inconsistent with our results for both gender.

Evaluation of the GP in Permanent Maxillary Anterior Teeth

When the GP was calculated from the mean values of the maxillary anterior teeth widths for both gender, males expressed GP for both ratios (MCI/MLI = 1.55 and MLI/MC = 1.6) for the right side. There was however no GP on the left side (MCI/MLI = 1.49 and MLI/MC = 1.67). Females only expressed GP on the right side for MLI/MC which was found to be 1.58 from the calculated mean ratios. The ratios on the right side was found to be 1.52 for MCI/MLI on the right and 1.46 and 1.78 for left mci/mli and left MLI/MC respectively. Comparison of our MCI/MLI results with the study done by Pesson *et al.*, revealed GP in a higher percentage of our subjects than the Ivorian melanoderms [16]. The re-

sults from the Ivorian study showed mean GP to be 1.24 for MCI/MLI whilst our results were 1.49 for the left side and 1.55 for the right side in males and 1.46 for the left and 1.52 for the right in females.

5. Conclusion

The golden proportion has been seen as an instrument of harmony and beauty and has served as a standard or guide in aesthetics for so many years in dentistry. Nonetheless, its universal application can be questioned. Although many researchers studied the differences in the maxillary anterior proportions using various types of geometric patterns, it was difficult to compare our results with theirs due to variations in the variables incorporated and racial differences. The results that emerged from our study were that the GP did not exist in majority of Ghanaians. We also could not establish the fact that the proportion had no gender influence as have already been established by previous similar studies. The results from our study showed different percentages of males and females who expressed the GP and different values for the left and right sides.

Limitations

Limitations of this study may be associated with our sample size and also may have been influenced by the method of our data collection. In addition, the method used in this study gives information about tooth width ratios mathematically and ignores the perceived personal judgment.

Another limitation to our study could be the fact that we did not consider specific tooth shape and length as part of our inclusion criteria. We believe if this had been considered we would have had results that were more consistent with the previous studies done in the field of esthetic dentistry.

Recommendation

Further research is still needed to overcome the limitations of this study which includes studying a larger sample, including other methods of anterior teeth esthetic determination, different age groups and incorporation of the maxillary and mandibular arch forms which may be needed before the results of this study can be applied on the general population.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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