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SYSTEMATIC REVIEW

# Evaluation of the golden proportion in the natural dentition: A systematic review and meta-analysis

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## ABSTRACT

**Statement of problem.** Different proportions of tooth width ratios have been evaluated, and the golden proportion is the best known. Although the prevalence of the golden proportion has been evaluated in different ethnic groups and populations, a meta-analysis of these studies is lacking.

**Purpose.** The purpose of this systematic review and meta-analysis was to investigate the existence and suitability of the golden proportion for tooth width ratios and to assess the prevalence of the golden proportion among populations.

**Material and methods.** A systematic search based on the Patient, Intervention, Comparison, Outcome (PICO) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was conducted in PubMed, Cochrane, Scopus, Web of Science, and Embase in January 2021 without any time limitations and included English and non-English-language articles. Additional studies were identified by searching the reference lists of the retrieved articles. Two reviewers independently performed the literature search and data extraction, selecting articles based on the inclusion and exclusion criteria. Eligible studies were selected based on the inclusion criteria, and quality assessments were conducted. Descriptive statistics were applied for a number of outcome measures. Using a meta-analysis software program, data extracted from each selected study were statistically combined by using weighted mean differences and 95% confidence intervals, and heterogeneity was calculated for each measurement.

**Results.** A total of 566 articles were retrieved based on the keyword search. After the articles were assessed based on the inclusion and exclusion criteria, only 6 articles were included in the meta-analysis.

**Conclusions.** The outcomes of the review and analyses demonstrate that evidence supporting the existence of the golden proportion in natural smiles is lacking and that the existence of the golden proportion in dentistry is a myth and not a fact. However, the golden percentage theory can be applied with modified percentages that consider critical aspects of esthetic dentistry. (J Prosthet Dent 2021;■:■-■)

An eye-catching smile is key to sustaining and improving an appealing appearance and, accordingly, self-confidence.[1] Although societies have their own definitions of beauty, analyses of attractive smiles have shown that repeatable, calculable, and evenly applied principles can be logically used to assess and improve dental esthetics.[2] Given that beauty is an exceedingly subjective issue, the esthetic appearance of a smile depends mainly on what a practitioner perceives as beautiful. Therefore, the establishment of esthetic guidelines in prosthodontic treatment can significantly alleviate misunderstandings and redundant treatments and enhance outcomes.

Lombardi[3] first reported a correlation between the golden proportion and teeth, and Levin[4] then applied this proportion in dental esthetics, proposing that the width of the maxillary lateral incisor should be 0.618 of the width of the maxillary central incisor and that the lateral incisor should be 0.618 of the width of the canine in a frontal view (Fig. 1). Ward[5] recommended the "recurring esthetic dental proportion" (RED)[5] based on the successive width of the teeth remaining constant as they progress distally from the midline. Snow[2] recommended the golden mean or golden percentage, in which each

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## Clinical Implications

Clinicians should update their esthetic concepts and limit their use of the golden proportion when restoring patients' smiles. In addition, modified gauges that are distinct from the golden proportion are needed.

canine is 10% of the intercanine width from the frontal view, each lateral incisor is 15%, and each central incisor is 25% to attain an esthetically attractive smile (Fig. 2). In 1993, Preston[6] studied the tooth-to-tooth width proportions in a small population and reported that the golden proportion was not observed in the majority of smiles. He reported that the average width of the maxillary lateral incisor was 66% of the width of the central incisor, and the average width of the maxillary canines was 55% of the width of maxillary central incisors when viewed frontally.

The presence of different proportions may be directly related to ethnicity and sex, and the average dimensions of the maxillary anterior teeth reportedly vary.[7-11] However, in other studies, no correlation between dental morphology and sex has been reported.[7-14] These outcomes necessitate the evaluation of anterior dentition among various populations or ethnic groups. This information also helps inform esthetic treatment plans to meet esthetic and functional criteria in multiple ethnic populations in contemporary societies.[15-18]

Starting points for helping clinicians to decide on specific proportions when treating patients with esthetic needs or diagnosing dental esthetic problems have been described, including the use of the golden proportion.[3,4] Nevertheless, the authors are unaware of systematic reviews and meta-analyses that clearly define whether this proportion is sufficient for appropriately and accurately determining the size of the maxillary anterior teeth and establishing normal relationships among them. The aim of this meta-analysis was to delineate the prevalence of the golden proportion in dentition in various populations. The null hypothesis is that there is no dominance of the golden proportion in natural dentition.

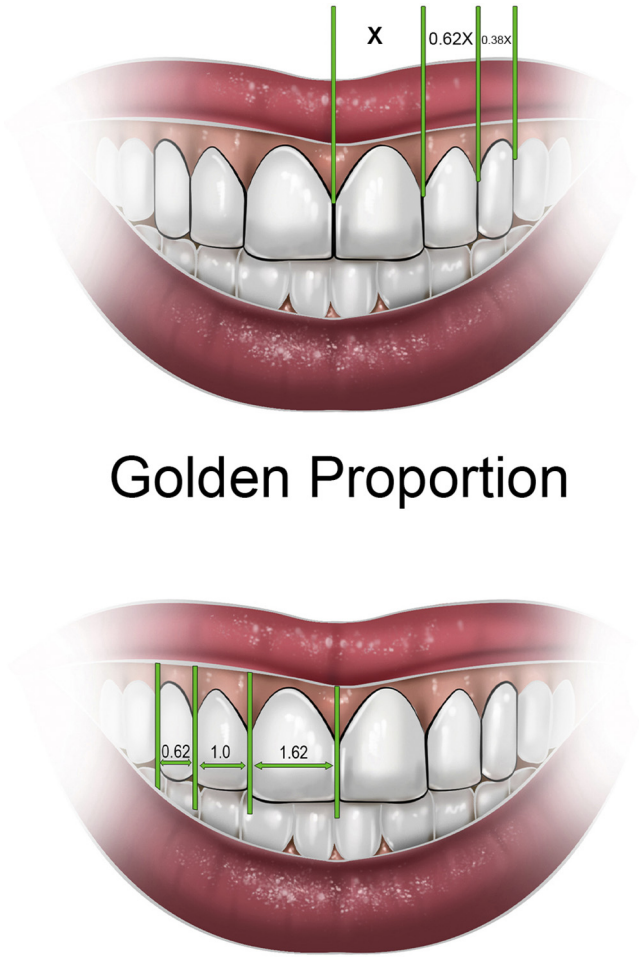


**Figure 1.** Golden proportion.

## MATERIAL AND METHODS

Major databases were searched in January 2021 for review articles that met specific inclusion and exclusion criteria (Table 1) without any time or language limits. The search was based on the Patient Intervention Comparison Outcome (PICO) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Fig. 3). The references of review articles were manually searched to identify additional articles. For non-peer-reviewed articles available in Scopus, secondary documents for conference papers, book chapters, and notes were searched.

The keywords were selected based on 2 topics: anterior maxillary teeth and studies that included the golden proportion. The inclusion criteria were studies that assessed the presence of the golden proportion in the study population. The exclusion criteria were studies that applied a proportion other than the golden proportion or identified an optimal proportion in the study population; studies that compared the presence of the golden proportion to other proportions; studies that included patients with missing teeth, syndromes, or deformities; studies that included patients who had undergone esthetic treatments such as orthodontia or veneers; and studies for which the full text was not available. These studies were excluded because the goal was to study the prevalence of the golden proportion in the natural dentition and not in dentition that had been modified based on the practitioner's concept of beauty.

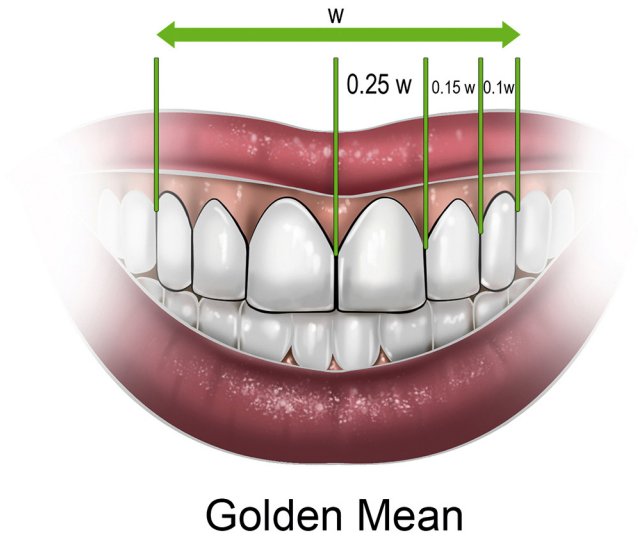


**Figure 2.** Golden mean.

## RESULTS

The search strategy returned 69 articles. After the titles and abstracts were reviewed, 10 articles were eliminated, leaving 59 articles. Five additional articles were excluded because they were not available in a full-text format, and their authors did not respond to email or message requests, leaving 54 articles. Seven articles were identified after manual searches of the references of other articles. Hence, a total of 61 articles were finally chosen for full-text review.

After performing a hand search of the 7 reviews included in the sample, 5 reviews were found that included studies not previously on the list. Eighteen new articles were identified from these 5 reviews, none of which met the inclusion criteria. Two reviews did not include new articles,[2]18 articles were found during the hand search of review articles, but all of them were excluded because they did not conform to the methodology of this meta-analysis.[19-40]

Four forest plots of continuous data with mean ±standard deviation (SD) were used to analyze data based on the inverse variance (IV) method, and the strength of their association was determined by the mean difference. Heterogeneity (I2), which is the variation in study outcomes, was calculated by using the Higgins I2 statistic and chi-squared tests. Based on the heterogeneity value, either a fixed-effects or a random-effects model was used to calculate the effect size of the study. For studies with heterogeneity >50% or $P \leq .05$, a random-effects model was used; otherwise, a fixed-effects model was used. Higher heterogeneity corresponds to higher variation among studies. A Z score $\geq 1.96$ or $P \leq .05$ was considered significant.

For the meta-analysis, only studies that reported the mean and standard deviation of tooth width for men and women were selected. Six studies were presented in a meta-analysis that compared the tooth width ratios of male and female participants. In the 6 studies, 395 men and 446 women were assessed. The tooth width ratio of the lateral incisor to the central incisor did not differ ($P$=.22) between men and women but exhibited high heterogeneity (I2=89%). High heterogeneity among the studies, especially in cases of >50% heterogeneity, negatively affected the precision of the results. The comparison of tooth width ratio of the canine to the lateral incisor showed a significant difference ($P$<.001) and acceptable heterogeneity ($I^2$=47%), indicating that male participants had a greater tooth width ratio of the canines to lateral incisors than female participants (Figs. 4 and 5).

**Table 1.** Summary of search findings

| Database | Keywords | Results |
|---|---|---|
| PubMed | ("Maxillary Anterior teeth" OR "Maxillary Central Incisor" OR "Maxillary Lateral Incisor" OR "Maxillary Anterior Teeth Width" OR "Maxillary Central Incisor Width" OR "Maxillary Lateral Incisor Width" OR "Proportion" OR "Width Proportion" OR "Tooth Proportion" OR "Tooth Width") AND ("Golden Proportion") | 89 |
| Cochrane | golden proportion | 35 |
| Scopus | (TITLE-ABS-KEY ("maxillary anterior teeth") OR TITLE-ABS-KEY ("maxillary central incisor") OR TITLE-ABS-KEY ("maxillary lateral incisor") OR TITLE-ABS-KEY ("maxillary anterior teeth width") OR TITLE-ABS-KEY ("maxillary central incisor width") OR TITLE-ABS-KEY ("maxillary lateral incisor width") OR TITLE-ABS-KEY (proportion) OR TITLE-ABS-KEY ("width proportion") OR TITLE-ABS-KEY ("tooth proportion") OR TITLE-ABS-KEY ("tooth width")) AND (TITLE-ABS-KEY ("golden proportion")) | 168 |
| Web of Science | ALL=("Maxillary Anterior Teeth" OR "Maxillary Central Incisor" OR "Maxillary Lateral Incisor" OR "Maxillary Anterior teeth Width" OR "Maxillary Central Incisor Width" OR "Maxillary Lateral Incisor Width" OR "Proportion" OR "Width Proportion" OR "Tooth Proportion" OR "Tooth Width") AND ALL=("Golden Proportion") Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=All years | 96 |
| Embase | ('maxillary anterior teeth':ti,ab,kw OR 'maxillary central incisor':ti,ab,kw OR 'maxillary lateral incisor':ti,ab,kw OR 'maxillary anterior teeth width':ti,ab,kw OR 'maxillary central incisor width':ti,ab,kw OR 'maxillary lateral incisor width':ti,ab,kw OR 'proportion':ti,ab,kw OR 'width proportion':ti,ab,kw OR 'tooth proportion':ti,ab,kw OR 'tooth width':ti,ab,kw) AND 'golden proportion':ti,ab,kw | 96 |
| Scopus Secondary Documents (Gray Literature) | (TITLE-ABS-KEY ("maxillary anterior teeth") OR TITLE-ABS-KEY ("maxillary central incisor") OR TITLE-ABS-KEY ("maxillary lateral incisor") OR TITLE-ABS-KEY ("maxillary anterior teeth width") OR TITLE-ABS-KEY ("maxillary central incisor width") OR TITLE-ABS-KEY ("maxillary lateral incisor width") OR TITLE-ABS-KEY (proportion) OR TITLE-ABS-KEY ("width proportion") OR TITLE-ABS-KEY ("tooth proportion") OR TITLE-ABS-KEY ("tooth width")) AND (TITLE-ABS-KEY ("golden proportion")) | 82 |

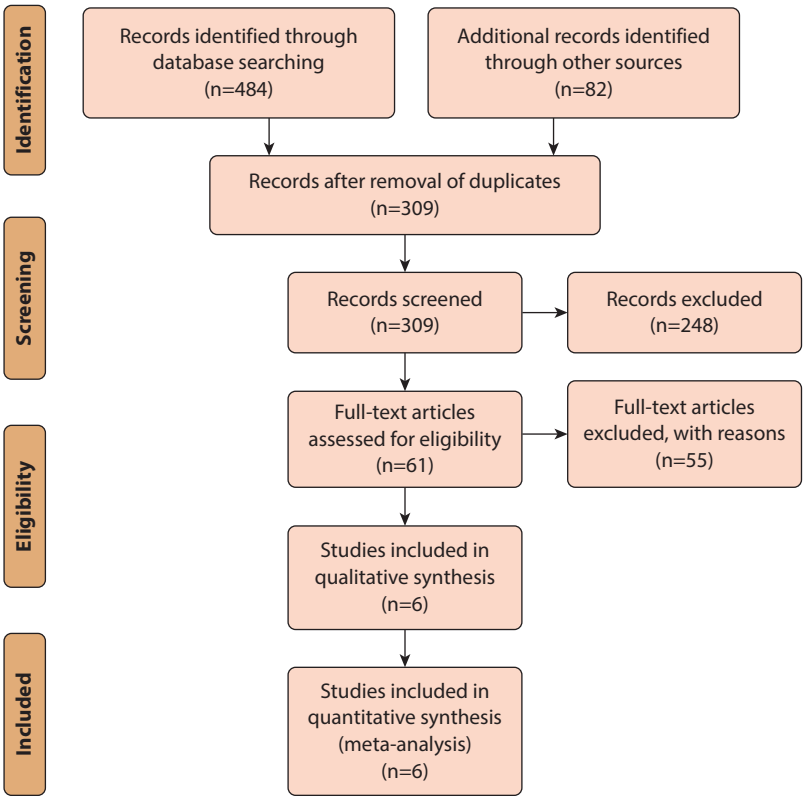


**Figure 3.** Search and selection criteria for published articles.

| | Male | | | Female | | | | Mean Difference | | Mean Difference |
|---|---|---|---|---|---|---|---|---|---|---|
| **Study of Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Random, 95% CI** | **Year** | **IV, Random, 95% CI** |
| Aldegheishem 2019 | 0.96 | 0.08 | 25 | 0.99 | 0.13 | 36 | 11.7% | −0.03 (−0.08, 0.02) | 2019 | |
| Kantrong 2019 | 0.72 | 0.06 | 55 | 0.72 | 0.05 | 85 | 18.3% | 0.00 (−0.02, 0.02) | 2019 | |
| Mahajan 2019 | 0.711 | 0.0784 | 100 | 0.7811 | 0.0812 | 100 | 17.8% | −0.07 (−0.09, −0.05) | 2019 | |
| Özdemir 2018 | 0.69 | 0.065 | 69 | 0.67 | 0.051 | 81 | 18.3% | 0.02 (0.00, 0.04) | 2018 | |
| Al-Kaisy 2017 | 0.624 | 0.059 | 26 | 0.62 | 0.068 | 24 | 15.1% | 0.00 (−0.03, 0.04) | 2017 | |
| Sandeep 2015 | 0.672 | 0.054 | 120 | 0.703 | 0.063 | 120 | 18.9% | −0.03 (−0.05, −0.02) | 2015 | |
| **Total (95% CI)** | | | **395** | | | **446** | **100.0%** | **−0.02 (−0.05, −0.01)** | | |

Heterogeneity, $\tau^2$=00; $\chi^2$=44.81, *df*=5 (*P*<.001); $I^2$=89%
Test for overall effect Z=1.23 (*P*=22)

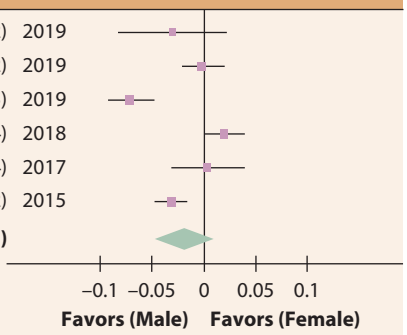


**Figure 4.** Forest plot showing comparisons of tooth width ratios of lateral incisor to central incisor between men and women.

## DISCUSSION

The null hypothesis was accepted because the golden proportion was not common in the populations included. Race, ethnicity, and sex have been reported to affect the average size and shape of anterior maxillary teeth in certain populations.[14,17] Although most esthetic rules use an objective standard for defining ratios and proportions, studies on the factors that determine an esthetically pleasing smile are lacking. Plastic surgeons evaluate proportions and angles when assessing patients before planning possible surgeries. Norms collected must correspond to the ethnic or racial origin of the study group. A quantitative diagnosis of abnormities is based on anthropometric measures (linear projective measurements, arcs, angles, and proportions).[41] Direct measurement procedures can be painstaking and time-consuming but are necessary because "this descriptive phase has brought us to a new stage where accuracy and quantitation have become desirable."[42] Orthodontists regularly measure cephalometric radiographs to determine critical angles of hard tissues and compare them with accepted norms.[43]

The present systematic review and meta-analysis showed the presence of a golden ratio of the maxillary

| Study of Subgroup | Male Mean | Male SD | Male Total | Female Mean | Female SD | Female Total | Weight | Mean Difference IV, Fixed, 95% CI | Year |
|---|---|---|---|---|---|---|---|---|---|
| Aldegheishem 2019 | 0.52 | 0.06 | 25 | 0.51 | 0.06 | 36 | 15.5% | 0.01 (−0.02, 0.04) | 2019 |
| Kantrong 2019 | 0.82 | 0.14 | 55 | 0.78 | 0.11 | 85 | 7.6% | 0.04 (−0.00, 0.08) | 2019 |
| Mahajan 2019 | 0.6945 | 0.0818 | 100 | 0.6715 | 0.0697 | 100 | 32.8% | 0.02 (0.00, 0.04) | 2019 |
| Özdemir 2018 | 0.86 | 0.11 | 69 | 0.88 | 0.1 | 81 | 12.7% | −0.02 (−0.05, 0.01) | 2018 |
| Al-Kaisy 2017 | 0.732 | 0.14 | 26 | 0.661 | 0.108 | 24 | 3.1% | 0.07 (0.00, 0.14) | 2017 |
| Sandeep 2015 | 0.744 | 0.084 | 120 | 0.714 | 0.095 | 120 | 28.3% | 0.03 (0.01, 0.05) | 2015 |
| **Total (95% CI)** | | | **395** | | | **446** | **100.0%** | **0.02 (0.01, 0.03)** | |

Heterogeneity, $\chi^2$=9.49, *df*=5 (*P*=.09); $I^2$=47%
Test for overall effect Z=3.29 (*P*≤.001)

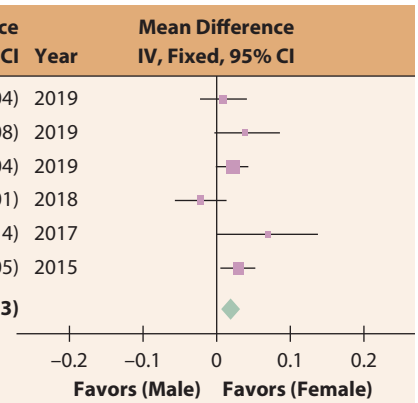


**Figure 5.** Forest plot showing ratio comparisons of tooth width from canine to lateral incisor between men and women.

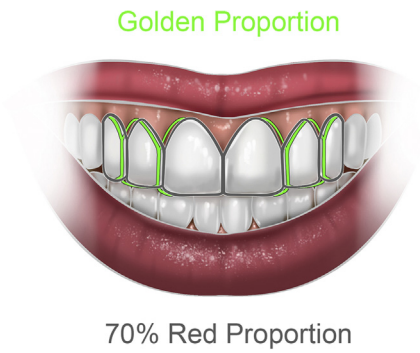


**Figure 6.** Comparison of golden proportion to 70% RED proportion.

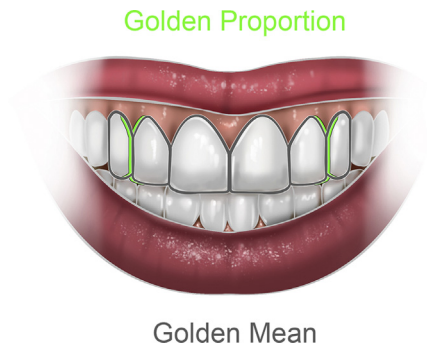


**Figure 7.** Comparison of golden proportion to golden mean.

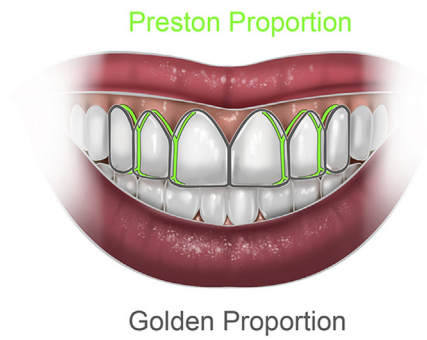


**Figure 8.** Comparison of golden proportion to Preston proportion.

lateral incisor to the central incisor and of the canine to the lateral incisor with a 95% confidence level based on reviews identified with a keyword search, selected based on the term "anterior maxillary teeth," and studies that included the golden proportion.[21] In earlier studies, measurements and data were obtained from extracted teeth. More recent studies have attempted to measure the clinical dimensions of teeth by using computer images, casts, or intraoral assessments of the relative size of the teeth in the arch.[5,44]

Various database searches were used to identify studies that assessed the presence of the golden ratio in individuals in the target population who were evaluated from the frontal view. The presence of the golden ratio was assessed in individuals deemed to have an esthetically pleasing smile, with the conclusion that the golden ratio was not observed in the natural dentition of the majority of individuals. In 1993, Preston[6] reported that only 17% of maxillary lateral incisors were in golden proportion to the maxillary central incisors, and none of the canines were in golden proportion to the maxillary lateral incisors. The results of the present study were consistent with those reported by Mahshid et al.[45] The variation in the values obtained in this study compared with those of the Preston study can be attributed to the differences in ranges noted in the present study and the comparison of the mean ratio of the maxillary lateral incisor to the maxillary central incisor with the mean ratio of the maxillary canine to the maxillary lateral incisor.

Comparisons of the proportions from the anterior view are shown in Figures 6–8. Figure 9 presents a summary of how each proportion was calculated. Although the findings for these proportions were consistent with the results of the present study, it seemed inappropriate to calculate proportional means and compare them with one another because a repetitive proportion must be estimated for each individual separately. Therefore, by changing the

**Formulas Used for Tooth Width Calculations**

| Tooth - to - Tooth Width Proportion | Central Incisor (CI) Width | Lateral Incisor (LI) Width | Canine Width |
|---|---|---|---|
| Golden proportion | IC width×0.25 | CI width×0.62 | LI width×0.62 |
| Golden Mean | IC width×0.25 | IC width×0.15 | IC width×0.10 |
| Preston Proportion | Preston CIW$^{+}$ | CI width×0.66 | LI width×0.84 |
| 70% RED Proportion | Red CIW$^{-}$ | CI width×0.70 | LI width×0.70 |

RED=recurring esthetic dental; IC width=intercanine width of six maxillary teeth (as viewed from front).

RED expressed as decimal: 70% RED is entered as 0.7.

$$^{+}\text{Preston CIW}=\frac{\text{Total intercanine frontal view width}}{2(1+0.66+(0.66\times0.84))}$$

$$^{-}\text{RED CIW}=\frac{\text{Total intercanine frontal view width}}{2(1+\text{RED}+\text{RED}^{2})}$$

**Figure 9.** Solving two equations reveals that maxillary central incisor width of 70% RED proportion (1/4.38 rounded to 0.23) similar to width of maxillary central incisor using Preston proportion (1/4.42 rounded to 0.23).

assessment method to accommodate the limitations of this study, the conclusion was drawn that the golden ratio does not exist in the natural dentition of a significant number of people and is thus irrelevant; that is, if these proportions are not used, patients will not have visible abnormalities in their prostheses, and proportions should be chosen that are harmonious with each patient's face.

In the included studies, the average height of the lower part of the face was markedly different from the interalar and interpupillary distances. This finding clearly indicates that these measurements cannot accurately predict the width of the maxillary anterior teeth. Therefore, these guidelines cannot be reliably used in facial approximations to predict intercanine distance.[46]

In addition, the present study did not identify a direct relationship between the intercanine distance and other measured parameters. Analyses of measurements showed that intercanine width can be used as guidance for different facial proportions, but not for all ethnic groups.[46]

Past studies may have included fewer minorities and geographically diverse populations, which would have skewed their data.[43,45] Different ethnic and cultural preferences should be taken into consideration when designing smiles. These preferences are systemic and complex, are supported by unequal power beliefs and relationships, and operate at the community, individual, and organizational levels, leading to the stigmatization, marginalization, and discrimination of ethnic minorities. In a review by Kinzer and Kokich,[47] 484 patients from 82 studies were included. In total, 62 of the studies were peer-reviewed, and 304 of the patients were considered eligible for inclusion. These results are essential to the design of public health interventions to reduce morbidity and mortality among ethnic minority groups.

Different approaches have been developed for conducting systematic reviews on a broader range of issues. For example, systematic reviews that examine diagnostic or prognostic issues, ethnicity variations, search engine databases and keywords, genetic associations and policy, and decision-making processes are ongoing. In the present review, broad categories of ethnicity were used to maximize inclusion in the pooled analyses; however, this choice will affect the accuracy of risk estimates for any further categorization of subgroups based on ethnicity.[9-11]

The limitations and differences between the results of this study and those of previous studies may be due to differences in methodology (the use of casts or photographs, rulers, compasses, or meters) or patient ethnicity and in the studies included in quantitative synthesis (meta-analysis). The results of this meta-analysis, which was performed by using a software program, indicate that the relationship between the anterior teeth and specific facial measurements should be used as a preliminary guide for assessing maxillary central incisor width or canine location. As the methodology of each study was different from the others, it was difficult to identify sufficient articles to conduct this meta-analysis. A more accurate meta-analysis regarding evaluating the golden proportion can be done only if a new comprehensive method is introduced that can include populations of different ethnicity and races.

Considering the results of the present study and previous conflicting data, further studies should investigate the application of the golden proportion for treatments of the maxillary lateral incisors. To differentiate among groups and treatment regimens, more patients and different methods of analysis are needed. Monitoring these patients is also necessary to assess the long-term esthetic outcomes of treatment.

The assessment of facial esthetics is a key element in diagnosis and treatment planning in restorative dentistry, with the goal of achieving a balanced smile. However, further research is needed to establish and confirm the proportions of the teeth and face that affect dentoalveolar esthetics.

## CONCLUSIONS

Based on the findings this systematic review and meta-analysis, the following conclusions were drawn:

1. The golden proportion was not prevalent in the population studied.
2. The studies incorporated into the meta-analysis also showed that the tooth width ratio of the lateral incisor to the central incisor did not differ between men and women.
3. The tooth width ratio of the canine to the lateral incisor was greater in men than in women.

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