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Original Article

Reevaluating the Golden Mean and Proportion in Dental Esthetics Following Orthodontic Treatment: A Retrospective Clinical Study

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ABSTRACT

The golden ratio, first defined around the sixth century BC, has been adapted to dentistry through the theories of Levin and Snow, which apply the golden proportion to achieve an ideal smile. This study reviewed the literature and evaluated the contemporary clinical relevance of these concepts by analyzing a cohort of patients treated by an experienced orthodontic team. A retrospective analysis was conducted on 400 orthodontic patients (241 females, 159 males). Intraoral frontal photographs were examined both before and after treatment to determine whether there were statistically significant differences in tooth display in relation to the golden mean and golden proportion principles. After orthodontic treatment, the canine teeth were more prominent than the proportions suggested by Levin and Snow. While aspects of these theories may still provide guidance, they are not entirely consistent with current clinical outcomes. Among the two, Snow's theory aligns more closely with the observed post-treatment dental esthetics.

Keywords: Golden mean, Golden proportion, Dental esthetics, Orthodontics

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Introduction

In recent years, smile analysis and design have become essential components of orthodontic diagnosis and treatment planning. In the context of facial esthetics, an attractive and balanced smile is considered a fundamental objective and a primary goal of contemporary orthodontics.

Evaluating smile esthetics involves multiple parameters, reflecting the complex interplay of dental and facial characteristics. Various authors across dental disciplines have conducted studies to identify guidelines and protocols that may facilitate the creation of an ideal smile. While esthetic judgments are inherently subjective, often shaped by the clinician's perception of beauty, establishing scientific principles for dental treatment could help standardize and improve outcomes [1]. Previous research indicates that analysis of visually appealing smiles can reveal reproducible principles applicable in clinical practice [1].

The dimensions, shape, and color of the maxillary anterior teeth are particularly important for both dental and overall facial esthetics [2–4]. Several theories have been proposed to guide the evaluation of dental proportions, among which the golden proportion is frequently cited as a foundational concept in smile design [1, 4]. Lombardi [1, 5] was the first to identify a relationship between the golden ratio and tooth proportions, which Levin [1, 6] later formalized into the golden proportion (GP) theory. Ward [1, 7] introduced the concept of the recurrent esthetic dental proportion (RED), while Snow [1, 8] developed the golden percentage or golden mean (GM).

Historically, the idea of a "golden" or "divine" proportion, likely coined by Phidias (hence the symbol φ), has served as a standard for aesthetic harmony in art, sculpture, painting, and architecture. The golden proportion reflects the principle that mathematical relationships underlie natural beauty [9].

The aim of this study was to determine whether these proportional principles could be effectively applied in orthodontic treatment planning [10-14]. By analyzing pre- and post-treatment records, the study sought to evaluate the practical applicability of GP and GM theories in assessing dimensional relationships among the maxillary anterior teeth, specifically from canine to canine, using a frontal occlusal view. The null hypothesis was that the golden proportion-based theories would not be supported by clinical cases, whereas the alternative hypothesis posited that these proportions would be observed in practice.

Materials and Methods

A retrospective analysis was performed on 400 patients from a private orthodontic practice in Trento, Italy, comprising 241 females and 159 males, with a mean age of 14 years and 9 months (± 3 years and 2 months). The sample size for this study was notably larger than those reported in previous literature, where studies investigating the relationship between the golden proportion and dental morphology included between 48 and 384 patients [15–23].

The analysis relied on intraoral frontal photographs captured both before and after orthodontic treatment to determine whether statistically significant changes occurred in tooth display and whether the principles of the golden proportion were observed.

Patients were selected from the photographic archive according to the following inclusion criteria:

- Caucasian ethnicity.
- Presence of natural permanent dentition in the maxillary anterior region (canine to canine).
- Availability of pre- and post-treatment intraoral photographs.

No categorization was performed based on skeletal patterns or arch morphology. Photographs were taken with a Nikon N90 digital reflex camera equipped with a 60 mm lens and subsequently processed using Adobe Photoshop 8.0**.** All images were organized into a Keynote presentation for systematic analysis.

Exclusion criteria were applied to ensure the sample consisted of patients with natural, proportionate dentition:

- Presence of restorations or prosthetic work in the maxillary anterior region.
- Congenital agenesis or microdontia.
- Upper arch crowding exceeding 4 mm.

These criteria were intended to exclude cases in which dental anomalies or severe crowding could interfere with accurate measurements or distort pre-treatment assessments.

Measurements were conducted at both the pre-treatment and post-treatment stages to evaluate changes in tooth display and the degree to which the golden proportion was respected in patients with a harmonious final smile achieved under an experienced orthodontic team. Additionally, analyses were performed to examine inter-arch differences between the right and left sides of each patient before and after treatment.

For each intraoral photograph, the following perpendicular reference lines were drawn **(Figure 1)**:

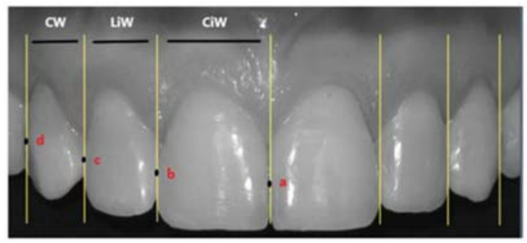

Figure 1. The photograph illustrates the critical points used to conduct dental measurements in this study. The width of the upper central incisors (CiW) was determined by measuring the distance between points *a* and *b*, while the lateral incisor width (LiW) was calculated between points *b* and *c*. The width of the canine (CW) was measured from point *c* to point *d*.

For each image, a reference framework was established, including the inter-incisive line and tangent lines along the distal extremities of the central and lateral incisors, as well as the vestibular surface of the canines. Using this system, a grid was superimposed on each photograph to allow precise and reproducible measurement of the tooth widths. The resulting linear distances were then compared according to the models proposed by Levin and Snow. Under Levin's golden proportion (GP) theory, the widths of the upper anterior teeth are expected to follow specific ratios when viewed from the frontal plane. In this model, if the lateral incisor is assigned a value of 1, the central incisor should ideally measure 1.618, while the upper canine should correspond to a width of 0.6 [6, 21] **(Figure 2)**. This framework was used to assess whether the proportional relationships suggested by the theory were present in the study population.

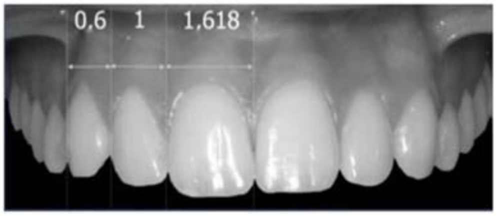

Figure 2. Representative image of GP theory.

According to Snow's golden mean (GM) theory, in a frontal view of the smile, the width of the central incisor (CiW) should correspond to 25% of the total distance measured between the external tangents of the upper canines (points *p1* to *p2*, **(Figure 3)**). In this framework, the lateral incisor (LiW) is expected to account for 15% of that distance, while the canine (CW) should represent 10% [8] **(Figure 3)**.

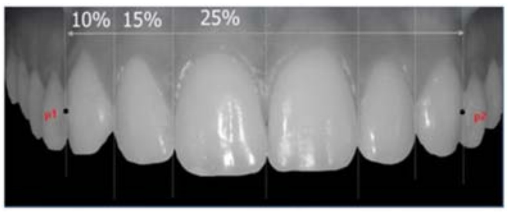

Figure 3. Representative image of GM theory. The distance between points *p1* and *p2* represents the inter-canine distance.

The collected measurements were first analyzed descriptively to determine whether the observed tooth proportions in the sample aligned with the predictions of the GP and GM theories or deviated from them. Subsequently, a paired Student's t-test was conducted to examine differences between pre-treatment and post-treatment values. All statistical analyses were performed using **R version 3.5** (R Foundation for Statistical Computing, Vienna, Austria). Patient information was handled anonymously, and no formal ethical approval was required due to the retrospective nature of the study.

Results and Discussion

Due to the large sample size, individual patient data are not presented [24]. Instead, the analysis focuses on group-level results. The mean measurements for the sample are reported separately according to Levin's theory **(Table 1)** and Snow's theory **(Table 2)**, including both pre- and post-treatment values. Statistical significance was determined using a threshold of $p < 0.05$.

Table 1. Sample values calculated by applying GP theory (Levin).

Dental Element	Pre-Treatment	Post-Treatment	p-Value
Right Upper Canine			
Mean	0.915	0.844	0.000006 (***)
SD	0.176	0.006	
Right Upper Lateral Incisor			
Mean	1.000	1.000	/
SD	/	/	
Right Upper Central Incisor			
Mean	1.572	1.485	0.000711 (***)
SD	0.208	0.170	
Left Upper Central Incisor			
Mean	1.631	1.646	0.004660 (***)
SD	0.754	0.141	
Left Upper Lateral Incisor			
Mean	1.000	1.000	/
SD	/	/	
Left Upper Canine			
Mean	0.940	0.876	0.026841 (*)
SD	0.658	0.098	

SD: standard deviation. *: *p*-value < 0.05, ***: *p*-value < 0.01.

Table 2. Sample values calculated by applying GM theory (Snow).

Dental Element	Pre-Treatment	Post-Treatment	p-Value
Right Upper Canine			
Mean (%)	13.09	12.96	0.000063 (***)
SD	1.16	0.410	
Right Upper Lateral Incisor			
Mean (%)	14.52	15.41	0.003546 (***)
SD	1.43	1.569	
Right Upper Central Incisor			
Mean (%)	22.57	22.75	0.102258 (ns)
SD	1.38	0.292	
Left Upper Central Incisor			
Mean (%)	22.43	22.81	0.648437 (ns)
SD	1.91	0.381	
Left Upper Lateral Incisor			
Mean (%)	14.53	13.92	0.000003 (***)
SD	1.78	1.429	
Left Upper Canine			
Mean (%)	12.87	12.15	0.014120 (*)
SD	1.66	0.123	

SD: standard deviation. The values reported as the *p*-value represent the evaluation of the pre- and post-treatment statistical data using the Student's *t*-test. A statistical evaluation of the pre- and post-treatment data was then performed using the Student's *t*-test and the statistical significance was assessed using a *p*-value threshold of 0.05. *: *p*-value < 0.05, ***: *p*-value < 0.01.

The golden ratio, historically attributed to Phidias in the sixth century BC, has long served as a measure of aesthetic harmony in art, architecture, and sculpture. Over time, this concept has been applied in medicine to explore correlations between mathematics and perceived beauty. In mathematical terms, two quantities are in the golden ratio if the ratio of the smaller to the larger is equal to the ratio of the larger to their sum, represented by the symbol "ϕ" and approximately equal to 1.618. This ratio has traditionally been associated with notions of beauty and proportion, inspiring attempts to replicate it as a standard in multiple fields [1, 9].

In dentistry, Lombardi was among the first to extend the golden ratio to the anterior teeth in 1973, suggesting that the widths of central incisors, lateral incisors, and canines followed systematic proportions [1, 5]. He proposed a "repeated ratio" model in which the relationship between these teeth progresses in a predictable anterior-to-posterior sequence. Levin later formalized this concept into the golden proportion (GP) theory in 1978, proposing that, from a frontal perspective, the lateral incisor should measure 0.618 of the central incisor, while the canine should measure 0.618 of the lateral incisor [1, 6]. Snow subsequently introduced the golden mean (GM) theory in 1999, emphasizing the importance of symmetry and balance in designing smiles, with the central incisor corresponding to 25% of the inter-canine width, the lateral incisor to 15%, and the canine to 10% [1, 8]. George suggested that the golden ratio could serve as a predictor for determining maxillary central incisor width [2, 25].

Despite the appeal of these theories, empirical evidence has challenged their universality. Preston (1993) observed that the proportional relationships proposed by Levin were present in only 17% of individuals, and none of the canines conformed to the golden ratio relative to the lateral incisors [1, 26]. He instead reported average ratios of 66% for lateral incisors and 55% for canines relative to central incisors, highlighting deviations from the theoretical model [1]. Ward further noted that strict application of the golden ratio could result in excessively narrow lateral incisors and insufficiently prominent canines, leading him to develop the recurring esthetic dental proportion (RED), which emphasizes alignment with overall facial and dental harmony rather than rigid mathematical ratios [1, 7, 22, 23]. More recent studies have similarly reported that golden proportion-based models do not consistently correspond with the natural dentition observed in clinical populations, suggesting that individual variation, ethnic background, and cultural factors are more relevant in aesthetic evaluation [1, 7, 21, 22, 27].

Additional variables further influence dental proportions in practice. Some investigations have found correlations between tooth morphology and patient age or sex, while others report no significant relationship [1, 15–18, 28–34]. Clinically, tooth visibility and smile aesthetics are affected by arch shape, skeletal divergence, buccal corridor dimensions, and overall facial morphology. Narrower arches tend to reduce anterior tooth exposure, and inter-canine distances can vary significantly across arch types [35, 36]. The buccal corridor, or lateral space between posterior teeth and the corners of the lips, has been recognized as a critical contributor to smile aesthetics. Frush and Fisher indicated that excessive closure of buccal corridors may produce an unnatural appearance [37, 38], whereas Moore found that smaller corridors are often associated with enhanced attractiveness [37, 39].

Although a few studies have suggested that buccal corridors do not significantly influence the aesthetic evaluation of smiles [37, 40–42], the majority of research emphasizes that the size of these spaces plays a critical role in perceived smile attractiveness, particularly from the perspective of orthodontic professionals [10-12, 37, 39, 43]. Skeletal divergence also contributes to smile aesthetics and is closely linked to muscle tone and overall facial morphology. Understanding the interplay between dental and skeletal characteristics is essential for accurate diagnosis and effective treatment planning [13]. Specifically, vertical facial patterns affect upper arch morphology, with hyperdivergent individuals typically exhibiting narrower transverse arch widths and hypodivergent individuals showing broader arches [13, 14, 44].

Some theoretical frameworks propose a connection between facial shape and tooth morphology, suggesting that narrow or elongated faces are associated with slender teeth, whereas hypodivergent facial types may correspond to taurodontic tooth forms [19, 32, 45]. Facial analysis is often considered a valuable tool in prosthetic and restorative dentistry, guiding the selection of tooth shape for individualized smile design [46]. However, subsequent investigations have yielded mixed results, and this association is not consistently supported across the literature [32, 33, 47], though it continues to inform prosthetic strategies for edentulous patients [47].

Dental morphology itself can also influence the applicability of Levin and Snow’s proportional models. Alterations such as an atypical Bolton Index or generalized microdontia can negatively impact the perceived harmony of a smile, as reported by Mirabella [20]. Additionally, factors not examined in the present study, such as tooth color and shade, are likely to affect aesthetic perceptions and the evaluation of proportional relationships [48].

The findings of this study aligned with several of Levin and Snow’s observations [6, 8], yet some discrepancies were noted. Variations in proportionality between the right and left sides of the dentition were largely attributed to the photographic methodology. All intraoral images were captured with patients slightly rotated to the right, which may have limited perfect perpendicularity and influenced measurement accuracy. Evaluating dental casts directly could have minimized this discrepancy, although such a process would have required the use of reference grids and significantly increased the complexity and duration of the study, given the large sample size.

Future research should examine the impact of individual tooth rotations on proportionality, as 79 of the 400 patients presented rotated teeth (totaling 102 elements), though these rotations did not exceed the 4 mm crowding threshold established in the inclusion criteria.

The stronger alignment of statistical data with Snow’s golden mean ratios, compared to Levin’s golden proportions, likely reflects differences in the methods of quantification. Levin’s model emphasizes the measurement of individual teeth, whereas Snow’s approach considers proportions relative to the total inter-canine distance. Analysis of Levin’s model revealed that the canine width (CW) exceeded the golden proportion, with mean values of approximately 0.92 pre-treatment and 0.85 post-treatment (averaging right and left sides) compared with the GP-theoretical value of 0.6. This difference was statistically significant and indicated a reduction in canine projection following orthodontic treatment.

The CiW values, in contrast, did not differ significantly from those suggested by Levin, with averages of 1.60 pre-treatment and 1.57 post-treatment, compared with Levin’s 1.68 based on the golden proportion theory. A more consistent and representative model was the frontal sector representation proposed by Snow, which closely matched the data obtained in our study. Nonetheless, a lower representation of the central incisors was observed compared with Snow’s model, both before and after treatment (mean: 22.5% pre-treatment; mean: 22.78% post-treatment), while the

CW was slightly higher in both phases (average: 13% pre-treatment; 12.56% post-treatment). These minor variations could be associated with dental rotations present in the sample. According to Snow's evaluation of the golden mean, only the proportions of the lateral incisors (from 14.53% to 14.67%) and canines (from 12.98% to 12.56%) showed significant changes. Central incisors, however, exhibited no statistically significant differences between pre- and post-treatment measurements. Data analysis also indicated that the projection increased for lateral incisors after treatment, while it decreased for canines, likely reflecting specific orthodontic procedures.

Conclusion

The study assessed 400 patients using GP and GM theories to evaluate dental proportions. The findings suggested that while these models remain largely valid, certain updates are necessary. Snow's proportions were generally better represented in our sample; however, the superior canine in the frontal smile view was more prominent mesiodistally than Levin and Snow had proposed. The observed differences between pre- and post-orthodontic treatments provide a foundation for future investigations into how dental proportions relate to factors such as gender, ethnicity, and skeletal patterns.

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