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Assessment of Golden Proportion among Natural Maxillary Anterior Teeth of Global Population: A Systematic Review

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Abstract: The purpose of this systematic review was to analyze studies, identify the existence of golden proportion between the perceived widths of the maxillary anterior teeth among the different geographical populations, and evaluate the range of dental proportion that exists regionally. An electronic search was conducted using PubMed, Medline, EMBASE, Scopus, Science Direct, Web of Science, and the Cochrane Library. The focused question was, "Does golden proportion exist in natural, aesthetically pleasing smiles among different populations around the world?" The search conducted included studies from January 2000 to September 2020, identifying articles in English with the specific combination of MeSH and other related terms. The title search yielded eight hundred and ninety-eight articles, and seventy-five articles were selected for full-text analysis. However, only fifty-two full-text articles were included in the systematic review. The mean predicted dental ratios were either larger or smaller than the successive widths of maxillary natural anterior teeth. Golden proportions were not found consistently among anterior teeth in different populations observed in the systematic review. The golden proportion is still a useful tool for the reconstruction of lost or damaged anterior tooth widths; however, it is not the only standard for restoring esthetic smiles worldwide, and anterior tooth proportions differ among populations based on their geographic, ethnic, and racial background. Moreover, consideration should also be given to an individual's dentofacial variations in restoring anterior teeth.

Keywords: laboratory technology; removable prosthodontics; aesthetics

1. Introduction

Dental aesthetics is one of the primary goals in oral rehabilitation, having a positive effect on the self-esteem and psychosocial wellbeing of patients [1,2]. In modern dentistry, esthetic outcomes have become increasingly critical for patient satisfaction, which comprises adequate size, shape, color, biotype, gingival zenith, smile line, minimized negative space, axial inclination graduation, incisal embrasure gradation, and gingival frame contour [2,3]. Several guidelines are introduced to achieve an organizational balance between the aesthetic harmony of the face with the dentofacial structures. These guidelines form the base of aesthetic knowledge and are widely followed by aesthetic and restorative practitioners worldwide [3–10].

One of the widely accepted classic esthetic principles is the golden proportion (GP) (1.618:1.0), as proposed by Lombardi and applied to esthetic dentistry by Levin in 1978 [11]. It was proposed that the golden proportion existed between the dimensions of the central incisor (CI), lateral incisor (LI), and the canine (Ca), as well as within the dimensions of a smiling face, and should be applied to the arrangement of anterior teeth in their esthetic rejuvenation [8,11]. Later, the golden proportion in dentistry was also advocated by other authors [12,13]. On the contrary, Preston in 1993 denied the existence of golden proportions in the average natural dentition [14]. He argued that the tooth dimensions vary greatly by race and gender, therefore the golden proportion cannot be applied to the relationship of maxillary anterior teeth [14]. Mahshid et al. shared similar thoughts as they proposed that use of the golden proportion is theoretical, and its application is challenging in esthetic dentistry [15]. Furthermore, in a study by Rosenstiel et al., it was suggested that GP was preferred only when the patient had long teeth [3]. Moreover, Umer et al., proposed that a range of anterior teeth proportions should be considered to determine dental attractiveness rather than a single value despite finding GP in 63% of the Pakistani population using the Phi dental grid [16].

Multiple authors have proposed an altered version of GP in dentistry and introduced their own set of guidelines for anterior esthetic rehabilitation [4–6]. Studies have suggested that gender, ethnicity, and various genetic and environmental factors are associated with different tooth proportions. Genetic factors can affect the calcification of teeth, the shape of a coronal structure, and the composition of minerals in the process of growth and development of teeth, whereas environmental factors such as diet, nutrition, radiation, and chemicals also affect the mesiodistal width of teeth [9,10,17–20]. Nevertheless, ethnicity is suggested to have a greater influence on tooth proportions than gender [21–24]. However, it is recommended that the golden principle can be applied if the percentages are adjusted with variations in the ethnicity of the population [21,25]. In a study by Al-Kaisy et al. [26], a golden proportion was found to exist between the apparent widths of maxillary anterior teeth for LI/CI (lateral incisor/central incisor) in both Kurdish and Arab populations for men and women, but not for Ca/LI (canine/lateral incisor). However, the proportions among Iraqi Arabs and Kurds were 1.59:1:0.73 and 1.62:1:0.69, respectively. By contrast, in a study by Al-Marzok et al., no significant difference in the comparison among the ethnic groups for the golden proportion was found [23].

These outcomes necessitate the evaluation of anterior dentition among various populations or ethnic groups. Nevertheless, different approaches have been developed for conducting systematic reviews on a broader range of issues. This article specifically targeted the presence of GP in different ethnicities and races around the globe. In addition, it aimed to find out the proportions that are present regionally, which was never taken into consideration previously. The importance of local proportion should be given consideration to restore teeth in harmony with distinct facial features, the color of hair and eyes specific to a particular race. Therefore, the purpose of this systematic review was to analyze studies, to identify the occurrence of the GP between the perceived widths of the maxillary anterior teeth among the population in different geographical regions, and to find out the proportions that are present regionally. The null hypothesis was that golden proportions would not be consistent in anterior esthetic smiles among different populations worldwide.

2. Materials and Methods

A research-focused question "Does golden proportion exist in natural aesthetically pleasing smile among different populations around the world?" was constructed according to the updated Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol. As shown in Supplementary Table S1. In accordance with the population, intervention, comparison, outcome (PICO) statement [27] participants with all permanent natural maxillary anterior teeth present were considered. Intervention was the proportion comparison of maxillary anterior teeth, relative to each other i.e., the LI compared to CI, and the proportion of Ca compared to LI. Dental proportion values obtained in included articles were compared with a constant 62% golden proportion. The primary outcome was to establish if the mean perceived ratio between CI-LI and LI-Ca is 62% i.e., does golden proportion exist in aesthetically pleasing smiles. The secondary outcome was to determine the mean range value of CI-LI and Ca-LI proportion between different global regions as reported in the studies. For this review, we only considered case-control studies published in the English language. This review was not registered in a database and research protocol was not prepared.

2.1. Literature Search

Two investigators (NA and MSA) conducted systematic of PubMed, MEDLINE, EMBASE, Scopus, Science Direct, Web of Science, and the Cochrane Library electronic database. The search was conducted from January 2000 to September 2020, identifying articles in English with the following combination of MeSH terms, "Dental Restoration, Permanent/methods", "Esthetics, Dental*", "Odontometry", "Photography, Dental", "Smiling", "teeth", "Dental", "Aesthetics, Esthetics", "Attractive"; all field key words: "dental", "photography, Dental Esthetics", "dental and smile and attractive", "smile and attractive"; free text keywords: "golden proportion in teeth", "smile and attractiveness", "smile and dental and improvement", "Esthetics and dental proportion", "dental proportion and smile". In addition, references to relevant papers were examined to find eligible studies. All authors reviewed the texts individually to identify articles that fulfilled the predetermined inclusion criteria. The search strategy is illustrated using PRISMA flow diagram in Figure 1.

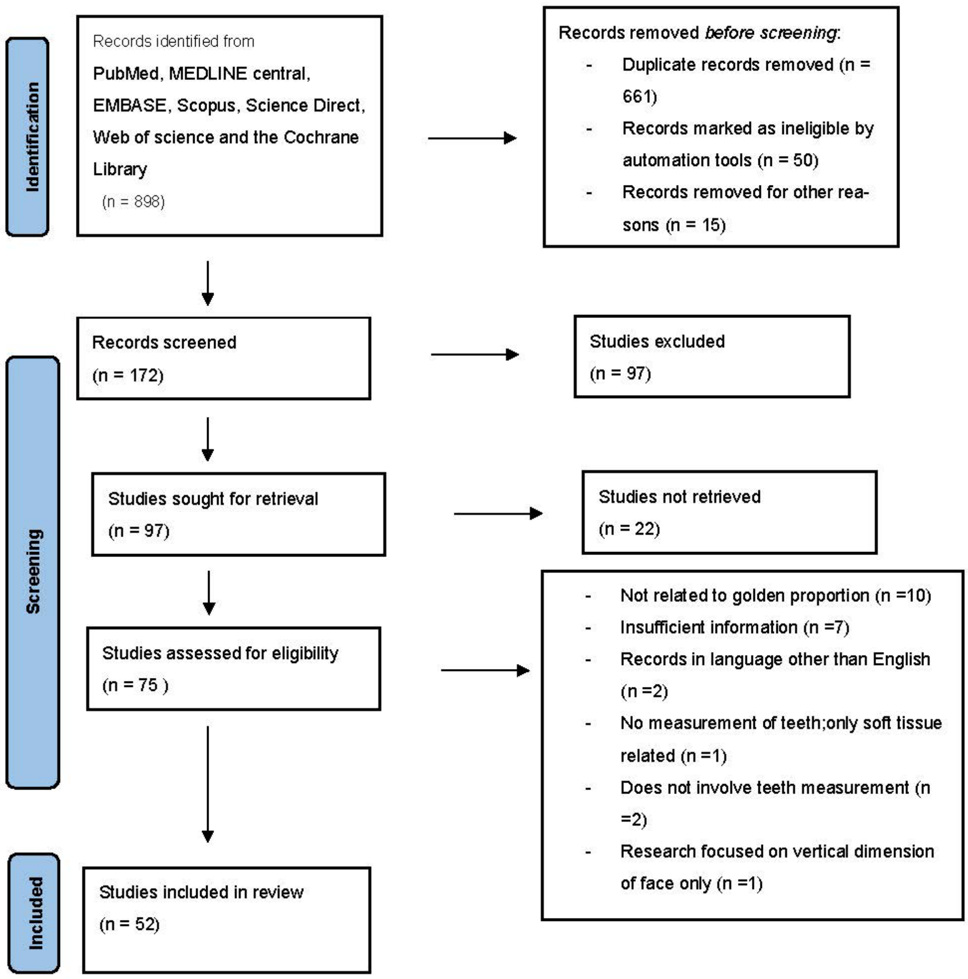

Figure 1. PRISMA flow diagram of study analysis.

2.2. Eligibility Criteria

The inclusion criteria were case-control studies in English language with human subjects, regardless of their age and gender, reporting GP of intact maxillary anterior teeth with no dental defects, and no history of orthodontic treatment or anterior prosthodontic restoration. Included studies should have validated data collection methods, statistical analysis, and declared number of participants, used. Studies having less than 14 participants, unclear or dubious statistic strategies, and measurement methods; inclusion of deciduous teeth were excluded.

2.3. Data Items and Abstractions

The data extraction was carried out independently by two authors (N.A. and M.S.A.) who first organized the included studies according to their general description and final outcomes. Any ambiguity was settled through discussion and consultation with a third examiner (F.V.). We divided the data into regions according to the geographic location of the included studies.

The quality assessment of the included articles was performed based on the Cochrane handbook for systematic reviews of interventions (CHSRI) (v5.1.0) [28] and New Castle Ottawa quality assessment scale (NOS) [29]. The CHSRI analyzed if the standard parameters outlined by the assessment were clearly stated. The risk of bias was determined for each study to be (a) low: if 6 or more criteria were met, (b) moderate if from 3 to 5 criteria were met, or high if at least 2 or fewer criteria were met. The NOS analyzed the following three core parameters: case and group (selection, definition, and representativeness); comparability (comparison of case and control groups; analysis and control of confounding variable); exposure (outcome assessment of golden percentage, tooth measurements, universal assessment method, and dropout rate). A maximum of 4 stars for clear selection and exposure and 2 stars for comparability were awarded. The score range was from 1 to 9 stars, a higher score demonstrating better quality.

Due to heterogeneity of the outcome and variables in the selected articles, the research team was not able to conduct meta-analysis in the current review. Since this study does not analyze the difference between gender and ethnicity or the differences in sizes of teeth within one country, where such differences were found, we used the formula from the Cochrane Handbook for Systematic Reviews of Interventions to find the combined mean percentage and standard deviations.

3. Results

The title search yielded 898 articles from 1978 to 2020; 726 duplicates, and 97 articles that did not analyze dental proportions were removed. Seventy-five articles were selected for full-text analysis, which led to the further exclusion of 23 articles as they were not topic-related, contained insufficient information, a language other than English was used, did not involve teeth measurement, and/or research focused on the vertical dimension of the face only as shown in Supplementary Table S2.

A total of 52 full-text articles were included. The general characteristics and outcomes of the included studies are presented in Table 1.

Table 1. Characteristics of golden proportion among included studies (n = 52).

No	Author	GP Control Group	Unit	Golden Proportion 62% Study Group				[b] Local Proportion % Study Group			
				Right		Left		Right		Left	
				Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %
1.	JD Preston [14]	62% GP	Mean	17.00	NR	17.00	NR	66.00	84.00	66.00	84.00
			Sd	2.34	NR	2.34	NR	0.17	0.23	0.17	0.23
2.	M Mahshid [15]	62% GP	Mean	34.00	10.00	34.00	10.00	67.00	84.00	67.00	84.00
			Sd	6.71	2.22	6.71	2.22	0.07	0.15	0.07	0.15

Table 1. *Cont.*

No	Author	GP Control Group	Unit	Golden Proportion 62% Study Group				[b] Local Proportion % Study Group			
				Right		Left		Right		Left	
				Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %
3.	F Umer [16]	62% GP	Mean	63.60	63.60	63.60	63.60	75.00	61.30	75.00	61.30
			Sd	0.07	0.07	0.07	0.07	0.20	0.12	0.20	0.12
4.	S Muhammad [17]	62% GP	Mean	18.57	18.57	18.57	18.57	35.00	35.00	35.00	35.00
			Sd	0.18	0.18	0.18	0.18	0.14	0.12	0.14	0.12
5.	NT Niranjan [18]	62% GP	Mean	21.70	13.00	21.70	13.00	2.56	2.55	2.56	2.55
			Sd	2.11	1.77	2.11	1.77	3.76	3.68	3.76	2.56
6.	U Hasanreisoglu [19]	62% GP	Mean	NR	NR	NR	NR	53.00	79.00	53.00	79.00
			Sd	NR	NR	NR	NR	0.08	0.14	0.08	0.14
7.	TB Shetty [20]	62% GP	Mean	NR	NR	NR	NR	21.00	92.00	21.00	92.00
			Sd	NR	NR	NR	NR	0.09	0.08	0.09	0.08
8.	BVS Murthy [21]	62% GP	Mean	16.10	14.30	17.90	25.00	NR	NR	NR	NR
			Sd	2.18	2.98	3.90	4.87	NR	NR	NR	NR
9.	Sandeep et al. [22]	62% GP	Mean	21.25	7.50	21.25	7.50	68.75	72.90	68.75	72.90
			Sd	3.56	6.98	2.31	6.87	0.06	0.09	0.06	0.09
10.	MI Al Marzok [23]	62% GP	Mean	20.40	20.40	20.40	20.40	73.16	77.32	73.16	77.32
			Sd	4.76	4.76	4.76	4.76	0.06	0.11	0.06	0.11
11.	Alhababhah et al. [24]	62% GP	Mean	42.00	20.20	45.50	23.90	NR	NR	NR	NR
			Sd	2.87	5.87	3.89	5.23	NR	NR	NR	NR
12.	A Fayyad et al. [25]	62% GP	Mean	29.20	14.90	34.30	12.50	NR	NR	NR	NR
			Sd	5.80	4.87	6.89	3.78	NR	NR	NR	NR
13.	N Al-Kaisy [26]	62% GP	Mean	NR	NR	NR	NR	62.68	71.52	62.68	71.52
			Sd	NR	NR	NR	NR	0.06	0.13	0.06	0.13
14.	Shahnawaz et al. [30]	62% GP	Mean	NR	NR	NR	NR	67.00	67.00	67.00	67.00
			Sd	NR	NR	NR	NR	0.15	0.15	0.15	0.15
15.	S Azam [31]	62% GP	Mean	10.00	2.00	10.00	6.00	NR	NR	NR	NR
			Sd	0.10	0.10	0.10	0.09	NR	NR	NR	NR
16.	Masood et al. [32]	62% GP	Mean	18.57	18.57	18.57	18.57	35.00	35.00	35.00	35.00
			Sd	0.89	0.89	0.89	0.89	0.18	0.18	0.18	0.18
17.	VS Agrawal [33]	62% GP	Mean	3.75	6.25	3.75	6.25	NR	NR	NR	NR
			Sd	0.043	0.52	0.48	1.59	NR	NR	NR	NR
18.	R Meshramkar [34]	62% GP	Mean	3.90	0.60	3.90	0.60	NR	NR	NR	NR
			Sd	3.98	0.82	3.12	0.82	NR	NR	NR	NR
19.	NG Chander [35]	62% GP	Mean	1.00	1.00	1.00	1.00	25.00	25.00	25.00	25.00
			Sd	0.02	0.02	0.02	0.02	0.16	0.01	0.16	0.01
20.	TA Naqash [36]	62% GP	Mean	9.00	9.00	9.00	9.00	25.00	25.00	25.00	25.00
			Sd	2.28	2.28	2.28	2.28	0.06	0.09	0.060	0.09
21.	S Rana [37]	62% GP	Mean	35.00	NR	35.00	NR	49.00	NR	49.90	NR
			Sd	3.23	NR	3.23	NR	0.15	NR	0.15	NR
22.	MN Hegde [38]	62% GP	Mean	NR	NR	NR	NR	18.00	NR	23.00	NR
			Sd	NR	NR	NR	NR	0.15	NR	0.15	NR
23.	SA Shah [39]	62% GP	Mean	9.00	9.00	9.00	9.00	25.00	25.00	25.00	25.00
			Sd	1.89	1.89	1.89	1.89	0.07	0.14	0.07	0.14
24.	Kulreshtha et al. [40]	62% GP	Mean	NR	NR	NR	NR	47.00	33.00	47.00	33.00
			Sd	NR	NR	NR	NR	0.18	0.22	0.18	0.22
25.	R. Gyawali [41]	62% GP	Mean	NR	NR	NR	NR	68.10	75.70	67.70	75.60
			Sd	NR	NR	NR	NR	0.07	0.14	0.08	0.15

Table 1. *Cont.*

No	Author	GP Control Group	Unit	Golden Proportion 62% Study Group				[b] Local Proportion % Study Group			
				Right		Left		Right		Left	
				Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %
26.	A Maharjan [42]	62% GP	Mean	14.28	12.69	14.28	12.69	NR	NR	NR	NR
			Sd	2.98	2.01	2.98	2.01	NR	NR	NR	NR
27.	Rokaya et al. [43]	62% GP	Mean	NR	NR	NR	NR	66.00	70.00	66.00	70.00
			Sd	NR	NR	NR	NR	0.60	0.06	0.60	0.06
28.	MK Mishra [44]	62% GP	Mean	NR	NR	NR	NR	83.00	112.00	85.00	110.00
			Sd	NR	NR	NR	NR	0.09	0.12	0.10	0.13
29.	M Aziz [45]	62% GP	Mean	17.00	4.00	17.00	4.00	NR	NR	NR	NR
			Sd	1.87	0.08	1.87	0.08	NR	NR	NR	NR
30.	Parnia et al. [46]	62% GP	Mean	NR	NR	NR	NR	66.00	66.00	63.00	68.00
			Sd	NR	NR	NR	NR	0.07	0.13	0.08	0.13
31.	A Nikgoo [47]	62% GP	Mean	42.13	13.63	42.13	13.63	NR	NR	NR	NR
			Sd	5.87	3.61	5.87	3.61	NR	NR	NR	NR
32.	M. Azimi [48]	62% GP	Mean	25.00	2.10	25.00	2.10	NR	NR	NR	NR
			Sd	3.98	1.87	3.98	1.87	NR	NR	NR	NR
33.	H Ozdemir [49]	62% GP	Mean	NR	NR	NR	NR	68.08	86.92	68.08	87.46
			Sd	NR	NR	NR	NR	0.06	0.11	0.06	0.10
34.	Sulaiman et al. [50]	62% GP	Mean	19.00	17.00	19.00	17.00	70.00	82.00	70.00	82.00
			Sd	2.98	1.77	2.98	1.77	0.07	0.15	0.07	0.15
35.	AA Swelem [51]	62% GP	Mean	6.65	10.00	6.65	10.00	52.00	60.00	52.00	60.00
			Sd	5.85	2.90	5.85	2.90	0.09	0.01	0.09	0.01
36.	Aldegheishem et al. [52]	62% GP	Mean	NR	NR	NR	NR	78.00	72.00	96.00	75.00
			Sd	NR	NR	NR	NR	0.53	0.14	0.11	0.16
37.	A Kanaparthy [53]	62% GP	Mean	NR	NR	NR	NR	65.75	57.50	65.75	57.50
			Sd	NR	NR	NR	NR	0.09	0.12	0.09	0.12
38.	Sah et al. [54]	62% GP	Mean	NR	NR	NR	NR	78.05	76.73	78.05	76.73
			Sd	NR	NR	NR	NR	0.53	0.14	0.53	0.14
39.	Q Zhao [55]	62% GP	Mean	NR	NR	NR	NR	19.50	13.40	19.50	13.40
			Sd	NR	NR	NR	NR	0.09	0.09	0.09	0.09
40.	Yagasaki et al. [56]	62% GP	Mean	1.90	0.60	1.90	0.60	36.00	84.00	36.00	84.00
			Sd	0.76	0.02	0.76	0.02	0.09	0.09	0.09	0.09
41.	MX Jin [57]	62% GP	Mean	NR	NR	NR	NR	38.90	83.30	38.90	83.90
			Sd	NR	NR	NR	NR	0.11	0.09	0.11	0.09
42.	I Al-Sheakli [58]	62% GP	Mean	NR	NR	NR	NR	67.20	79.64	67.13	82.20
			Sd	NR	NR	NR	NR	5.36	11.78	6.91	11.78
43.	LM Ramirez [59]	62% GP	Mean	NR	NR	NR	NR	69.00	82.00	68.00	82.00
			Sd	NR	NR	NR	NR	0.06	0.14	0.06	0.13
44.	R Kalia [60]	62% GP	Mean	10.00	1.40	10.00	1.40	51.10	82.60	51.10	82.60
			Sd	2.89	2.10	2.89	2.10	0.01	0.01	0.01	0.01
45.	Melo et al. [61]	62% GP	Mean	NR	NR	NR	NR	61.60	83.20	61.60	83.20
			Sd	NR	NR	NR	NR	0.06	0.14	0.06	0.14
46.	Becerra et al. [62]	62% GP	Mean	NR	NR	NR	NR	80	NR	80	NR
			Sd	NR	NR	NR	NR	0.15	NR	0.15	NR
47.	D Calcada [63]	62% GP	Mean	NR	NR	NR	NR	65.74	85.47	65.12	85.84
			Sd	NR	NR	NR	NR	0.17	0.01	0.17	0.01

Table 1. *Cont.*

No	Author	GP Control Group	Unit	Golden Proportion 62% Study Group				[b] Local Proportion % Study Group			
				Right		Left		Right		Left	
				Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %	Central/ Lateral Incisor %	Lateral/ Canine %
48.	A Forster [64]	62% GP	Mean	NR	NR	NR	NR	59.00	85.00	58.00	89.00
			Sd	NR	NR	NR	NR	0.24	0.21	0.28	0.22
49.	Condon et al. [65]	62% GP	Mean	NR	NR	NR	NR	65.00	89.00	65.00	89.00
			Sd	NR	NR	NR	NR	0.06	0.01	0.06	0.01
50.	Pesson et al. [66]	62% GP	Mean	NR	NR	NR	NR	24.00	14.50	24.00	14.50
			Sd	NR	NR	NR	NR	0.08	0.11	0.08	0.11
51.	F Beyuo [67]	62% GP	Mean	4.50	10.70	4.50	10.70	49.60	67.70	49.60	67.70
			Sd	4.90	3.56	4.90	3.56	0.08	0.21	0.08	0.21
52.	MA Swileh [68]	62% GP	Mean	2.40	4.90	2.40	4.90	59.00	59.00	59.00	59.00
			Sd	1.09	3.87	1.09	3.87	0.24	0.21	0.24	0.21

0: Indicates no values for 62% golden proportion or local proportion given in included articles, GP: golden proportion, [b] Local proportion: value other than 62% found in studied population, Sd: standard deviation, GP: golden proportion.

3.1. General Analysis of Included Studies

Fifty-two articles were included. The number of participants ranged from 14 to 903. Twenty-nine studies analyzed GP through 2D photographs [14,15,17,20,21,25,26,31–33,37,40–42,45–51,56,58–60,63,64,68], 10 studies used dental casts [16,23,24,30,43,44,53–55,61] while six studies used both methods of assessment [18,19,22,57,62,65]. Six studies performed direct clinical measurements of teeth on patients [35,36,38,39,66,67] and one study reported digital impressions, digital casts, and 2D photograph analysis in their research [52] (Table 2). All included studies [14–26,30–68] were categorized according to their geographical location. The majority (n = 27) of studies were carried out in the South Asian region, followed by West Asia (n = 13), Europe (n = 8), Africa (n = 3), North America (n = 3), East Asia (n = 2), Southeast Asia (n = 2), the Middle East (n = 2), and South America (n = 1) (Table 3).

Table 2. Study characteristics of included articles (n = 52).

Authors	Study Design	Research Groups		Assessment Method	Sample Size		Conclusion/Outcome
		Study	Control		C	S	
JD Preston [14]	Case control	Anterior teeth measurement	62% Golden Proportion	2D photographs of dental cast analysis	58	58	Golden proportion was not found in all anterior teeth
M Mahshid [15]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	157	157	Golden proportion was not found in all anterior teeth
F Umer [16]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast and grid analysis	100	100	Golden proportion was not found in all anterior teeth
S. Muhammad [17]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	70	70	Golden proportion was not found in all anterior teeth
NT Niranjan [18]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast and 2D photographs analysis	60	60	Golden proportion was not found in all anterior teeth

Table 2. *Cont.*

Authors	Study Design	Research Groups		Assessment Method	Sample Size		Conclusion/Outcome
		Study	Control		C	S	
U Hasanreisoglu [19]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast and 2D photographs analysis	100	100	Golden proportion was not found in all anterior teeth
TB Shetty [20]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	100	100	Golden proportion was not found in all anterior teeth
BVS Murthy [21]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	56	56	Golden proportion was not found in all anterior teeth
Sandeep et al. [22]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast and 2D photograph analysis	240	240	Golden proportion was not found in all anterior teeth
MI Al Marzok [23]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	49	49	Golden proportion was not found in anterior teeth
Alhabahbah et al. [24]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	150	150	Golden proportion was not found in anterior teeth
Fayyad et al. [25]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	376	376	Golden proportion was not found in anterior teeth
N Al- Kaisy [26]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photographs of dental cast analysis	100	100	Golden proportion was not found in central and lateral incisor teeth
Shahnawaz et al. [30]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	100	100	Golden proportion was not found in all anterior teeth
S. Azam [31]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	50	50	Golden proportion was not found in all anterior teeth
Masood et al. [32]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	140	140	Golden proportion was not found in all anterior teeth
VS Agrawal [33]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	80	80	Golden proportion was not found in all anterior teeth
R Meshramkar [34]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	214	214	Golden proportion was not found in all anterior teeth
NG Chander [35]	Case control	Anterior teeth measurement	62% Golden Proportion	Direct clinical measurement of teeth	576	576	Golden proportion was not found in all anterior teeth
TA Naqash [36]	Case control	Anterior teeth measurement	62% Golden Proportion	Direct clinical measurement of teeth	100	100	Golden proportion was not found in all anterior teeth
S Rana [37]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	14	14	Golden proportion was not found in all anterior teeth
MN Hegde [38]	Case control	Anterior teeth measurement	62% Golden Proportion	Direct clinical measurement of teeth	100	100	Golden proportion was not found in all anterior teeth
SA Shah [39]	Case control	Anterior teeth measurement	62% Golden Proportion	Direct clinical measurement of teeth	100	100	Golden proportion was not found in all anterior teeth

Table 2. *Cont.*

Authors	Study Design	Research Groups		Assessment Method	Sample Size		Conclusion/Outcome
		Study	Control		C	S	
Kulreshtha et al. [40]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	120	120	Golden proportion was not found in all anterior teeth
R Gyawali [41]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	160	160	Golden proportion was not found in all anterior teeth
A Maharjan [42]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	63	63	Golden proportion was not found in all anterior teeth
Rokaya et al. [43]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	150	150	Golden proportion was not found in all anterior teeth
MK Mishra [44]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	140	140	Golden proportion was not found in all anterior teeth
M Aziz [45]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	50	50	Golden proportion was not found in all anterior teeth
Parnia et al. [46]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	100	100	Golden proportion was not found in all anterior teeth
A Nikgoo [47]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	903	903	Golden proportion was not found in all anterior teeth
M azimi [48]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	116	116	Golden proportion was not found in all anterior teeth
H Ozdemir [49]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	150	150	Golden proportion was not found in all anterior teeth
Sulaiman et al. [50]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	100	100	Golden proportion was not found in anterior teeth
AA Swelem [51]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	360	360	Golden proportion was not found in anterior teeth
Aldegheishem et al. [52]	Case control	Anterior teeth measurement	62% Golden Proportion	Digital impression, Digital cast and 2D Photograph analysis	61	61	Golden proportion was not found in anterior teeth
A Kanaparthy [53]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	60	60	Golden proportion was not found in anterior teeth
Sah et al. [54]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	147	147	Golden proportion was not found in anterior teeth
Q Zhao [55]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	101	101	Golden proportion was not found in anterior teeth
Yagasaki et al. [56]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	162	162	Golden proportion was not found in anterior teeth

Table 2. *Cont.*

Authors	Study Design	Research Groups		Assessment Method	Sample Size		Conclusion/Outcome
		Study	Control		C	S	
MX Jin [57]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast and 2D photographs analysis	30	30	Golden proportion was not found in anterior teeth
I Al-Sheakli I [58]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	80	80	Golden proportion was not found in anterior teeth
LM Ramirez [59]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	351	351	Golden proportion was not found in anterior teeth
R Kalia [60]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	509	509	Golden proportion was not found in anterior teeth
Melo et al. [61]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental cast analysis	384	384	Golden proportion was not found in anterior teeth
Becerra et al. [62]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph and dental cast analysis	203	203	Golden proportion was not found in anterior teeth
D Calcada [63]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	50	50	Golden proportion was not found in anterior teeth
A Forster [64]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	109	109	Golden proportion was not found in anterior teeth
Condon et al. [65]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph and dental cast analysis	109	109	Golden proportion was not found in anterior teeth
Pesson et al. [66]	Case control	Anterior teeth measurement	62% Golden Proportion	Direct clinical measurement of teeth	80	80	Golden proportion was not found in anterior teeth
F Beyuo [67]	Case control	Anterior teeth measurement	62% Golden Proportion	Dental measurement	140	140	Golden proportion was not found in anterior teeth
MA Swileh [68]	Case control	Anterior teeth measurement	62% Golden Proportion	2D Photograph analysis	82	82	Golden proportion was not found in all anterior teeth

C: control group, S: study group.

Table 3. Incidence of golden proportion among included studies based on the geographical regions (n = 52).

Country [ä]	*N* *	*Unit*	Golden Proportion 62% [β]				Local Proportion % [α]			
			Right		Left		Right		Left	
			CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %
Pakistan	07	Mean	27.68	26.68	27.68	25.68	53	49.57	53	49.57
		Sd	24.281	25.313	24.281	26.456	0.147	0.150	0.147	0.150
India	16	Mean	13.61	8.60	13.41	7.58	40.84	42.76	41.41	31.41
		Sd	11.139	7.884	11.069	4.962	0.113	0.150	0.118	0.153
Nepal	03	Mean	14.28	12.69	14.28	12.69	74.50	91	75.50	90
		Sd	0.56	1.56	0.56	1.56	0.343	0.092	0.348	0.095

Table 3. *Cont.*

Country [ä]	*N* *	*Unit*	Golden Proportion 62% $^{\beta}$				Local Proportion % $^{\alpha}$			
			Right		Left		Right		Left	
			CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %
Bangladesh	01	Mean	17	4	17	4	NR	NR	NR	NR
		Sd	0.148	0.035	0.148	0.035	NR	NR	NR	NR
SOUTH ASIA	27	Range	14–28	4.0–27	14–28	4–26	40–75	43–91	42–76	32–90
Iran	04	Mean	34.01	8.57	34.01	8.57	66.50	75	65	76
		Sd	8.599	5.895	8.599	5.895	0.707	12.727	2.828	11.313
Turkey	02	Mean	NR	NR	NR	NR	60.54	82.96	60.54	83.23
		Sd	NR	NR	NR	NR	10.663	5.600	10.663	5.982
Iraq	02	Mean	NR	NR	NR	NR	64.90	75.58	64.90	76.86
		Sd	NR	NR	NR	NR	2.710	5.955	3.484	5.954
Saudi Arabia	03	Mean	6.65	10	6.65	10	65.25	63.16	71.25	64.16
		Sd	0.028	0.194	0.028	0.194	0.130	0.310	0.100	0.139
Jordan	02	Mean	39.90	18.20	35.60	17.55	NR	NR	NR	NR
		Sd	7.919	8.061	9.050	3.747	NR	NR	NR	NR
WEST ASIA	13	Range	7–40	9–19	7–36	9–18	61–67	64–84	61–72	65–84
Canada	02	Mean	NR	NR	NR	NR	48.77	45.06	48.77	45.06
		Sd	NR	NR	NR	NR	0.090	0.060	0.089	0.085
United States	01	Mean	17.00	NR	17.00	NR	51.00	19.00	51.00	19.00
		Sd	2.340	NR	2.340	NR	0.170	0.230	0.170	0.230
NORTH AMERICA	03	Range	15–20	NR	15–20	NR	49–52	20–46	49–51	19–46
South Korea	01	Mean	NR	NR	NR	NR	38.90	83.30	38.90	83.30
		Sd	NR	NR	NR	NR	0.113	0.092	0.113	0.092
Japan	01	Mean	1.90	0.60	1.90	0.60	36.00	84.00	36.00	84.00
		Sd	0.760	0.020	0.760	0.020	0.090	0.090	0.090	0.090
EAST ASIA	02	Range	2–3	1–2	2–3	1–2	36–39	83–85	36–38	83–85
Jordan	02	Mean	39.90	18.20	35.60	17.55	NR	NR	NR	NR
		Sd	7.919	8.060	9.050	3.740	NR	NR	NR	NR
MIDDLE EAST	02	Range	32–48	11–27	27–45	14–22	NR	NR	NR	NR
Malaysia	02	Mean	19.70	18.70	19.70	18.70	71.58	79.66	71.58	79.66
		Sd	0.989	2.404	0.989	2.404	2.234	3.309	2.234	3.309
SOUTHEAST ASIA	02	Range	19–21	17–22	19–21	17–22	70–74	77–83	70–74	77–83
United Kingdom	03	Mean	10	1.40	10	1.40	36.05	87.30	36.05	87.30
		Sd	0.098	0.021	0.098	0.021	0.051	0.046	0.051	0.046
Spain	02	Mean	NR	NR	NR	NR	61.60	83.20	61.60	83.20
		Sd	NR	NR	NR	NR	0.06	0.14	0.06	0.14
Portugal	01	Mean	NR	NR	NR	NR	65.74	85.47	65.12	85.84
		Sd	NR	NR	NR	NR	0.17	0.01	0.17	0.01
Hungary	01	Mean	NR	NR	NR	NR	59	85	58	89
		Sd	NR	NR	NR	NR	0.24	0.21	0.28	0.22
Ireland	01	Mean	NR	NR	NR	NR	65	89	65	89
		Sd	NR	NR	NR	NR	0.06	0.01	0.06	0.01
EUROPE	08	Range	9–11	1–3	9–11	1–3	37–66	84–89	37–66	84–89

Table 3. *Cont.*

Country [ä]	*N* *	*Unit*	Golden Proportion 62% $^{\beta}$				Local Proportion % $^{\alpha}$			
			Right		Left		Right		Left	
			CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %	CI-LI %	LI-Ca %
Cote d'Ivoire	01	Mean	NR	NR	NR	NR	24	14.50	24	14.50
		Sd	NR	NR	NR	NR	0.080	0.108	0.080	0.108
Zimbabwe	01	Mean	4.50	10.70	4.50	10.70	49.60	67.70	49.60	67.70
		Sd	4.90	3.56	4.90	3.56	0.08	0.21	0.08	0.21
Sudan	01	Mean	2.40	4.90	2.40	4.90	55–64	55–64	55–64	55–64
		Sd	1.09	3.87	1.09	3.87	0.24	0.21	0.24	0.21
AFRICA	03	Range	3–5	5–11	3–6	5–11	24–64	15–68	24–64	15–64
Colombia	01	Mean	NR	NR	NR	NR	69	82	68	82
		Sd	NR	NR	NR	NR	0.060	0.140	0.060	0.130
SOUTH AMERICA	01	Range	NR	NR	NR	NR	68–70	81–83	67–69	81–83

[ä] The geographical region from where the study was reported; * number of studies reported from a specific geographic region; $^{\beta}$ The standard golden proportion values; $^{\alpha}$ the value other than 62% found in the studied population.

3.2. Main Outcomes of the Studies

All 52 articles [14–26,30–68] included concluded that 62% GP was partially found in six anterior teeth of the population with an aesthetically pleasing smile. Nine studies [14,15,18,22,37,42,45,47,48] found that GP only existed between apparent widths of LI and CIs. Five studies [16,17,23,32,50] concluded that although GP was present in some patients, statistically reliable value explained in the form of range would be more clinically applicable for dental practitioners to support the existing theories on aesthetic parameters. Three studies [21,24,25] reported variability in GP values in the left and right arch quadrant. In addition, four studies [17–20] claimed that the incidence of GP might be different for various ethnic populations as inter-arch tooth size relationships are population and gender-specific. Among all study participants, the mean dental ratios between the successive widths of maxillary anterior teeth were either larger or smaller than GP (Table 1).

GP, as observed in the included studies for maxillary anterior teeth, was identified. The ratio between right CI-to-LI; right Ca-to-LI was 18.514 ± 14.138 and 12.180 ± 12.545, respectively. The mean ratio between the left CI-to- LI; left Ca-to-LI was 18.259 ± 13.958 and 11.788 ± 12.333, respectively (Table 4). The observed proportion in the population between right CI-to- LI; right Ca-to-LI was 54.526 ± 14.684 and 63.975 ± 13.121, respectively. The local proportions in left CI-to- LI; were left Ca-to-LI 55.024 ± 13.072 and 63.9 ± 13.121, respectively (Tables 4 and 5).

Table 4. Mean values of golden proportion found in included articles (n = 26).

Golden Proportion 62%	*N*	Mean Percentage $^{\alpha}$	Standard Deviation
Right central and lateral incisor	26	18.514	14.138
Right lateral incisor and canine	26	12.180	12.545
Left central and lateral incisor	26	18.259	13.958
Left lateral incisor and canine	26	11.788	12.333

N, number of articles; $^{\alpha}$ Mean percentage, presence of golden proportion in articles included.

Table 5. Mean values of observed proportion from included articles (n = 38).

Local Proportion $^{\alpha}$	N *	Range	Mean Percentage $^{\beta}$	Standard Deviation
Right central and lateral incisor	38	40–70	54.526	14.684
Right lateral incisor and canine	36	51–78	63.975	13.121
Left central and lateral incisor	38	42–69	55.024	13.072
Left lateral incisor and canine	36	51–78	63.975	13.121

* Number of articles; $^{\alpha}$ geographic-based proportion of anterior teeth from included articles; $^{\beta}$ Mean value of dental proportion.

3.3. Outcomes of Proportions According to Geographic Regions

According to geographic regions, Europeans displayed the lowest ratios between both right and left CI-to-LI (R = 36 to 38%, L = 36–39%). West Asians displayed the highest ratio of the right CI-to-LI (from 61–67 to 64–84%), while the highest ratio of the left CI-to-LI was recorded in Southeast Asians (from 77 to 83%). For right and left Ca-to-LI ratios, Africans had the lowest values (R = 15–64% and L = 15–68%), while the highest ratios were in Southeast Asia (77–83%). Differences in the range of tooth proportions between populations showed no difference on both sides of the arch. The participants from Nepal had the highest Ca-to-LI ratio of 91%. The average tooth proportions based on geographic regions are presented in Table 3.

3.4. Quality Assessment Outcomes

According to CHSRI, six studies [15,24,35,45,47,48] mentioned choosing their patients randomly, and none mentioned blinding their participants or assessors. Eight studies [15,20,47,55,58,63,65,68] mentioned the withdrawal/dropout of their participants. Only 24 studies [14,15,17,19,20,22,23,26,32,35,36,38,39,41,43,51,52,54–57,59,61,67] repeated the measurement of their variables, likewise 6 studies [30,41,42,46,47,62] carried out sample size estimation and 35 studies [14,15,17,19–21,23–26,31–33,35,36,38,41,43,45,47–52,54,55,59–61,64–68] tested their examiner reliability. Fifty-two studies [14–26,30–68] clearly mentioned their inclusion and exclusion criteria. All the included studies clearly reported their outcomes. Through this assessment, 43 studies were categorized as "moderate" risk of bias, three studies were "low" risk of bias, and 6 studies were "high" risk of bias (Table 6). In accordance with NOS for quality assessment, the included studies scored in the range from 5 to 9 points, with a mean score of 6.84. Three studies carried a "low" risk of bias, while 44 studies and 5 studies showed moderate and high risk of bias, respectively (Table 7).

Table 6. Newcastle-Ottawa scale for quality assessment of included articles (n = 52).

No.	Author ID Year	Selection	Comparability	Exposure	Quality
1.	JD Preston 1993	****	*	*	6
2.	M Mahshid 2004	****	**	***	9
3.	F Umer 2010	***	**	**	7
4.	Shahnawaz et al. 2019	***	*	**	6
5.	S. Azam 2014	**	*	**	5
6.	S. Muhammad 2016	****	*	**	7
7.	Masood et al. 2019	****	*	**	7
8.	VS Agrawal 2016	**	*	**	5
9.	BVS Murthy 2008	**	*	**	5
10.	Sandeep et al. 2015	****	**	**	8
11.	R Meshramkar 2013	****	**	**	8
12.	NG Chander 2012	****	*	**	8

Table 6. *Cont.*

No.	Author ID Year	Selection	Comparability	Exposure	Quality
13.	NT Niranjan 2016	****	*	**	7
14.	TA Naqash 2013	***	*	**	6
15.	S Rana 2014	**	*	**	5
16.	MN Hegde 2016	****	*	**	7
17.	SA Shah 2014	***	*	**	6
18.	Kulshresthaet al 2017	***	*	**	6
19.	R Gyawali 2017	****	**	**	8
20.	A Maharjan2018	****	*	**	7
21.	Rokaya et al. 2015	****	**	**	8
22.	MK Mishra 2018	***	*	**	6
23.	M. Aziz 2017	***	*	**	6
24.	Parnia et al. 2010	***	*	**	6
25.	Nikgoo et al. 2009	****	**	***	9
26.	M Azimi 2016	***	**	**	7
27.	H Ozdemir	***	*	**	6
28.	U Hasanreisoglu	****	**	**	8
29.	MI Al-Marzok	****	**	**	8
30.	Sulaiman et al.	***	*	**	6
31.	AA Swelem	****	*	**	7
32.	Aldegheishemet al	****	*	**	7
33.	A Kanaparthy	***	*	**	6
34.	Sah et al.	****	*	**	7
35.	Q Zhao	****	**	***	9
36.	Yagasaki et al.	***	*	**	6
37.	MX Jin	****	**	**	8
38.	N Al-Kaisy	****	**	*	7
39.	I Al-Sheakli	**	*	***	6
40.	Fayyad MA et al.	**	*	**	5
41.	Alhabahbah et al.	****	**	**	8
42.	LM Ramirez	***	**	**	7
43.	TB Shetty	***	*	***	7
44.	R. Kalia	***	*	**	6
45.	Melo et al.	****	*	**	7
46.	Becerra et al.	****	*	**	7
47.	D Calçada	***	*	***	6
48.	A Forster	***	**	**	7
49.	Condon et al.	****	*	***	8
50.	Pesson et al.	***	*	**	6
51.	F. Beyuo	****	**	**	8

Table 6. *Cont.*

No.	Author ID Year	Selection	Comparability	Exposure	Quality
52.	MASwileh	****	*	***	8

A study can be awarded a maximum of 1 star for each numbered item within the selection and exposure categories. A maximum of 2 stars can be given for comparability. Each study can be awarded a total of 9 stars. A study was rated to have a low risk of biasness if it received the maximum allowed number of 9 "stars" while moderate risk if it received 8, 7 or 6 "stars" and high risk if it received 5 "stars" or less.

Table 7. Methodological quality assessment results of the included studies (Cochrane Handbook for Systematic Reviews of Interventions).

No.	Study	Patient Chosen Randomly	Blinding		Withdrawal/ Dropout Mentioned	Variables Measured Many Times	Sample Size	Inclusion/ Exclusion Criteria Clear	Examiner Reliability Tested	Clearly Report All Expected Outcomes Prespecified	Quality of Study/Bias Risk
			Participants	Assessor							
1.	JD Preston	Unclear	Unclear	Unclear	No	Yes	No	Unclear	Yes	Yes	Moderate
2.	M Mahshid	Yes	Unclear	Unclear	Yes	Yes	No	Yes	Yes	Yes	Low
3.	F Umer	Unclear	unclear	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
4.	Shahnawaz et al.	Unclear	No	Unclear	No	Unclear	Yes	Yes	Unclear	Yes	Moderate
5.	S. Azam	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
6.	S. muhammad	Unclear	Unclear	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
7.	Masood et al.	Unclear	Unclear	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
8.	VS Agrawal	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
9.	BVS Murthy	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
10.	Sandeep et al.	Unclear	No	Unclear	No	Yes	No	Yes	Unclear	Yes	Moderate
11.	R Meshramkar	Unclear	No	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
12.	NG Chander	Yes	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
13.	NT Niranjan	Unclear	No	Unclear	No	Unclear	No	Yes	Unclear	Yes	Low
14.	TA Naqash	Unclear	Unclear	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
15.	S Rana	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
16.	MN Hegde	Unclear	Unclear	Unclear	No	Yes	No	Yes	Unclear	Yes	Moderate
17.	SA Shah	Unclear	Unclear	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
18.	Kulshrestha et al.	Unclear	No	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
19.	R Gyawali	Unclear	No	Unclear	No	Yes	Yes	Yes	Yes	Yes	Moderate
20.	A Maharjan	Unclear	No	Unclear	No	Unclear	Yes	Yes	Unclear	Yes	Moderate
21.	Rokaya et al.	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
22.	MK Mishra	Unclear	No	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
23.	M. Aziz	Yes	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
24.	Parnia et al.	Unclear	Unclear	Unclear	No	Unclear	Yes	Yes	Unclear	Yes	Moderate
25.	A Nikgoo	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Low
26.	M Azimi	Yes	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
27.	H Ozdemir	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
28.	Hasanreisoglu U	Unclear	No	No	No	Yes	No	Yes	Yes	Yes	Moderate
29.	MI Al-Marzok	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
30.	Sulaiman et al.	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
31.	AA Swelem	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
32.	Aldegheishemet al	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
33.	A Kanaparthy	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Unclear	Yes	High
34.	Sah et al.	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
35.	Q Zhao	Unclear	No	Unclear	Yes	Yes	No	Yes	Yes	Yes	Moderate
36.	Yagasaki et al.	Unclear	Unclear	Unclear	No	yes	No	Yes	No	Yes	Moderate

Table 7. *Cont.*

No.	Study	Patient Chosen Randomly	Blinding		Withdrawal/ Dropout Mentioned	Variables Measured Many Times	Sample Size	Inclusion/ Exclusion Criteria Clear	Examiner Reliability Tested	Clearly Report All Expected Outcomes Prespecified	Quality of Study/Bias Risk
			Participants	Assessor							
37.	MX Jin	Unclear	Unclear	Unclear	No	Yes	No	Yes	Unclear	Yes	Moderate
38.	N Al-Kaisy	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
39.	I Al-Sheakli	Unclear	No	Unclear	Yes	Unclear	No	Yes	Unclear	Yes	Moderate
40.	Fayyad et al.	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
41.	Alhabahbah et al.	Yes	No	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
42.	LM Ramirez	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
43.	TB Shetty	Unclear	No	Unclear	Yes	Yes	No	Yes	Yes	Yes	Moderate
44.	R. Kalia	Unclear	No	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
45.	Melo et al.	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
46.	Becerra et al.	Unclear	No	Unclear	No	Unclear	Yes	Yes	Unclear	Yes	Moderate
47.	D Calçada	Unclear	Unclear	Unclear	Yes	Unclear	No	Yes	Unclear	Yes	Moderate
48.	A Forster	Unclear	Unclear	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
49.	Condon et al.	Unclear	Unclear	Unclear	Yes	Unclear	No	Yes	Yes	Yes	Moderate
50.	Pesson et al.	Unclear	No	Unclear	No	Unclear	No	Yes	Yes	Yes	Moderate
51.	F. Beyuo	Unclear	No	Unclear	No	Yes	No	Yes	Yes	Yes	Moderate
52.	M.A. Swileh	Unclear	No	Unclear	Yes	Unclear	No	Yes	Yes	Yes	Moderate

4. Discussion

The present study systematically reviewed the occurrence of GP between the perceived widths of the maxillary anterior teeth among populations in different geographic regions of the world. The null hypothesis that GP would not be consistently present between the perceived widths of the maxillary anterior teeth among populations in different geographic regions was accepted. The review determined that GP manifests only in a small percentage of the population and, therefore, cannot be reliably used to determine tooth width for pleasing aesthetic dental rehabilitation.

Since the introduction of GP in dentistry, over 52 [14–26,30–68] case-control studies have been carried out worldwide to investigate the existence of the golden proportion between the perceived widths of the maxillary anterior teeth. A majority of these studies (n = 27) were carried out in the South Asian region, with most in India (n = 16), followed by Pakistan (n = 7). The mean percentage on the right side for the apparent width of CI-to-LI was found to be greatest in the Pakistani population (27.68%) [16,17,30–32] as compared to the Bangladeshi population (17%) [45], the Nepalese (14.28%) [40–42] or the Indian population (13.61%) [18,21,22,33–41]. In addition, lower mean percentages were found for Ca-to-LI among populations; 26.68% (Pakistan), 12.68% (Bangladesh), 4% (Nepal) and 8.60% (India). Interestingly, different results were found between the apparent widths of CI-to-LI-to-Ca when comparing the left to the right side [30,45]. These differences in tooth proportions may be due to various ethnic and racial backgrounds. Another notable reason could be the assessment method used to record the GP and the sample size among the studies in the South Asian population. Umer et al. [16], in a pilot study on 44 patients, utilized dental cast and grid analysis for assessing tooth proportions and observed 66% of the results. While the 15 included studies performed evaluations with 2D photograph analysis [17,21,22,31–33,35,40–42,45] and direct clinical measurement of teeth [35,36,38,39]. In addition, 12 studies [22,30,32,34–36,38–41,43,44] had a sample size of more than 100. This heterogeneity in the assessment methods and sample size could have influenced the observed review outcomes.

The range of GP in the South Asian population for CI-to-LI was 13.61–27.68% and Ca-to-LI was 4.0–26.68%. Whereas local proportion for CI-to-LI was 40.84–74.50% and Ca-to-LI was 42.76–91% on the right side, CI-to-LI was 41.41–75.50% and Ca-to-LI was 31.41–90%

on the left side. On the contrary, in the West Asians, proportions for CI-to-LI were 60.54–66.50%, and Ca-to-LI was 63.16–82.96% on the right side; CI-to-LI was 60.54–71.25%, and Ca-to-LI 64.16–83.23% on the left side. The majority of the studies in these regions used 2D photographs for the assessment of GP [15,25,26,46–49,51,58]. In addition, the sample size varied by great numbers (n = 60–903), and so did the male-to-female ratio. These factors, along with racial and ethnic differences, might have played a major role in the final outcome. In a study by Kanaparthy et al. [53], in Saudi Arabia, GP was found for CI-to-LI in females (0.62) and between Ca-to-LI in males (0.60). The study sample size was limited to 60 patients only, and casts were used to assess the GP. By contrast, Aldegheishem et al. [52] conducted a study on the same population with the same sample size using a digital impression, digital cast, and 2D photograph for assessment. They reported conflicting results [CI-to-LI (78%), Ca-to-LI (72%) on the right side, CI-to-LI (96%), and Ca-to-LI (75%) on the left side] due to the difference in methodologies and gender disparity. Contrasting results were also observed by Gyawali et al. [39] in the Indian population, with a local proportion of CI-to-LI (68%) and Ca-to-LI (75%) on both sides. The different outcomes could be the result of racial differences and assessment methods.

Moreover, it is pertinent to mention that a difference in methodology was observed among the included studies. In addition, most of the studies used a single method of tooth proportion evaluation [14–17,20,21,23–26,30–51,53–56,58–61,63,64,66–68]. Out of which, 29 studies used 2D photograph analysis to investigate the occurrence of the GP between the perceived widths of the maxillary anterior teeth [14,15,17,20,21,25,26,31–34,37,40–42,45–51,56,58–60,63,65,68]. Followed by 10 studies which used dental cast analysis [16,23,24,30,43,44,53–55,61]. All these studies might have flaws, including the volumetric changes in the impression or inaccuracies in the pouring of dental casts and positional differences or magnification errors that can occur during 2D photography. Only six studies considered direct clinical measurement of teeth [35,36,38,39,66,67] as an assessment method. A few others (06) used both 2D photograph and dental cast analysis [18,19,22,57,62,65]. Therefore, it is suggested that a combination of assessment methods with low error, including direct clinical measurements and digital scans, should be employed for the assessment of tooth proportions in future studies.

Few studies reported GP to exist between the apparent widths of all anterior teeth on both sides, including Umer et al. [16], where 63% of the population observed GP in all anterior teeth; however, this was a pilot study with a sample of 44 patients only. GP was also found in a small number of 4 other studies, including Al-Marzok [23] (20.4%), Sulaiman [50] (19%), and 18.57% in studies by Muhammad et al. [17] and Masood et al. [32], respectively. They concluded that although GP was present in some participants, statistically reliable value explained in the form of a range would be more clinically applicable for dental practitioners to support the existing theories on aesthetic parameters. Nikgoo et al. [47] suggested that rather than emphasizing a single value such as GP of 62%, a range of dental proportion ratios should be proposed to achieve ideal aesthetics. The current systematic review proposes a range of dental proportions based on geographic location, which could be utilized to restore anterior teeth in different races and ethnicities.

In addition, it is suggested that GP only existed between apparent widths of lateral and central incisors by S Rana et al. 35%, Mahshid et al. 34%, Azimi et al. 25%, Niranjan et al. 21.70%, Sandeep et al. 21.25%, Preston et al. 17%, and Maharjan et al. 14.28%, respectively [14,15,18,22,37,42,45,47,48]. These studies found that the frequency of the golden proportion was quite low for La and Ca ($\leq$10%) [14,15,22,37,45,48]. Ward believed that when the golden proportion is used, the lateral incisor appears too narrow, and the resulting canine is not esthetic. He preferred using a 70% proportion [6]. Therefore, it was concluded that GP could be helpful to achieve aesthetic restorations of the maxillary central and lateral incisors, though it should not be considered as a decisive factor in determining dental attractiveness and other factors should be considered.

Furthermore, variations in GP were also noted between the right and left sides of the arches [21,24,25]. Murthy et al. observed that 17.9% had left CI in GP to left LI, whereas

16.1% had right CI in GP to right LI. Whereas 25% had left LI in GP to left Ca and 14.3% had right LI in GP to right Ca [21]. Similar variations were noted by Fayyad et al. and Alhabahbah et al. [24,25]. These differences can be due to misalignment, including rotation, spacing, overlapping, and other forms of malalignment of teeth. If the misalignment factors are absent or eliminated, then the apparent width is affected by the curvature of the arch form and the inter-arch tooth size relationships themselves. Studies have claimed that the incidence of GP may be different for diverse ethnic populations as inter-arch tooth size relationships are population and gender-specific [17–20].

Some authors also argue that gender has no significant effect when the golden proportion is applied, but ethnic differences should be considered to determine exactly those percentages that are really golden [16,21–24]. Although the present study investigated the existence of GP proportions in individuals from different geographic populations, nevertheless, the population's ethnic background and race critically influence tooth proportions [21–24]. Studies have highlighted the importance of ethnic origins, suggesting that GP can be applied to populations only after appropriate adjustments due to variations in the populations' race [21,25]. For instance, golden proportions were observed between the apparent widths of maxillary anterior teeth for LI/CI in Kurdish and Arab populations [26]. However, proportions of 1.59:1:0.73 and 1.62:1:0.69 were observed in Iraqi Arabs and Kurds, respectively. Despite the presence of GP in some portions of the population in the reviewed studies, the majority of literature disproves its use as the only standard for restoration of an aesthetic smile, and consideration of ethnic background, race, and geographic origins is pertinent.

Despite the strengths of this study, there were certain limitations in the systematic review. For instance, take the heterogeneity of the methods used in the included studies. Moreover, less than half of the studies tested their examiner reliability and/or repeated the measurement of their variables, which could have affected the results of the studies. Moreover, 44 studies showed a moderate and 5 studies a high risk of bias, respectively. Therefore, the outcome should be used cautiously. It is suggested that tooth proportion range values should be employed for esthetic dental rehabilitation in combination with the soft and hard tissue coherence, occlusal harmony, and the patient's perception of a pleasant smile. Furthermore, the authors suggest that additional comparative and observational studies of various dental proportions with proper criteria and design can be carried out to explore their effects on dental aesthetics.

5. Conclusions

Based on the findings of this systematic review, the following conclusions were drawn: In total, 62% of golden proportions were not found in the successive widths of maxillary anterior teeth in the majority of the population in the reviewed studies from different geographic regions. The overall mean CI-to-LI and Ca-to-LI observed proportion values were 54.526 ± 14.684, 63.975 ± 13.121, on the right side, and 55.024 ± 13.072, and 63.975 ± 13.121 on the left side of the arch from the included studies. The use of golden proportion still provides a baseline for the reconstruction of lost or damaged anterior tooth widths; however, it is not the only standard for restoring esthetic smiles worldwide, and anterior tooth proportions differ among populations based on their geographic, ethnic, and racial background. Moreover, consideration should also be given to an individual's dentofacial variations in restoring anterior teeth.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app12126196/s1. Refs. [69–90] are cited in Supplementary Materials.

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