ORIGINAL ARTICLE

Evaluation of "Golden Proportion" in Saudi individuals with natural smiles

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Abstract *Background:* The Golden Proportion (GP) has been considered by many as the most harmonious recurrent tooth-to-tooth ratio and has long been proposed as an aesthetic guideline for restoring/replacing maxillary anterior teeth. Researchers investigated GP in various populations.

Purpose: The aim of the current study was to investigate the occurrence and prevalence of the GP between the perceived widths of maxillary anterior teeth in a Saudi population with natural smiles.

Materials and Methods: A total of 360 Saudi dental students (180 males and 180 females) with natural smiles and who met the inclusion criteria were included in the study. Frontal photographs were captured for all participants while maximally smiling using a digital camera with standardized settings. Photo-editing software was used to measure the perceived mesiodistal width of each anterior maxillary tooth in all digital images. Paired and student *t*-tests were performed to detect side and/or gender differences respectively. Calculated ratios of the perceived mesiodistal widths of the teeth were compared with their respective GP values using a one sample *t*-test. Statistical significance was set at 5%.

Results: For both genders, there were significant differences (P < 0.001) between the calculated ratios and the golden ratios. No side differences in the GP were detected. Males had wider teeth than females however significant differences between genders was detected for the centrals (P < 0.001) only.

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Conclusions: Width ratios of the maxillary anterior teeth did not follow the GP for the examined Saudi population. Males had wider anterior teeth with the centrals exhibiting a significant gender-based difference. There was no side-dependent variation for both genders.

1. Introduction

Dental aesthetics has always been and continue to be a primary concern for most individuals. Maxillary anterior teeth play a vital role as they are not only important to dental aesthetics, but have a major contribution as well to overall facial aesthetics and appearance (Owens et al., 2002; Hasanreisoglu, 2005). Arrangement, size and shape of maxillary anterior teeth were found to be the most influential factors that contribute to a harmonious and balanced anterior dentition, especially maxillary central incisors when viewed from the front (Brisman, 1980; Ricketts, 1982; Ward, 2001; Marquardt, 2002). In 1973, Lombardi introduced the Golden Proportion (GP) concept in an attempt to achieve balance between the dentition and the facial profile. Dental and facial aesthetics were hence claimed to be optimized if proportion between widths of maxillary anterior teeth is repeated when the individual is viewed from the front (Lombardi, 1973). In the proposed GP ($1/1.618 = 0.618$), the visible (perceived) width of the canine is 62% (0.618) of the lateral incisor and the visible width of the lateral incisor is 62% (0.618) of the central incisor (Snow, 1999).

The GP has been investigated and mentioned extensively in the dental literature (Levin, 1978; Preston, 1993; Qualtrough and Burke, 1994; Snow, 1999; Rosenstiel et al., 2000; Ward, 2001; Javaheri and Shahnavaz, 2002; Mahshid et al., 2004; Simon, 2004; Hasanreisoglu et al., 2005; Ali Fayyad et al., 2006; Murthy and Ramani, 2008; Petricevic et al., 2008; Nikgoo et al., 2009; Chander et al., 2012; Pini et al., 2012; Meshramkar et al., 2013; Rossetti et al., 2013; Forster et al., 2013; Al-Marzok et al., 2013; Calçada et al., 2014; Sandeep et al., 2015; Jin et al., 2016; Bragatto et al., 2016; Kanaparthy et al., 2016; Koidou et al., 2018; Parciak et al., 2017; Al-Kaisy and Garib, 2017). It has been considered by many researchers as the most harmonious recurrent tooth-to-tooth ratio that occurs more consistently in aesthetically pleasing smiles (Richardson and Malhotra, 1975; Levin, 1978; Ward, 2001; Marquardt, 2002) and has long been proposed as an aesthetic guideline for restoring and replacing maxillary anterior teeth (Richer, 1971; Rosenstiel et al., 2001; Levin, 2011). However, other studies revealed that many beautiful smiles did not show proportions coinciding with the GP (Qualtrough and Burke, 1994; Rosenstiel et al., 2000; Mahshid et al., 2004; Rossetti et al., 2013; Calçada et al., 2014; Koidou et al., 2018). In fact, Preston (1993) reported that natural tooth ratios seldom follow the GP. A different concept, known as the "recurring aesthetic dental proportion" (RED) has also been introduced by Ward (2001). According to his concept, clinicians can use a proportion of their own choice, as long as that it remains consistent, proceeding distally in the arch. The author reported that this proportion offers great flexibility to match tooth with facial proportions (Ward, 2001). Despite that majority of North American dentists preferred smiles created using the RED proportion principle (Ward, 2007), yet still others reported that the RED proportion was unsuitable in relating the successive width of maxillary anterior teeth in natural dentition (Ali Fayyad et al., 2006; Murthy and Ramani, 2008).

It is worth mentioning, that tooth size and morphology varies from one population to the other. Published data has in fact shown differences, not only between, but within ethnic groups as well (Lee, 1977; Keene, 1979; Tsukiyama et al., 2012; Fernandes et al., 2013). Early on, Bailit (1975) emphasized that clinicians should essentially consider minor differences in dental traits among population types as such variations may possibly influence the prosthodontic restoration of an aesthetic smile.

The width and/or length ratios of maxillary anterior teeth has been studied universally for different populations and ethnicities including Kenyan and British (Turner and Richardson, 1989), Caucasian (Sterrett et al., 1999; Rosenstiel et al., 2000), Turkish (Hasanreisoglu et al., 2005), Jordanian (Ali Fayyad et al., 2006), Asian (Marcuschamer et al., 2011; Tsukiyama et al., 2012), Indian (Chander et al., 2012; Meshramkar et al., 2013), Hungarian (Forster et al., 2013), Portugese (Calçada et al., 2014), Korean (Jin et al., 2016), and Iraqi (Al-Kaisy and Garib, 2017) populations. Fernandes et al. (2013) investigated mesiodistal tooth widths in Caucasian, African and Japanese individuals. Parciak et al. (2017) investigated the relationship between mesiodistal dimensions of maxillary anterior teeth and specific facial dimensions in Asian, African-American, and white ethnicities. Earlier, Bishara et al. (1989) compared mesiodistal and buccolingual crown dimensions of permanent teeth in three populations from Egypt, Mexico and the United States. To the best of the authors' knowledge, only one article investigated maxillary anterior teeth widths and their relation to the GP in the southwestern part of Saudi Arabia (Kanaparthy et al., 2016).

Hence, the aim of the current study was to investigate the occurrence and prevalence of the GP between the perceived widths of maxillary anterior teeth in a general Saudi population with natural smiles and with no representatives to a specific region. The null hypothesis was that there would be no differences between the proportions of maxillary anterior teeth of Saudi individuals and the GP values.

2. Materials and methods

This study protocol was accepted and attained an ethical approval (No.040-15) from the Institutional Ethical Committee. Dental student volunteers were solicited by emails, verbal and written announcements to participate in the study. A total

of 360 Saudi dental students (180 males and 180 females) who met the inclusion criteria participated after signing a written informed consent. Participants' age ranged from 18 to 23 years with a mean age of 21.4 years. The study was conducted on the same age group to eliminate the influence of age on tooth dimensions. Participants were from all around the country with no representatives to a specific region and were chosen according to the following inclusion criteria: (1) presence of all anterior (maxillary and mandibular) teeth with no interdental spacing, diastemas or crowding; (2) anterior teeth are not carious, rotated, intruded, or extruded; (3) absence of any periodontal or gingival conditions (hyperplasia, recession or inflammation) that may affect a healthy tooth-to-tissue relationship; and (4) no history of anterior teeth size alteration by restorations, orthodontic treatment or maxillofacial surgery. Volunteers who had any of the following criteria were excluded: (1) evidence of dental irregularities or any gingival alteration; (2) apparent loss of tooth structure due to caries, fracture or attrition; (3) microdontia or any other dental anomalies. The current study considered randomly selected natural smiles; hence participants were not pre-evaluated for the presence or absence of an "aesthetic" smile.

A frontal photograph was captured for each participant while in maximum smiling position to expose all maxillary teeth. Photographic conditions were standardized for all participants and all photographs were taken by the same investigator. Participants were seated comfortably in a dental chair with the head upright, supported by the headrest. Head position was adjusted so that the occlusal plane of the maxillary teeth was parallel to the floor and the head aligned with the center of the camera lens. All photographs were taken under a standard light source with a constant focal distance of 60 cm using the same digital camera (Canon 1200 D; Canon Inc) with a 100-mm macro lens. Camera settings were as follows: 1/125 shutter speed, f/5.6 aperture, ISO 200 sensitivity.

All photos were then transferred to a personal computer (HP Pavilion; Hewlett-Packard) and opened using photo-editing software (Adobe Photoshop CS 6; Adobe Systems Inc). To minimize measurement errors, all measurements were performed by the same individual and image size was standardized for all photos so as to be 90 mm in width and 45 in height. Using the measuring tool of the imaging software (Adobe Photoshop CS 6; Adobe Systems Inc), the perceived mesiodistal width (the widest distance between the mesial
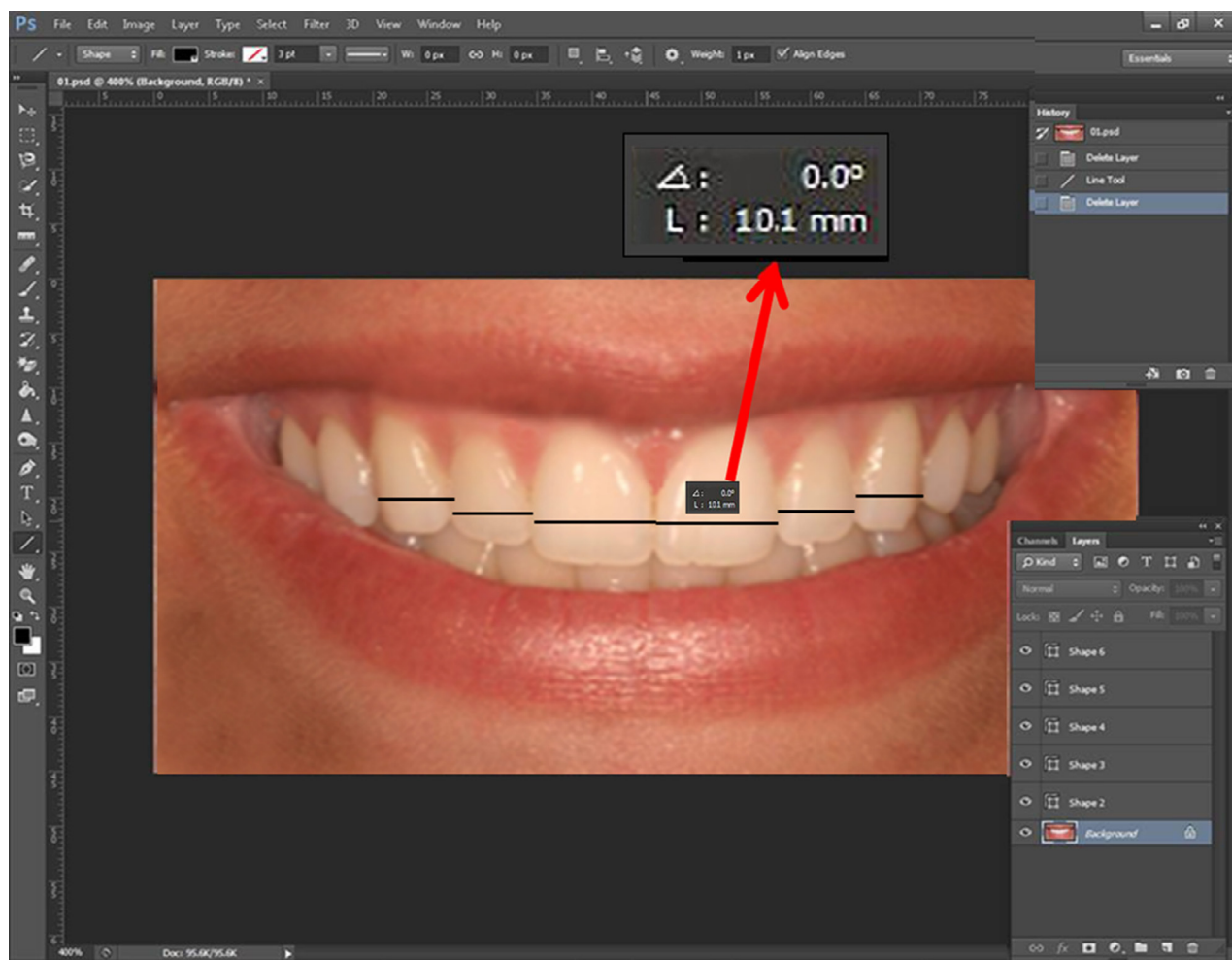

Fig. 1 Perceived mesiodistal widths of maxillary teeth measured using imaging software (red arrow: magnification of one of the measurements).

and distal contact points of the tooth as viewed from the front) of each anterior maxillary tooth was measured in mm (Fig. 1). Each measurement was made 3 times by the same operator, and their average was calculated. Mean values for all six maxillary anterior teeth were then tabulated.

Data was statistically analyzed using SPSS software (SPSS 20.0; IBM Inc.) and presented as minimum values, maximum values, means and standard deviations. Data distribution was tested for normality with the Kolmigorov-Smirnov test and found to be normally distributed. A paired *t*-test was conducted to detect any side differences (right versus left) in each gender. A student *t* test was performed to determine if there were any gender (males versus females) differences in the perceived widths of each tooth group for both sides. The perceived widths of the central incisors and canines were divided by the perceived width of the lateral incisors; the calculated ratio values were then compared with the anticipated golden ratio values of the related teeth (Hasanreisoglu et al., 2005) using a one sample *t* test. For all statistical evaluations, the level of significance was established as alpha = 0.05.

3. Results

There were significant differences between genders for the right and left central incisors only. However statistical analysis revealed insignificant differences between right and left sides within each gender for all tooth groups (Fig. 2). So for each tooth group, data for the right and left sides were grouped together for further analysis. The means and standard deviations for the combined perceived widths of the maxillary central incisors (CI), lateral incisors (LI), and canines (CA) for both genders are displayed in Table 1. The mean perceived width was always greater in the males than in the females for all tooth groups. However statistical analysis revealed significant differences between the genders for the central incisors only.

The calculated mean ratios for the perceived widths of the maxillary central incisors and the canines in reference to that of the lateral incisors as compared to their ideal golden ratios (1.618 and 0.618 respectively) are shown in Fig. 3. The CI:LI ratio was 1.53 for the males and 1.51 for the females, while the CA:LI ratio was 0.6 for both males and females. For both
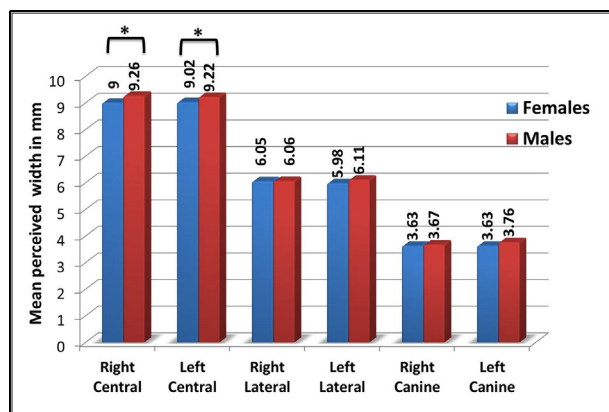

Fig. 2 Perceived mesiodistal widths of all tooth groups by gender and side (*p < 0.05).

genders, there were highly significant differences between the calculated ratios and the golden ratios. Hence, results revealed narrower central incisors and narrower canines compared to golden ratio measurements.

4. Discussion

Results of the current study rejected the null hypothesis as there were highly significant differences between the calculated ratios and the golden ratios for both genders.

In the current study, frontal photographs were acquired by a digital camera and directly analyzed using a computer program. This method offers several advantages that collectively improve the accuracy of measurements. They include simplicity, feasibility of repeated measurements, and the possibility to magnify the photographs using the computer program (Jin et al., 2016).

In general, the study results suggest low prevalence of the GP among the Saudi participants. The GP between CI and LI was found only in 9 (5.0%) males and 15 (8.3%) females. Similarly, GP between LI and CA was found in 10 (5.5%) males and 26 (14.5%) females only. Nearly similar results were found in other studies including individuals with different nationalities but with nearly the same age group as in the current study. Ali Fayyad et al. (2006) reported that in a Jordanian population, the GP between CI and LI existed in 31% of the males and 27.1% of the females. While that between LI and CA existed in 13.1% of the males and 11.8% of the females. Mahshid et al. (2004) found it in 34.1% between the CI and LI and in < 10% between LI and CA in Iranians. Preston (1993) reported 17% existence of the GP between CI and LI and 0% existence between LI and CA. Murthy and Ramani (2008), found the GP in only 14 (25%) out of 56 Indian dental students. Further comparable findings were reported for Malasian (Al-Marzok et al., 2013), Turkish (Hasanreisoglu et al., 2005), Caucasian (Petricevic et al., 2008), Hungarian (Forster et al., 2013), Kurdish and Arabic (Al-Kaisy and Garib, 2017) populations.

In the current study, an aesthetically appealing smile was not one of the inclusion criteria in selecting the participants. To suggest that this factor could have been a major contributor to the low prevalence of the GP in this study may not be completely fair for two reasons. First, despite all participants were considered to have just a natural smile, none of them was aesthetically unpleasant as perceived by the authors and three other Prosthodontic professors. Second, other researchers have contended that the GP is more of a theoretical concept that does not essentially exist in natural dentitions (Mahshid et al., 2004; Ali Fayyad et al., 2006; Murthy and Ramani, 2008; Al-Marzok et al., 2013; Sandeep et al., 2015; Ward, 2007; Parnia et al., 2010) and may not even be necessary for the perceived attractiveness of a smile (Rosenstiel et al., 2000; Ward, 2007; Nikgoo et al., 2009; Pini et al., 2012). In their study, Mhashid et al. (2004) concluded that the GP was not even a common factor in aesthetic smiles. Actually, earlier studies reported that the GP can only be applied for the anterior teeth within narrow limits (Lombardi, 1973) since it tends to result in narrower maxillary CIs and narrower Cs than normal (Lombardi, 1973; Preston, 1993; Sterrett et al., 1999).

Previously published study conducted on southwestern Saudis by Kanaparthy et al. (2016), found that GP existed

Table 1 Mean perceived width (mm) of maxillary anterior teeth by gender (n = 180).

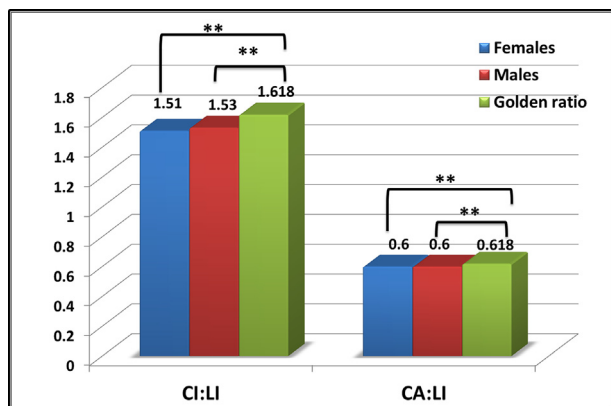| Tooth	Gender	Mean	SD	95% CI		p
				Lower	Upper	
Central incisor	Female	9.01	0.66	−0.3706	−0.0920	< 0.001[**]
	Male	9.24	0.59			
Lateral incisor	Female	6.02	0.64	−0.2267	0.0949	0.145
	Male	6.09	0.66			
Canine	Female	3.63	0.49	−0.1554	0.0274	0.121
	Male	3.69	0.59			

[**] Highly significant at p ≤ 0.001.

Fig. 3 Comparison of calculated ratios (perceived width) of central incisors (CI) and canines (CA) to lateral incisors (LI), with anticipated golden ratio for central incisor (1.618) and canine (0.618) teeth by gender (**p < 0.001).

between CI-LI in the females and between CA-LI in the males. This contradicts with our results, mainly due to the differences in the measurement method, smaller sample size, and they included participants with "aesthetic" smiles not just natural smiles. In addition their results represented Saudi individuals from a specific region. It's worth mentioning however that their CA:LI ratio for the males (0.6) was exactly the same as that reported in the current study for both males and females.

In the current study, the average calculated ratios for males and females together were 1.52:1:0.60. Apparently, Saudi individuals have narrower central incisors and canines when compared to the golden ratios (1.618:1:0.618). When compared to other Arab populations such as Iraqis, it was found that the average calculated ratios for the Kurdish group was 1.62:1:0.69 and for the Arab group was 1.59:1:0.73. It seems that the Saudi CI:LI ratios are closer to the Iraqi population of an Arabic origin and the Saudi CA:LI ratios are closer to the Iraqi Kurdish populations. Saudi individuals seem to have narrower centrals than their Kurdish equivalents and narrower canines than their Iraqi equivalents of an Arabic origin. When compared to other Asian populations, similar observations were found in Turkish (Hasanreisoglu et al., 2005) individuals for the central incisors. Calculated CI/LI ratios were 1.516 (males) and 1.544 (females) for the Turkish population indicating narrower centrals compared to the GP as well. However, Turkish individuals seemed to have wider canines compared to the Saudi population as their calculated CA/LI ratios were 0.803 (males) and 0.778 (females). The mean perceived widths

for the maxillary CI, LI and CA in the Turkish population were 8.8 mm, 5.8 mm, 4.6 mm respectively. In this study, they were 9.1 mm, 6.06 mm, and 3.66 mm (average for males and females together) indicating that Saudis have wider centrals and laterals but narrower canines compared to their Turkish equivalents. It seems that maxillary arches in Saudi individuals are wide anteriorly then tend to be more curved posteriorly, hence when observed from the frontal view, the widths of the centrals and laterals appear wider and canines appear narrower. Such observation emphasize the rationale that not only tooth size and morphology differ from one population to the other, but also arch morphology plays a role.

Further in depth analysis of the results revealed the following findings. First, for both genders, there were no arch side differences, indicating that tooth proportions were symmetrical on both sides of the maxillary arch. Such finding confirm the suggestion that restoring symmetry is critically essential and may be even more important than establishing GP, when planning for prosthodontic treatment especially in the aesthetic zone (Al-Kaisy and Garib, 2017). Secondly, Saudi males had wider perceived maxillary anterior teeth width than females for all teeth groups. It is noteworthy however that these gender differences were significant for the central incisors only. This may explain why the CI/LI ratio was higher and relatively closer to the GP in the males than in the females.

Collectively, our results suggest that the GP does not always necessarily exist in natural smiles and that what is believed to be aesthetically pleasing parameters may vary from one population to another. The Golden Proportion or any other specific proportion should not just be blindly applied during anterior prosthodontic restorations as it may on the contrary lead to unaesthetic results in some individuals. Anterior dental aesthetics should be restored with unique and reasonable proportions based on individual cultural characteristics and actual local measurements rather than following a general rule (Forster et al., 2013). The same conclusion was reported by Rokaya et al. (2018) who cited that "different cultures and ethnicities show varied proportions as well as preferences". Results of several researches confirm this conclusion. For example, In a North American population, CI/LI and CA/LI were found to be 66% and 84% respectively (Preston, 1993). In a Nepalese Population, a proportion of 66% for CI/LI and 70% for CA/LI were reported and considered to constitute the Nepalese Esthetic Dental (NED) proportion. The authors even proposed the NED proportion as a guideline for dental treatment in the maxillary anterior region in Nepalese populations (Rokaya et al., 2015). Results of the

current study show that 66% for CI/LI and 60% for CA/LI could be considered as aesthetically acceptable proportions in the Saudi population represented. Furthermore the results revealed that symmetrical side proportions and gender differences in the dimensions of maxillary anterior teeth seem to be critical factors that should be considered when restoring maxillary anterior teeth in Saudi individuals.

One of the limitations of the current study is the potential minor positional variations that may occur during photography and image acquisition. Furthermore, additional research on a greater sample size selected more systematically including various ages is necessary before extrapolating and generalizing the results to the Saudi population.

5. Conclusions

Within the limitations of the present study, the following conclusions were drawn:

- Mesiodistal width ratios of the maxillary anterior teeth did not follow the Golden Proportion for the examined Saudi population, with the relative ratios for the central incisors and canines being smaller than those specified in the Golden Proportion.
- Males had wider perceived widths of maxillary anterior teeth than females, with only the central incisors exhibiting a significant gender-based difference.
- For both genders, there was no side-dependent variation of the perceived widths of the maxillary anterior teeth.

6. Clinical significance

This article suggests that the Golden Proportion does not necessarily exist in natural smiles and cannot be generalized and applied for all populations. Symmetrical side proportions and gender differences in the dimensions of maxillary anterior teeth are more critical factors when restoring or replacing maxillary anterior teeth in Saudi individuals.

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Conflict of interest

The authors declare that there are no conflicts of interest associated with this publication and there has been no financial support for this research that could have influenced its outcome.

References

Al-Kaisy, N., Garib, B.T., 2017. Analysis of the golden proportion and width/height ratios of maxillary anterior teeth in Arab and Kurdish populations. J. Prosthet. Dent. Nov 15. 10.1016/j.prosdent.2017.08.017. [Epub ahead of print]

Al-Marzok, M.I., Majeed, K.R.A., Ibrahim, I.K., 2013. Evaluation of maxillary anterior teeth and their relation to the golden proportion in Malaysian population. BMC Oral Health 13, 1–5.

Ali Fayyad, M., Jamani, K.D., Agrabawi, J., 2006. Geometric and mathematical proportions and their relations to maxillary anterior teeth. J. Contemp. Dent. Pract. 7, 62–70.

Bailit, H.L., 1975. Dental variations among populations: an anthropologic view. Dent. Clin. North Am. 19, 125–139.

Bishara, S.E., Jakobsen, J.R., Abdallah, E.M., Fernandez Garcia, A., 1989. Comparisons of mesiodistal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico and the United States. Am. J. Orthod. Dentofac. Orthop. 96, 416–422.

Bragatto, F.P., Chicarelli, M., Kasuya, A.V., Takeshita, W.M., Iwaki-Filho, L., Iwaki, L.C., 2016. Golden proportion analysis of dental-skeletal patterns of class II and III patients pre and post orthodontic-orthognathic treatment. J. Contemp. Dent. Pract. 17, 728–733.

Brisman, A.S., 1980. Esthetics: a comparison of dentists' and patients' concepts. J. Am. Dent. Assoc. 100, 349–352.

Calçada, D., Correia, A., Araújo, F., 2014. Anthropometric analysis of anterior maxillary teeth with digital photography – a study in a Portuguese sample. Int. J. Esthet. Dent. 9, 370–380.

Chander, N.G., Kumar, V.V., Rangarajan, V., 2012. Golden proportion assessment between maxillary and mandibular teeth on Indian population. J. Adv. Prosthodont. 4, 72–75.

Fernandes, T.M., Sathler, R., Natalício, G.L., Henriques, J.F., Pinzan, A., 2013. Comparison of mesiodistal tooth widths in Caucasian, African and Japanese individuals with Brazilian ancestry and normal occlusion. Dental Press J. Orthod. 18, 130–135.

Forster, A., Velez, R., Antal, M., Nagy, K., 2013. Width ratios in the anterior maxillary region in a Hungarian population: addition to the golden proportion debate. J. Prosthet. Dent. 110, 211–215.

Hasanreisoglu, U., Berksun, S., Aras, K., Arslan, I., 2005. An analysis of maxillary anterior teeth: facial and dental proportions. J. Prosthet. Dent. 94, 530–538.

Javaheri, D.S., Shahnavaz, S., 2002. Utilizing the concept of the golden proportion. Dent. Today. 21, 96–101.

Jin, M.X., Hong, M.H., Lee, K.J., Lee, K.B., 2016. Does the maxillary anterior ratio in Korean adults follow the Golden Proportion? J. Adv. Prosthodont. 8, 125–130.

Kanaparthy, A., Kanaparthy, R., Boreak, N., Aalami, R., 2016. Evaluation of widths of maxillary anterior teeth and their relation to the golden proportion in the southwestern part of Saudi Arabia. J. Res. Med. Den. Sci. 4, 83–86.

Keene, H.J., 1979. Mesiodistal crown diameters of permanent teeth in male American Negroes. Am. J. Orthod. 76, 95–99.

Koidou, V.P., Chatzopoulos, G.S., Rosenstiel, S.F., 2018. Quantification of facial and smile esthetics. J. Prosthet. Dent. 119, 270–277.

Lee, G.T.R., 1977. Ethnic variations in teeth morphology. Prac. Brit. Paedod. Soc. 7, 23–27.

Levin, E.I., 1978. Dental esthetics and the golden proportion. J. Prosthet. Dent. 40, 244–252.

Levin, E.I., 2011. The updated application of the golden proportion to dental aesthetics. Aesthet. Dentist. Today 5, 22–27.

Lombardi, R.E., 1973. The principles of visual perception and clinical application to denture esthetics. J. Prosthet. Dent. 29, 358–382.

Mahshid, M., Khoshvaghti, A., Varshosaz, M., Vallaei, N., 2004. Evaluation of "golden proportion" in individuals with an esthetic smile. J. Esthet. Restor. Dent. 16, pp. 185–192; discussion 193.

Marcuschamer, E., Tsukiyama, T., Griffin, T.J., Arguello, E., Gallucci, G.O., Magne, P., 2011. Anatomical crown width/length ratios of worn and unworn maxillary teeth in Asian subjects. Int. J. Periodont. Restorat. Dent. 31, 495–503.

Marquardt, S.R., 2002. Dr. Stephen R. Marquardt on the Golden Decagon and human facial beauty. Interview by Dr. Gottlieb. J. Clin. Orthod. 36, 339–347.

Meshramkar, R., Patankar, A., Lekha, K., Arguello, E., Gallucci, G.O., Magne, P., 2013. A study to evaluate the prevalence of golden proportion and RED proportion in aesthetically pleasing smiles. Eur. J. Prosthodont. Restor. Dent. 21, 29–33.

Murthy, B.V., Ramani, N., 2008. Evaluation of natural smile: Golden proportion, RED or Golden percentage. J. Conserv. Dent. 11, 16–21.

Nikgoo, A., Alavi, K., Alavi, K., Mirfazaelian, A., 2009. Assessment of the golden ratio in pleasing smiles. World J. Orthod. 10, 224–228.

Owens, E.G., Goodacre, C.J., Loh, P.L., Hanke, G., Okamura, M., Jo, K.H., Muñoz, C.A., Naylor, W.P., 2002. A multicenter interracial study of facial appearance. Part 2: a comparison of intraoral parameters. Int. J. Prosthodont. 15, 283–288.

Parciak, E.C., Dahiya, A.T., AlRumaih, H.S., Kattadiyil, M.T., Baba, N.Z., Goodacre, C.J., 2017. Comparison of maxillary anterior tooth width and facial dimensions of 3 ethnicities. J. Prosthet. Dent. 118, 504–510.

Parnia, F., Hafezeqoran, A., Mahboub, F., Moslehifard, E., Koo-daryan, R., Moteyagheni, R., Saber, F.S., 2010. Proportions of maxillary anterior teeth relative to each other and to the golden standard in Tabriz dental faculty students. J. Dent. Res. Dent. Clin. Dent. Prospects 4, 83–86.

Petricevic, N., Stipetic, J., Antonic, R., Borcic, J., Strujic, M., Kovacic, I., Celebic, A., 2008. Relations between anterior permanent teeth, dental arches and hard palate. Coll. Antropol. 32, 1099–1104.

Pini, N.P., de-Marchi, L.M., Gribel, B.F., Ubaldini, A.L., Pascotto, R. C., 2012. Analysis of the golden proportion and width/height ratios of maxillary anterior dentition in patients with lateral incisor agenesis. J. Esthet. Restor. Dent., vol. 24, pp. 402–414.

Preston, J.D., 1993. The golden proportion revisited. J. Esthet. Dent. 5, 247–251.

Qualtrough, A.J., Burke, F.J., 1994. A look at dental esthetics. Quintessence Int. 25, 7–14.

Richardson, E.R., Malhotra, S.K., 1975. Mesiodistal crown dimension of the permanent dentition of American Negroes. Am. J. Orthod. 68, 157–164.

Richer, P., 1971. Artistic Anatomy. Watson-Guptill, New York.

Ricketts, R.M., 1982. The biologic significance of the divine proportion and Fibonacci series. Am. J. Orthod. 81, 351–370.

Rokaya, D., Kitisubkanchana, J., Wonglamsam, A., Santiwong, P., Srithavaj, T., Humagain, M., 2015. Nepalese Esthetic Dental (NED) Proportion in Nepalese Population. Kathmandu Univ. Med. J. 13, 244–249.

Rokaya, D., Humagain, M., Amornvit, P., 2018. Maxillary anterior teeth proportions for creating esthetically pleasuring smile in Nepalese patients. J. Nepal. Health Res. Counc. 16, 362.

Rosenstiel, S.F., Ward, D.H., Rashid, R.G., 2000. Dentists' preferences of anterior tooth proportion-a web-based study. J. Prosthodont. 9, 123–136.

Rosenstiel, S.F., Land, M.F., Fujimoto, J., 2001. Contemporary Fixed Prosthodontics. CV Mosby, St. Louis, pp. 598–599.

Rossetti, A., De Menezes, M., Rosati, R., Ferrario, V.F., Sforza, C., 2013. The role of the golden proportion in the evaluation of facial esthetics. Angle Orthod. 83, 801–808.

Sandeep, N., Satwalekar, P., Srinivas, S., Reddy, C.S., Reddy, G.R., Reddy, B.A., 2015. An analysis of maxillary anterior teeth dimensions for the existence of golden proportion: clinical study. J. Int. Oral Health 7, 18–21.

Simon, J., 2004. Using the golden proportion in aesthetic treatment: a case report. Dent Today. 23, 82–84.

Snow, S.R., 1999. Esthetic smile analysis of maxillary anterior tooth width: the golden percentage. J. Esthet. Dent. 11, 177–184.

Sterrett, J.D., Oliver, T., Robinson, F., Fortson, W., Knaak, B., Russell, C.M., 1999. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. J. Clin. Periodontol. 26, 153–157.

Tsukiyama, T., Marcushamer, E., Griffin, T.J., Arguello, E., Magne, P., Gallucci, G.O., 2012. Comparison of the anatomic crown width/length ratios of unworn and worn maxillary teeth in Asian and white subjects. J. Prosthet. Dent. 107, 11–16.

Turner, P.N., Richardson, A., 1989. Matters relating to tooth sizes in Kenyan and British subjects. Afr. Dent. J. 3, 17–23.

Ward, D.H., 2001. Proportional smile design using the recurring esthetic dental (red) proportion. Dent. Clin. North Am. 45, 143–154.

Ward, D.H., 2007. A study of dentists preferred maxillary anterior tooth width proportions: comparing the recurring esthetic dental proportion to other mathematical and naturally occurring proportions. J. Esthet. Restor. Dent. 19, 324–339.