

Analysis of the Golden Proportion and Width/Height Ratios of Maxillary Anterior Dentition in Patients with Lateral Incisor Agenesis

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ABSTRACT

Objective: The purpose of this study was to assess the presence of the golden proportion (GP) in the facial view tooth-to-tooth width proportion of the six maxillary anterior teeth and to evaluate the width/height (W/H) ratios of the incisors of patients with maxillary lateral incisor (LI) agenesis treated either with implants or orthodontically (by moving canines into the position of the laterals, recontouring them, and placing composite restorations over the repositioned teeth).

Materials and Methods: Forty-eight patients with LI agenesis were divided into four experimental groups: unilateral recontouring group ($N=10$), bilateral recontouring group (BRG, $N=18$), unilateral implant group (UIG, $N=10$), bilateral implant group ($N=10$), and a control group (CG, $N=25$) of patients without agenesis. GP ratios were determined on patients' dental casts placed over Levin's grids, whereas W/H ratios were measured directly on the casts and a millimeter ruler to determine these distances. Statistical analysis was performed with Shapiro–Wilk, Kruskal–Wallis, Mann–Whitney, Friedman, and Wilcoxon tests ($p < 0.05$).

Results: The incidence of GP in the tooth-to-tooth width proportions was significantly different between groups and more commonly found between centrals and laterals than between laterals and canines. The GP was more likely to be observed in the BRG, UIG, and CG. The results demonstrated that the GP was not found to be present in the majority of the cases treated with maxillary agenesis, regardless of the method of treatment. The mean W/H ratios of the laterals ranged between 0.75 and 0.90.

Conclusion: Although the GP may be a useful diagnostic guide, it was not observed in the majority of esthetic outcomes of patients treated with maxillary LI agenesis in this study.

CLINICAL SIGNIFICANCE

The assessment of the golden proportion and width/height ratio of upper anterior teeth in patients with upper lateral incisor agenesis treated with either implants or tooth re-contouring may assist dentists and patients in deciding the best treatment option based on the peculiarities of each case.

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INTRODUCTION

Agenesis of maxillary lateral incisors (LIs) is the third most common dental agenesis, excluding third molars. It is preceded by maxillary and mandibular premolars and comprises approximately 20% of all anomalies.¹ This condition is more prevalent in females, and the absence of the LI is more frequently bilateral than unilateral.^{1–5} There may be significant demand for esthetic treatment in such cases, as this condition can affect the harmony and balance of the dentofacial complex, thereby affecting the patient's self-esteem and social relationships.^{1,5}

To assist dental professionals in the planning of cases of congenital maxillary LI agenesis, a number of studies have analyzed the functional performance of treatments.^{1,6–9} However, to the best of our knowledge, there are no studies that comparatively address the final esthetic outcomes of different treatments. Although several authors have studied esthetic principles, such as the golden proportion (GP) and the width/height (W/H) ratios of the maxillary anterior teeth,^{10–26} there is little information on how these parameters have been applied in esthetic restorative treatments in cases of maxillary LI agenesis.

The GP was described by Pythagoras, an ancient Greek mathematician, as an attempt to correlate science with beauty. It was used to design the Parthenon, and later to label dimensions in da Vinci's classic drawings of human anatomy. The ratio is approximately 0.618 to 1, whereby the height of the shorter object divided by the height of the longer one is identical to the height of the longer object divided by the sum of the shorter plus the longer objects.^{16,25,26} Levin recommends the width of the maxillary LI be in GP to the width of the maxillary central incisor (CI) when viewing from the front.²⁷ However, a range of studies^{20,22,23,25,26} have not found this proportion to exist in a majority of patients in the general population.

Two procedures are commonly used in cases of unilateral or bilateral agenesis: space closure by mesially repositioning the canine (C) and recontouring it, or space opening or its maintenance in order for implants

or dentures to replace the missing LI.^{5,28,29} For esthetic rehabilitation, the GP and the W/H ratio of the teeth may be useful guides in the reestablishment of an attractive smile.^{19,23,30,31}

The aim of the present study was twofold: (1) to determine the presence of the GP between the anterior teeth as measured in pairs (CI:LI and LI:C), and (2) to determine the W/H ratio means of each anterior maxillary tooth, with particular emphasis on the results and discussion of the results of the W/H of the LI.

MATERIALS AND METHODS

In the experimental groups, patients presented with maxillary LI agenesis treated with either recontouring or implants, in contrast to a control group (CG) of patients with no history of orthodontic treatment or agenesis. Patients' selection criteria excluded those with prosthesis or implants for replacement of other teeth, such as Cs, CIs, and premolars, as well as patients whose agenesis treatment had not involved orthodontic repositioning.

The 48 patients (39 women, 9 men, aged between 18 and 45 years) had either unilateral ($N = 20$) or bilateral ($N = 28$) maxillary LI agenesis. Agenesis treatment consisted of either space closure involving mesial movement of Cs and remodeling of anterior teeth with composite resin ($N = 28$), or orthodontic LI space opening followed by implant placement in the region of the agenesis ($N = 20$).

In order to minimize differences between the widths and heights of an LI replacement and those of a natural tooth and to maintain the gingival height, all cases were orthodontically treated with the incisors being lined up at the gingival margin. For the recontouring cases, the Cs were moved mesially and the cusps and the widths remodeled. For the implant cases, as much as needed, bone and connective tissue were surgically placed, so that the gingival height was kept similar to that of a natural LI.

The patients were divided into four groups based on type of treatment: unilateral recontouring group (URG, $N=10$), bilateral recontouring group (BRG, $N=18$), unilateral implant group (UIG, $N=10$), and bilateral implant group (BIG, $N=10$). The CG consisted of 25 volunteers with no agenesis (except for third molars), good tooth alignment, no maxillary anterior tooth restorations affecting the relative size of the teeth, no laminate veneers or other prosthesis, no noticeable tooth wear, no history of orthodontic treatment, no use of a biteplate, and no bone base discrepancies. The study was approved by the local ethical committee (672/2008).

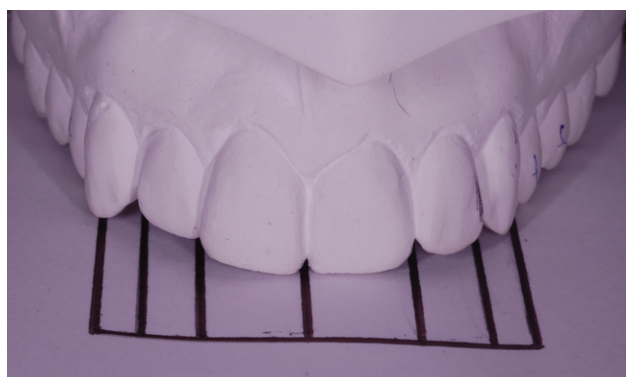


FIGURE 1. Levin's grid.

Concerning GP or successive tooth-to-tooth width proportion analyses, the apparent widths of each tooth were measured over a Levin's grid registered on a blank card and viewed from the front (Figure 1). Levin argued that successive GP occurs when both the CI and LI, and the LI and C relations are in agreement with the golden number, that is, 0.618. In other words, the width of the CI is in GP to the width of the LI, which is also in GP to the width of the C. The apparent widths were measured with the use of a caliper and a 1-mm increment ruler (Figure 2). The successive tooth-to-tooth width proportions between CIs and LIs (CI:LI), and between LIs and Cs (LI:C) were calculated by dividing the smaller width by the larger one. In the present study, ratios between 60% and 64% were considered to be within the range of the GP, as established by Preston.²⁶

With reference to the W/H evaluation, the real width and height of the teeth were measured directly over each subject's dental cast, parallel to the facial surfaces of the teeth, with the use of the same caliper and ruler used to measure the successive tooth-to-tooth width proportions. The W/H ratios were calculated by dividing each tooth's width by its height (Figure 3).

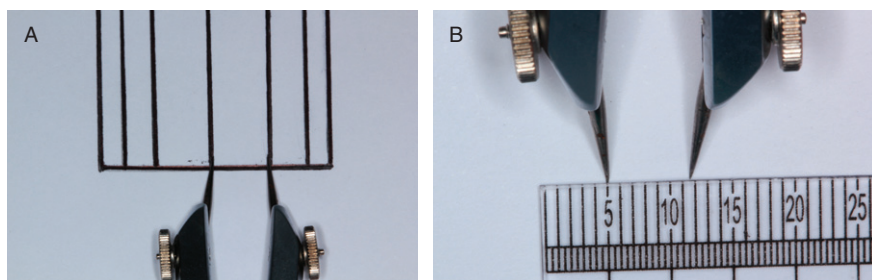


FIGURE 2. A, Measurement of Levin's grid with caliper and B, millimeter ruler.

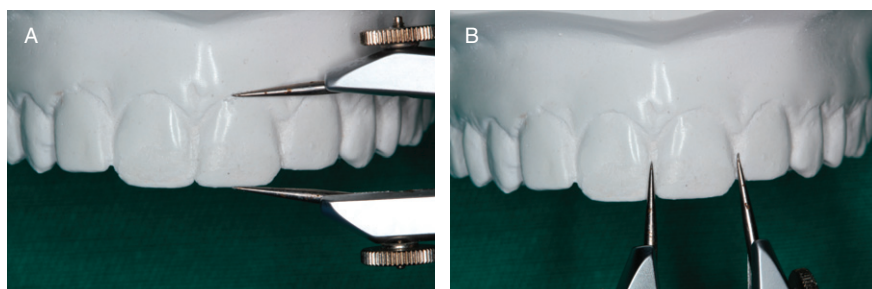


FIGURE 3. A, Measurement of height and B, width of anterior teeth.

Both the GP or tooth-to-tooth width proportion and the W/H ratios were further employed in order to analyze the correspondence between the measures of the right and the left side of the arch. These measures were used with different purposes depending on the type of LI agenesis: for the groups with unilateral agenesis, the proportion for each pair of teeth (CI:LI and LI:C) was used for within-group correspondences—the mean tooth-to-tooth width proportion in one side were compared with their correspondent measures on the contralateral side. For the groups with bilateral agenesis, apart from verifying within-group correspondences, the mean of the group treated with implants was compared with the means of the group treated with recontouring, as well as in relation to the CG. With relation to the W/H ratios, the measures were used to verify whether individual teeth ratios (CI, LI, and C) corresponded on both sides of the arch within the same type of treatment and also between different types of treatment. Bearing in mind that the GP deals with apparent widths only and given that the height of the built LI could vary whether it was recontoured or implanted, longer in the former case, one could find correspondence between right and left GP measures but not necessarily in the W/H ratios.

A further investigation of the two ways of measuring only the widths of the LIs was examined: (1) the apparent width as estimated over a Levin's grid, with the purpose of verifying whether the posterior–anterior transition of measures were reestablished, and (2) the real width verified directly over the cast, with the aim of analyzing whether the teeth proportion was preserved according to different types of treatment.

In order to guarantee the reliability of the examiner's assessments, the analyses of proportionality, both the GP/tooth-to-tooth width proportions and the W/H ratio, were performed twice by a single examiner, with a 30-day interval between the two moments. In the Results section, tables and figures express the data of the first analysis.

Statistical analyses were run with the use of the Software R 2.10.1 (R Foundation for Statistical Computing, Vienna, Austria) and level of significance at

$p < 0.05$. The results, reported as mean, standard deviation, and percentages, were checked for normality of distribution with Shapiro–Wilk test. Wilcoxon test was used to determine the statistical significance between the two moments in which the GP and the W/H were evaluated. Kruskal–Wallis test was used to verify between-group comparison of means, followed by Mann–Whitney U post hoc test in order to determine differences between two independent samples. Friedman test and post hoc Wilcoxon test were used for within-group comparison of means.

RESULTS

Analysis of the data involved 73 patients: 48 having LI agenesis and 25 having incisors not missing (control). With regard to the intraclass correlation analysis (Wilcoxon test), no significant difference was found between the two moments of measurements, either for the GP or the W/H ratio ($p > 0.05$). The results showed that the prevalence of missing right LI was higher in the URG (70%) when compared with that in the UIG (50%) (Figure 4). Concerning the presence of the GP or the other tooth-to-tooth width proportion prevalent, Table 1 displays all groups' minimum, maximum, and mean values (in mm), separated by the right and left side of measurements, as well as by the pair analysis—CI:LI and LI:C.

Keeping in mind that the present study adopted Preston's²⁶ GP range (60–64%), the mean proportions

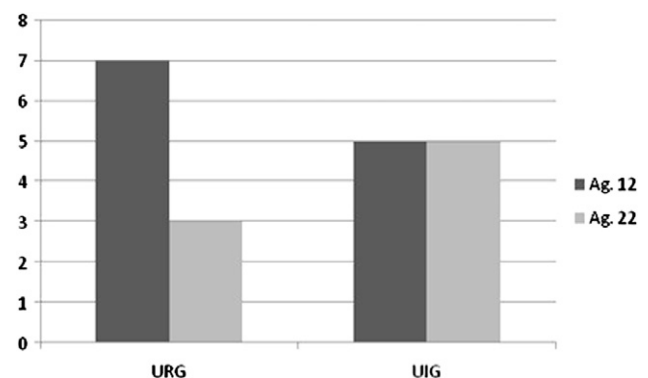


FIGURE 4. Distribution of unilateral agenesis by group. UIG = unilateral implant group; URG = unilateral recontouring group.

TABLE 1. Golden proportion analysis: minimum, maximum, mean, and standard deviation values by groups, side, and pair investigation

Group	Side	Pair	Minimum	Maximum	Mean	Standard deviation
BRG	Right	CI:LI	0.5263	0.7500	0.6575	0.0589
		LI:C	0.6667	0.9000	0.7597	0.0744
	Left	CI:LI	0.5263	0.7500	0.6575	0.0589
		LI:C	0.6667	0.9091	0.7799	0.0879
BIG	Right	CI:LI	0.5000	0.7647	0.6075	0.0802
		LI:C	0.6667	0.8889	0.7991	0.0566
	Left	CI:LI	0.5556	0.8750	0.6306	0.1126
		LI:C	0.6429	0.9000	0.7812	0.0753
URG	Right	CI:LI	0.5556	0.8235	0.6667	0.0990
		LI:C	0.6667	1.0000	0.8165	0.1102
	Left	CI:LI	0.5556	0.7778	0.6482	0.0683
		LI:C	0.5385	0.9091	0.7839	0.1196
UIG	Right	CI:LI	0.5000	0.7222	0.6241	0.0625
		LI:C	0.6154	1.0000	0.7902	0.1191
	Left	CI:LI	0.5000	0.7500	0.6359	0.0805
		LI:C	0.6154	1.0000	0.7877	0.1402
CG	Right	CI:LI	0.4000	0.7500	0.6186	0.0765
		LI:C	0.6364	1.2500	0.8649	0.1596
	Left	CI:LI	0.5000	0.7500	0.6211	0.0648
		LI:C	0.5714	1.2000	0.8662	0.1395

BIG = bilateral implant group; BRG = bilateral recontouring group; C = canine; CG = control group; CI = central incisor; LI = lateral incisor; UIG = unilateral implant group; URG = unilateral recontouring group.

between CI:LI in all groups varied from 60% to 66% with a range of 40% to 87.5%, whereas between LI:C, they varied from 76% to 86% with a range of 53.85% to 120%. In other words, in all groups, the mean width proportion between the CI:LI was closer to the 62%, a value closer to GP than the width proportions between the LI:C. This finding was more evident within the CG and the two groups treated with implants (BIG and

TABLE 2. Golden proportion analysis: mean comparisons (*p*-value) between different types of treatment. Significant differences in boldface

	Right		Left	
	CI:LI	LI:C	CI:LI	LI:C
BRG × CG	0.0555	0.0228	0.0360	0.0361
BIG × CG	0.5538	0.1555	0.6566	0.0200
URG × CG	0.3207	0.4189	0.3118	0.1183
UIG × CG	0.9853	0.1570	0.6465	0.1183
BRG × BIG	0.1033	0.1956	0.2310	0.7700
URG × UIG	0.5691	0.5690	0.8495	0.8197

BIG = bilateral implant group; BRG = bilateral recontouring group; C = canine; CG = control group; CI = central incisor; LI = lateral incisor; UIG = unilateral implant group; URG = unilateral recontouring group.

UIG), whereas the groups treated with recontouring (BRG and URG) showed more variation. In addition, the successive GP as suggested by Levin, in which the width relations between both the CI:LI and the LI:C are in agreement with the golden number, was not found in any group.

The tooth-to-tooth width proportion mean values were compared between the groups with bilateral incisor agenesis (BRG × BIG), between the groups with unilateral agenesis (URG × UIG), and between each of these groups (BRG, BIG, URG, or UIG) and the control (Table 2). No statistical difference was found between different types of treatment within the same type of agenesis. Significant differences were found between BRG and the CG concerning CI:LI on the left side and LI:C on both sides. As for BIG and CG groups, significant difference was found for the relation LI:C on the left side. No significant differences were found between CG and URG or CG and UIG.

The analysis of the percentage of patients who demonstrated the GP as defined by Preston (60–64%) in each of the experimental groups was averaged into a single group defined as agenesis group (AG). In doing so, the percentages of the CG and of the AG could be contrasted with those of previous studies. Figure 5

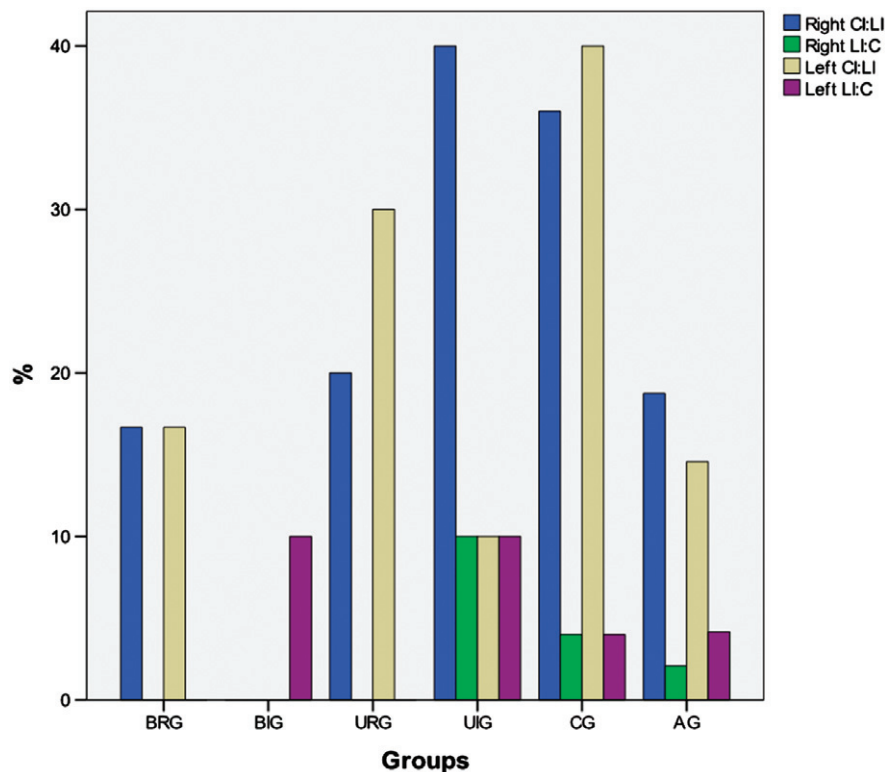


FIGURE 5. Percentage of patients that presented golden proportion (60–64%) for the relations central incisors:lateral incisors (CIs:LIs) and lateral incisors:canines (LIs:Cs). AG = agenesis group; BIG = bilateral implant group; BRG = bilateral recontouring group; CG = control group; UIG = unilateral implant group; URG = unilateral recontouring group.

shows that patients were broadly distributed among the relations and that not all of the relations were represented among the groups.

For the CI:LI relation on the right side, the percentage of patients who showed the GP varied from 0% to 40%, with no representatives in the BIG. On the left side, percentages varied from 0% to 10%, with no representatives in the BRG, BIG, and URG. For the LI:C relation on the right side, only four groups had representatives (URG, UIG, CG, and AG), with percentages varying between 10% and 40%. On the left side, URG had no patients with GP between LI:C, and among the other groups, percentages varied between 4% and 16.67%. Statistical analyses indicated significant differences in the CI:LI relation between the BIG and the CG on the right side (BIG 0%, CG 36%, $p = 0.030$), and the left side (BIG 0%, CG 4%, $p = 0.020$), and between CG (4%) and AG (2.08%) for the CI:LI relation on the left side only ($p = 0.015$). Therefore, the results

show that the presence of GP, particularly for the CI:LI relation, was more likely in the CG than in any other group, although it occurred in a minority of cases.

Although the present study was designed to determine the presence of GP between the widths of adjacent anterior teeth in the AG, the results showed that the tooth-to-tooth width proportions were more likely to be larger than the 62% range. The percentage of treated patients that had a tooth-to-tooth width proportion in the 65% to 70% range was found to be higher than those who exhibited the GP (Figure 6). This is consistent with reported tooth-to-tooth width proportions which have been considered to represent a pleasing smile proportion.²² As can be seen, within this range, all groups had representatives—for the CI:LI relation on the right side, percentages varied from 10% (URG) to 50% (BRG), and on the left side from 20% (BIG, UIG, and CG) to 55.56% (BRG). For the LI:C relation on the right side, the values varied between

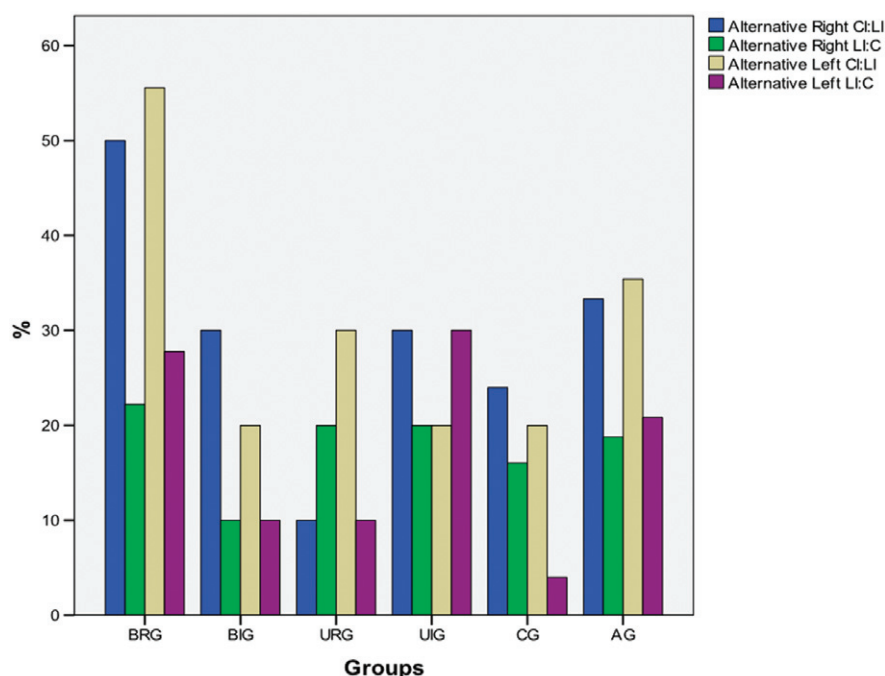


FIGURE 6. Percentage of patients that presented a 65% to 70% golden proportion between central incisors:lateral incisors (CIs:LIs) and lateral incisors:canines (LIs:Cs). AG = agenesis group; BIG = bilateral implant group; BRG = bilateral recontouring group; CG = control group; UIG = unilateral implant group; URG = unilateral recontouring group.

10% (BIG) and 22.22% (BRG), and on the left side between 4% (CG) and 30% (UIG). Significant differences were found between the BRG and the CG for the CI:LI relation on the left side (BRG 55.56%, CG 20%, $p = 0.017$), and for the LI:C relation on the left side (BRG 10%, CG 4%, $p = 0.028$), as well as between the UIG (30%) and the CG (4%) in the LI:C relation on the left side ($p = 0.031$).

The means of the W/H ratios of each maxillary anterior are shown in Table 3, separated by group, side, and tooth under analysis. As can be seen, means varied between 80% and 88% for most incisors and groups, with the exception of the left LI in the BIG (78%) and the right LI in the URG (90%). Regarding the LI comparison of means, no significant differences were found between the results of the CG and those of the two groups with implanted LI (BIG and UIG). Similarly, no differences were found between the means of the CG and those of recontoured groups (BRG and URG), with the exception of the right LI between the CG (82%) and the URG (90%).

With regard to the W/H ratio of the LI, the percentages of patients within a 10% range scale from ≥ 65 to ≤ 96 showed variation between 0% and 60% (Figure 7). As can be seen, most patients seem to have fallen within the range of 76% to 85% and 86% to 95%. However, between-group comparison of percentages showed significant differences only between the URG and the CG on the right side for the W/H ratio above 96%. Similarly, within-group comparison of percentages did not show differences for most groups—only the UIG within the W/H ratio of 86% to 95% yielded significance over the other percentages.

With the aim at verifying whether the W/H ratio means varied with regard to the type of treatment and within a type of agenesis, between-group comparison of means was run with the bilateral AGs (BRG $\times$ BIG), the unilateral AGs (URG $\times$ UIG), and between the CG and each of these groups. Significant differences were found only between the URG and the CG for the means of the right LI (Table 4).

TABLE 3. Width/height ratio analysis: mean and standard deviation values by groups, side, and tooth of investigation

Group	Side	Tooth	Mean	Standard deviation
BRG	Right	CI	0.8437	0.0810
		LI	0.8467	0.1235
		C	0.8370	0.1148
	Left	CI	0.8417	0.0751
		LI	0.8508	0.0920
		C	0.8556	0.1152
BIG	Right	CI	0.8528	0.0734
		LI	0.8283	0.1543
		C	0.8527	0.1595
	Left	CI	0.8536	0.0495
		LI	0.7808	0.0726
		C	0.8075	0.0508
URG	Right	CI	0.8545	0.0551
		LI	0.9041	0.1014
		C	0.8882	0.0853
	Left	CI	0.8507	0.0601
		LI	0.8621	0.0862
		C	0.8655	0.0850
UIG	Right	CI	0.8774	0.0714
		LI	0.8565	0.0585
		C	0.8228	0.0533
	Left	CI	0.8825	0.0788
		LI	0.8357	0.1089
		C	0.8109	0.0666
CG	Right	CI	0.8732	0.0838
		LI	0.8241	0.0924
		C	0.8698	0.0976
	Left	CI	0.8691	0.0803
		LI	0.8202	0.0793
		C	0.8535	0.0782

BIG = bilateral implant group; BRG = bilateral recontouring group; C = canine; CG = control group; CI = central incisor; LI = lateral incisor; UIG = unilateral implant group; URG = unilateral recontouring group.

The analysis of the correspondence between the right and left sides of the arch revealed no statistical differences among the means, both with regard to the incidence of the GP in the tooth-to-tooth width proportion analysis and to the W/H ratios for within or between types of treatment (the incidence of the GP in the tooth-to-tooth width proportion means can be seen in Table 1, and the W/H ratio means in Table 3). Thus, regardless of the type of agenesis, unilateral or bilateral, or type of treatment, recontouring or implant, right and left correspondence of measures were kept for both the incidence of the GP in the tooth-to-tooth width proportion analysis and the W/H ratios.

Concerning the investigation of the two ways of measuring the widths of the LI, real and apparent results showed quite variable mean widths between the groups with agenesis in comparison with the CG (Figure 8).

DISCUSSION

When present in the sample, the GP was most often found between the CI:LI, which corroborates the findings of previous studies.^{22,27} However, it did not occur for the LI:C relation, as found by some authors.^{13,23,27} It may be due to variations in the shape of the maxillary arch¹⁰ or to the alignment and positioning of the anterior teeth.¹⁴

The GP was found in 18.75% of the patients in the AG and 36% in the CG between CI:LI on the right side, and 40% and 14.58% on the left side, respectively, higher values than those reported by some authors.^{20,21,25,26} The GP has been proposed as a guide for a proportional and esthetic smile.^{27,32} However, according to Hasanreisoglu and colleagues, Mashid and colleagues, and Gillen and colleagues,^{19,20,25} it is not necessarily found in natural dentition and is not considered an essential factor for the attractiveness of the smile.²³ Some authors claim that smiles are more attractive when there is a proportion of around 70% between CI:LI and LI:C.^{13,18,22}

The groups URG, UIG, and control showed higher GP prevalence for the CI:LI relation when compared with

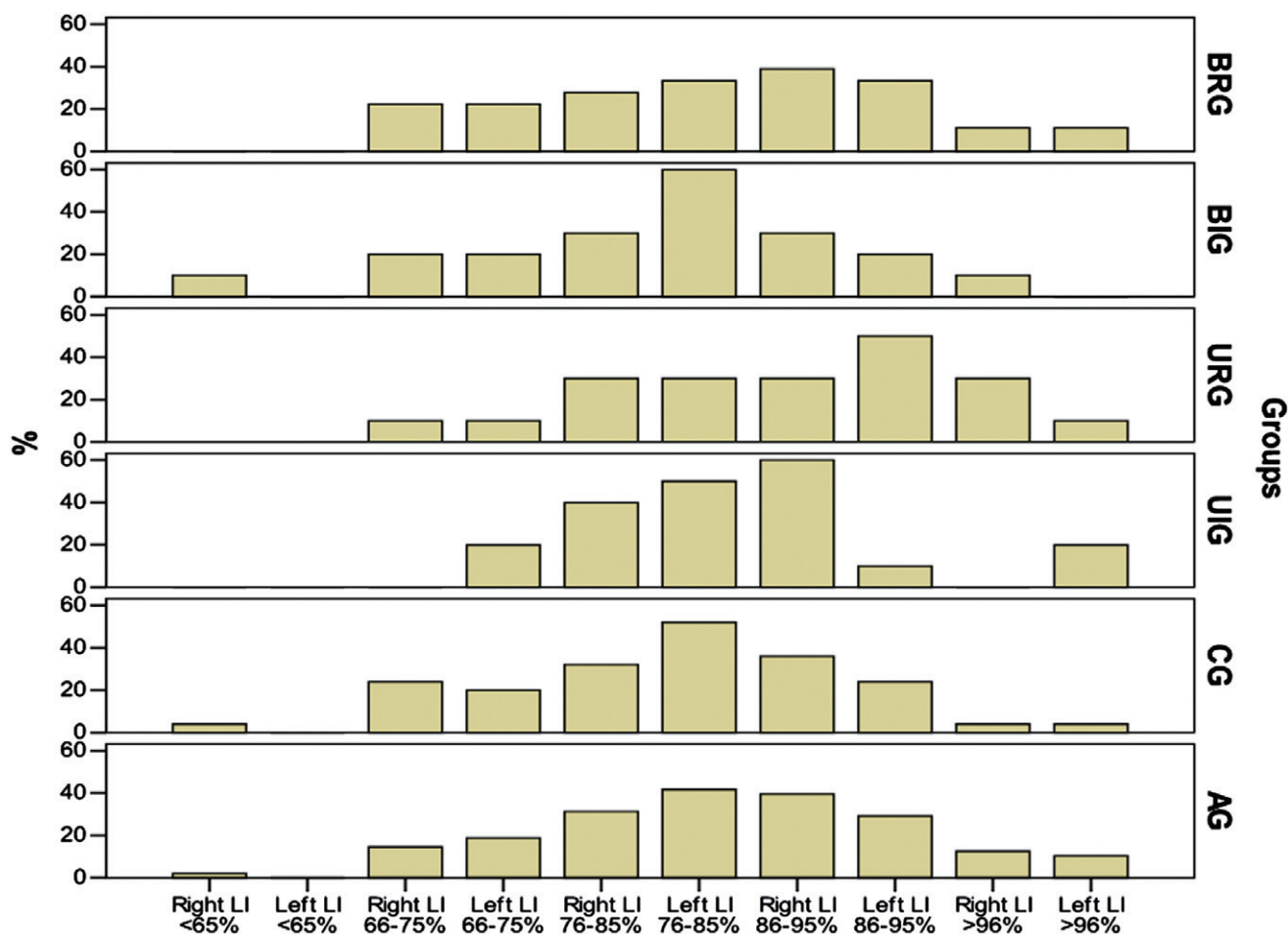


FIGURE 7. Width/height (W/H) analysis of the lateral incisors (LIs): percentage of patients within different W/H ratios of the right and the left LI. AG = agenesis group; BIG = bilateral implant group; BRG = bilateral recontouring group; CG = control group; UIG = unilateral implant group; URG = unilateral recontouring group.

TABLE 4. Width/height ratio analysis: mean comparisons (p-value) between different types of treatment

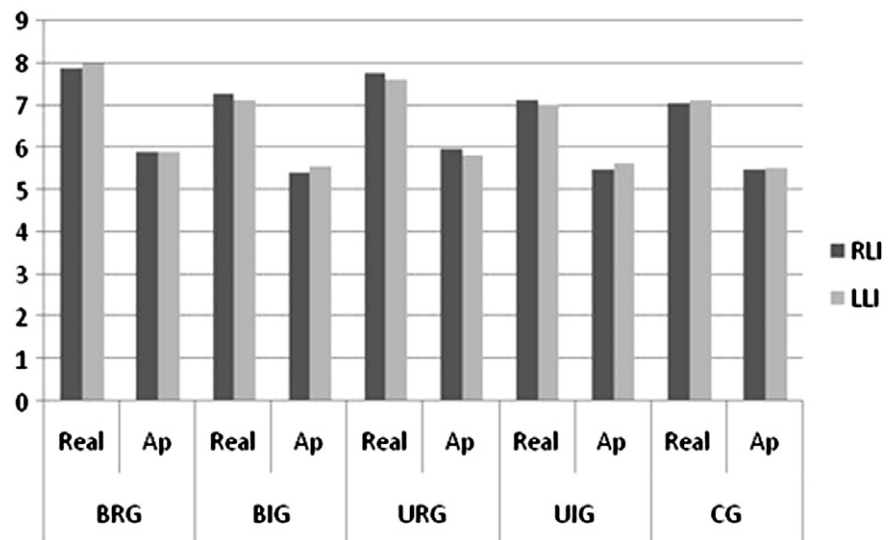
	Right			Left		
	CI	LI	C	CI	LI	C
BRG × CG	0.5196	0.3356	0.2176	0.4125	0.1745	0.8244
BIG × CG	0.7681	0.7826	0.4981	0.7392	0.1990	0.0671
URG × CG	0.7120	0.0383	0.5332	0.6438	0.2196	0.5458
UIG × CG	0.7690	0.2848	0.1287	0.7002	0.9562	0.1429
BRG × BIG	0.8273	0.3852	0.7729	0.5937	0.0537	0.3247
URG × UIG	0.5167	0.2399	0.0951	0.4471	0.4247	0.1107

BIG = bilateral implant group; BRG = bilateral recontouring group; C = canine; CG = control group; CI = central incisor; LI = lateral incisor; UIG = unilateral implant group; URG = unilateral recontouring group.

the other groups, suggesting that treatment with recontouring or implants in cases of bilateral agenesis does not follow a clear GP pattern. The differences found between the BIG and the CG may be due to the fact that patients with agenesis also present other morphological differences in relation to those without agenesis, as the crowns are usually reduced in size, and, because of this, patients from the BIG might have different tooth-to-tooth width proportion from those of the CG.

However, comparing the CI:LI means, the groups that came closest to the GP were the BIG, the UIG, and the CG. The similarity to the CG's results may be due the need of orthodontic treatment in order to adjust the space to the diameter of the tooth to be replaced

FIGURE 8. Comparison of real and apparent (Ap) widths of upper lateral incisors. BIG = bilateral implant group; BRG = bilateral recontouring group; CG = control group; LLI = left lateral incisor; RLI = right lateral incisor; UIG = unilateral implant group; URG = unilateral recontouring group.



(as for the case of the BIG), or to the diameter of the existing LI (as for the case of the UIG). The means of the BRG and of the URG differed the most from the GP/tooth-to-tooth width proportion. This may be due to the orthodontic treatment and transformation of the Cs into LI, a procedure that usually requires the recontouring of the other anterior teeth, such as that of the CI, which contributes to the existing proportion in the anterior segment of the smile.

Regarding the alternative analysis of GP or tooth-to-tooth width proportion that were found to fall within the 65% to 70% range, the differences for the CI:LI relation between the BRG and the CG on the left side and for the LI:C between the UIG and the CG on the left side, also the side in which agenesis was more frequent, can be explained by the fact that the recontoured Cs are wider than a natural LI.

With regard to the W/H ratios of the LIs, the BIG and UIG were the groups that came closest to the measurements found in the CG. This may be due to the type of treatment, implants, for which the agenesis space is adjusted to that of a natural LI. In the case of the UIG, this explanation applies only to the left side, which corresponds to the patients with agenesis of the tooth #22 treated with implants. The BRG and the URG had the highest LI means, which suggests that the width of this tooth is similar to its height, resulting in a

high W/H quotient. In addition, again it is important to keep in mind that the recontoured Cs are wider than a natural LI. The intention in comparing the right and left sizes of the smile was to verify if dentists are worried about reestablishing the symmetry in the treatment, mainly in the cases of unilateral agenesis in which the patients have a natural LI as a pattern to follow with implants or recontouring of the Cs into LIs.

Regardless the type of treatment, it is important to take into consideration a multidisciplinary approach involving Orthodontics, even for cases treated with implants. The correct alignment of the gingival contour is essential for the reestablishment of a natural W/H ratio, both for implants and recontoured Cs in patients with maxillary LI agenesis.²⁸

The prevalence of the W/H ratio of the LI was the same (76–85) for the right and left sides only in the BIG, which is in accord with previous findings.^{12,24} This symmetry is provided by the type of treatment as both sides are orthodontically adjusted to receive prosthesis to replace the missing LI. Only the prevalence of the W/H found in the BRG, UIG, and URG on the right side, was similar to that of the CG (86–95). These results were according to the previous studies.^{19,25} For the BRG, this indicates that even with anatomic differences between the Cs and LIs, recontouring treatment seems to be able to reestablish a natural

proportion when compared with individuals with natural LIs, such as those from the CG. The same reasoning applies to the UIG, as the implant is adjusted to the existing LI, which reestablishes a natural proportion similar to that found in the CG. The prevalence of the W/H in the URG, to whom the recontoured C was the treatment, was inconsistent on the right side, with a W/H ratio greater than 90, a value that has not been previously reported. For the left side, there was found a proportion of 75 to 80, as reported previously.^{12,24}

Comparing the GP/tooth-to-tooth width proportion and W/H ratios between the right and left sides of arch, all individuals in all groups exhibited symmetry ($p > 0.05$). This comparison shows the reestablishment of symmetry and balance of the smile in the rehabilitation of cases of agenesis. This aspect is especially important for individuals with unilateral agenesis, for whom treatment should involve symmetry with the existing LI.

The comparison between the real and the apparent widths of the LIs revealed significant discrepancies between the patients with agenesis and the CG. The apparent dimensions of the anterior teeth seem to be more important than the real measurements, because the proportional ratio of the anterior segment of the smile is based on the perceptible size of the teeth rather than the real size.^{13,20,23} The BRG and URG were the groups that most differed from the CG, which is probably due to the presence of recontoured Cs in these groups. The UIG showed the smallest real and apparent widths. This may be related to the prevalence of the GP in this group, that may be due to the size and shape of the teeth, which is usually narrower when the GP is present, as reported by some authors.^{13,24}

This is a pioneering study in the analysis of esthetic proportions of the smile in patients with maxillary LI agenesis treated with either orthodontic space closure followed by tooth recontouring or implant placement. In the present study, a Levin's grid was used for each individual measurement in order to determine the proportion between the maxillary anterior teeth and to

investigate the application of this device in the treatment of patients with maxillary LI agenesis. For such cases, the use of a Levin's grid as a tool to measure the apparent widths, and thus to obtain the GP as a guide for the planning of esthetic rehabilitation, is proposed in the literature.³² However, research suggests that a Levin's grid is not sufficiently precise to confirm the existence of the GP or other smile proportions.^{21,33} Whereas several authors defend the application of the GP in dentistry,^{27,31,32} others believe that the existence of exact smile proportions is not necessarily an important concept for the symmetry and esthetics of anterior teeth.^{14,15,19,20,33}

The limitations and the differences between the results of the present study and those of previous investigations may be attributed to several factors, such as variations in the methodology (use of casts or photographs, rulers, compasses, or calipers)^{10,17,20,25,26} and ethnic background of the patients.^{15,26} Castro and colleagues¹⁶ performed measurements in three ways—directly on patients' teeth using a millimeter periodontal probe and digital calipers, as well as on photographs. They¹⁷ found consistent results between methods regarding the prevalence of the GP between CI:LI. Studying Americans, Preston²⁶ found a prevalence of 17% for the GP between CI:LI, whereas Fayyad and colleagues¹⁵ studying Arabs, found a higher prevalence (38%). In a smile analysis using a digital software program, Basting and colleagues¹⁷ found a prevalence of 19% for the GP of smiles considered esthetically pleasing. However, Mashid and colleagues²⁰ and Gillen and colleagues²⁵ did not find this proportion in patients with smiles also considered esthetically pleasing.

Taking the results of the present study and the conflicting previous findings into consideration, further studies should investigate the application of esthetic proportions in the treatment of patients with maxillary LI agenesis. A larger number of patients and different methods of analysis are needed so that differences between groups and patterns of treatment can be established. The follow-up of these patients is also necessary in order to assess long-term esthetic results of the treatment.

CONCLUSION

Although the GP may be advocated by some researchers as a guide for the determination of the width of the missing maxillary LI, it was not found in the majority of cases in this study. Although the groups did not present a high prevalence of the GP in anterior successive tooth-to-tooth width proportions and the GP in W/H ratios, the smiles created were pleasing. Therefore, it is not believed to be necessary to recreate smiles exhibiting the GP between the views successive widths of the maxillary anterior teeth for the esthetic treatment of patients with LI agenesis.

REFERENCES

- Robertsson S, Mohlin B. The congenitally missing upper lateral incisor. A retrospective study of orthodontic space closure versus restorative treatment. *Eur J Orthod* 2005;22:697–710.
- Fekonja A. Hypodontia in orthodontically treated children. *Eur J Orthod* 2005;27:457–60.
- Pinho T, Tavares P, Maciel P, Pollmann C. Developmental absence of maxillary lateral incisors in the Portuguese population. *Eur J Orthod* 2005;27:457–60.
- Altug-Atac AT, Erdem D. Prevalence and distribution of dental anomalies in orthodontic patients. *Am J Orthod Dentofacial Orthop* 2007;131:510–4.
- Araújo EA, Oliveira DS, Araújo MT. Diagnostic protocol in cases of congenitally missing maxillary lateral incisors. *World J Orthod* 2006;7:376–88.
- Senty EL. The maxillary cuspid and missing lateral incisors: esthetics and occlusion. *Angle Orthod* 1976;46:365–71.
- Nordquist CG, McNeill RW. Orthodontic vs. restorative treatment of the congenitally absent lateral incisor—longterm periodontal and occlusal evaluation. *J Periodontol* 1975;46:139–43.
- Tuversen DL. Orthodontic treatment using canines in place of missing lateral incisors. *Am J Orthod Dentofacial Orthop* 1970;58:109–27.
- Carlson H. Suggested treatment for missing lateral incisors cases. *Angle Orthod* 1952;22:205–16.
- Nikgoo A, Alavi K, Alavi K, Mirfazaelian A. Assessment of the golden ratio in pleasing smiles. *World J Orthod* 2009;10:224–8.
- Murthy BVS, Ramani N. Evaluation of natural smile: golden ratio, RED or golden percentage. *J Conserv Dent* 2008;1:16–21.
- Zlataric DK, Kristek E, Celebic A. Analysis of width/length ratios of normal clinical crowns of the maxillary anterior dentition: correlation between dental proportions and facial measurements. *Int J Prosthodont* 2007;20:313–5.
- Ward DH. 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* 2007;19:324–39.
- Ong E, Brown RA, Richmond S. Peer assessment of dental attractiveness. *Am J Orthod Dentofacial Orthop* 2006;130:163–9.
- Fayyad MAI, Jamani KD, Agrabawi J. Geometric and mathematical proportions and their relations to maxillary anterior teeth. *J Contemp Dent Pract* 2006;5:62–70.
- Castro MVM, Santos NCM, Ricardo LH. Assessment of the "golden ratio" in agreeable smiles. *Quintessence Int* 2006;37:597–604.
- Basting RT, Trindade RS, Flório FM. Comparative study of smile analysis by subjective and computerized methods. *Oper Dent* 2006;6:652–9.
- Wolfart S, Thormann H, Freitag S, Kern M. Assessment of dental appearance following changes in incisor proportions. *Eur J Oral Sci* 2005;114:159–65.
- Hasanreisoglu U, Berskun S, Aras K, Arslan I. An analysis of maxillary anterior teeth: facial and dental proportions. *J Prosthet Dent* 2005;94:530–8.
- Mashid M, Khoshvaghti A, Varshosaz M, Vallaei N. Evaluation of "golden ratio" in individuals with an esthetic smile. *J Esthet Restor Dent* 2004;16:185–93.
- Magne P, Galluci GO, Belser UC. Anatomic crown width/length ratios of unworn and worn teeth in white subjects. *J Prosthet Dent* 2003;89:453–61.
- Ward DH. Proportional smile design using the recurring esthetic dental (RED) proportion. *Dent Clin North Am* 2002;45:143–54.
- Rosentiel SF, Ward DH, Rashid RG. Dentists' preferences of anterior tooth proportion—a web based study. *J Prosthodont* 2000;9:123–36.
- Sterret JD, Oliver T, Robinson F, et al. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. *J Clin Periodontol* 1999;26:153–7.
- Gillen RJ, Schwartz RS, Hilton TJ, Evans DB. An analysis of selected normative tooth proportions. *Int J Prosthodont* 1994;7:410–7.
- Preston JD. The golden ratio revisited. *J Esthet Dent* 1993;5:247–51.
- Levin EI. Dental esthetics and the golden ratio. *J Prosthet Dent* 1978;3:244–52.
- Kinzer GA, Kokich VO Jr. Managing congenitally missing lateral incisors—part 1: canine substitution. *J Esthet Restor Dent* 2007;3:2–6.

29. Turpin LT. Treatment of missing lateral incisors. *Am J Orthod Dentofacial Orthop* 2004;125:125–29.
30. Snow SR. Esthetic smile analysis of maxillary anterior tooth width: the golden percentage. *J Esthet Dent* 1999;11:177–84.
31. Ricketts RM. The biologic significance of the divine proportion and Fibonacci series. *Am J Orthod Dentofacial Orthop* 1982;5:351–70.
32. Lombardi RE. The principles of visual perception and their clinical application to denture esthetics. *J Prosthet Dent* 1973;4:358–82.
33. Javaheri DS, Shahnava S. Utilizing the concept of the golden ratio. *Dent Today* 2002;6:96–101.

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