Digital Analysis of Anterior Dental Esthetic Parameters in Patients with Bilateral Maxillary Lateral Incisor Agenesis

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ABSTRACT

Objective: To analyze anterior dental esthetic parameters—width/height ratio (WHR), gingival zenith (GZ), and apparent contact dimension (ACD)—in patients with maxillary lateral incisor agenesis (MLIA) bilaterally treated with space closure and recontouring of the canines, or with implant-supported prostheses.
Methods: Fifty-two participants were allocated into three groups as follows: MLIA patients ($N = 18$) treated with teeth recontouring (RG); MLIA patients ($N = 10$) treated with implants (IG); and volunteers without agenesis ($N = 24$), who served as controls (CG). Dental casts of all patients were obtained and electronically scanned. Digital images were analyzed with 3Shape A/S OrthoAnalyser software (Copenhagen, Denmark). Shapiro–Wilk test, Spearman correlation, and Kruskal–Wallis statistical tests ($p < 0.05$) were used for statistical analysis.
Results: Although IG presented smaller means when compared with RG and CG, no statistical differences were found for WHR among groups ($p > 0.05$). Concerning GZ, RG presented more discrepancies than IG and CG, with statistically significant differences ($p = 0.0165$). IG presented statistically significant differences for the ACD in comparison with RG and CG ($p < 0.05$).
Conclusion: Based on the results of this study, patients treated with space closure and teeth recontouring (RG) were shown to be closest to patients without agenesis (CG) in relation to the anterior dental esthetic parameters evaluated.

CLINICAL SIGNIFICANCE

The digital analysis of esthetic principles, such as those investigated in this study involving maxillary incisor agenesis, is paramount to successful esthetic treatment planning. The results of the present study, as well as those found in the literature, indicate that clinicians should use esthetic parameters, such as those investigated herein, when treatment planning extensive oral rehabilitation cases.

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INTRODUCTION

Dental agenesis of the anterior teeth may affect the balance and symmetry of a smile, negatively impacting interpersonal relationships and patients' self-esteem.[1,2] Thus, all professionals involved in the treatment of maxillary lateral incisor agenesis (MLIA) should aim at achieving both esthetic as well as functional dentofacial goals.[3–8] The current literature on cosmetic dentistry describes esthetic desirable characteristics in terms of proportion and shape of teeth, including width/height ratio (WHR), the apparent contact dimension (ACD) in proximal areas, as well as all the features of the gingiva.[9–12] Therefore, asymmetries present in teeth and/or the gingival margin may negatively influence the smile.[13,14]

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The esthetic appearance of a smile is based on the dentofacial complex as a whole.[3,15–18] The analysis of some esthetic parameters, such as the WHR, gingival zenith (GZ), and ACD, and how they relate to the esthetic perception and attractiveness of a smile, may be useful references for the diagnosis and treatment of MLIA.[9,19–24] Although several authors[23–34] have already studied the esthetic principles mentioned earlier, there is little information in the literature on how these parameters have been applied in the different forms of treatment commonly given to patients with agenesis.

Typically, agenesis has been treated either by space closure and recontouring of the canines into lateral incisors, or space opening/maintenance for the placement of implant-supported prostheses. Plaster casts, whose importance has been widely supported by many authors,[35,36] are generally used for the analysis and treatment of agenesis. Currently, the use of three-dimensional (3D) images of cast models has increasingly become a relevant tool in the diagnostic and treatment of several clinical dental conditions.[37–40]

The purpose of this study, therefore, was to analyze anterior dental esthetic parameters (WHR, GZ, and ACD) with the use of 3D digital images of dental casts obtained from patients with MLIA bilaterally treated either with space closure and recontouring of the canines, or with the placement of implant-supported prostheses, and compared with healthy controls.

MATERIALS AND METHODS

Twenty-eight patients with MLIA on both sides of the mouth were divided into two groups based on the treatment received: recontouring group (RG), patients treated with space closure and recontouring of the canines ($N = 18$); and implant group (IG), patients treated with the placement of implant-supported prostheses ($N = 10$). A control group (CG) composed of 24 volunteers selected based on the following inclusion criteria was also included: aged between 20 and 26 years; absence of agenesis (except third molar); absence of gingival recession in the anterior dentition; absence of anterior diastemata; absence of occlusal or proximal wear; good tooth alignment; no history of orthodontic treatment or use of biteplate; and no discrepancies in the bone base. All patients and volunteers signed an informed consent before participating in the study, which was duly approved by the local ethics committee (CAAE protocol N°. 0318.0.093.000-09—State University of Maringá, Brazil).

FIGURE 1. Plaster casts.

Dental casts of the maxillary arch were obtained from each participant using dental plaster (Asfer, Asfer Indústria Química Ltda, São Caetano do Sul, SP, Brazil) and alginate molds (Jeltrate Plus, Dentsply, Petrópolis, RJ, Brazil) (Figure 1), which were then scanned using a 3D scanner (R700, 3Shape A/S, Copenhagen, Denmark). Measurements for WHR, GZ, and ACD were performed using the OrthoAnalyser software (3Shape A/S) (Figure 2).

Reference points were marked on the digital images to measure the dimensions of every anterior-superior tooth. Height was measured from the most gingival to the most incisal point (Figure 3A), whereas width was measured from the most mesial to the most distal point (Figure 3B). WHR was calculated for all teeth by dividing width by height.

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FIGURE 2. Dental cast scanner (R250-3Shape A/S, Copenhagen, Denmark).

For GZ analysis, a line (GZL) joining the central incisor zenith (CIZ) and the canine zenith (CZ) was drawn from the right to the left side of the smile, and the distance between the lateral incisor zenith (LIZ) and GZL was perpendicularly measured (Figure 4). GZ points were located based on the concept proposed in the literature, in which GZ is the most apical point of the GZ contour.[9,22,38] The triangle formed by the union of these three points was evaluated. The CIZ/CZ distance was considered positive when LIZ was found to be below GZL, and negative when LIZ was found to be above GZL.

In order to measure ACD between adjacent teeth (#12/13, 11/12, 11/21, 21/22, and 22/23), two reference points were marked, one at the tip of the gingival papilla (gingival point) and another at proximal contact point (incisal point) (Figure 5).

Measurements obtained using the OrthoAnalyser software were performed by a single examiner on two separate occasions, with a 15-day interval between evaluations. For WHR, GZ, and ACD analyses, the Shapiro–Wilk test was employed to verify the normality of the data, whereas Spearman correlation and Kruskal–Wallis tests were performed to determine any differences among groups. The R 2.10.1 software program (R Foundation for Statistical Computing, Vienna, Austria) was used for the statistical analyses, with a level of significance set at 5%.

RESULTS

The Shapiro–Wilk test demonstrated normality for most of the data measured for WHR, GZ, and ACD, whereas the Spearman coefficient test showed a correspondence between the measurements carried out in the two occasions.

The Kruskal–Wallis test revealed no statistical differences concerning WHR among groups (Table 1). Nevertheless, overall, WHR mean values found for RG and IG were smaller in comparison with CG. Mean values found for RG were larger than those found for IG, showing that WHR found for RG were more similar to CG than IG (Table 2). Despite this similarity between RG and CG, WHR mean values found for the lateral incisors were proportionally larger for RG than for CG (Figure 6).

GZ analysis indicated that the mean values found for RG were always smaller than the values found for IG and CG, showing that most patients in this group presented an inverted gingival triangle, i.e., LIZ was positioned above GZL (Table 3). The Kruskal–Wallis test demonstrated statistically significant differences between RG and CG on the left side of the mouth (Table 4), indicating that there was an increased prevalence of the inverted triangle on that side (Figure 7).

IG always presented the largest ACD mean values, followed by RG and CG (Table 5, Figure 8). Moreover, IG presented greater mean embrasure between lateral and central incisor in comparison with the mean values found between central incisors (Figure 8). The comparison among the three groups showed statistically significant differences between IG and CG for teeth #12/13; and between RG and IG for teeth #11/12, 21/22, and 22/23 (Table 6). Table 7 presents ACD data in relation to the height of the tooth

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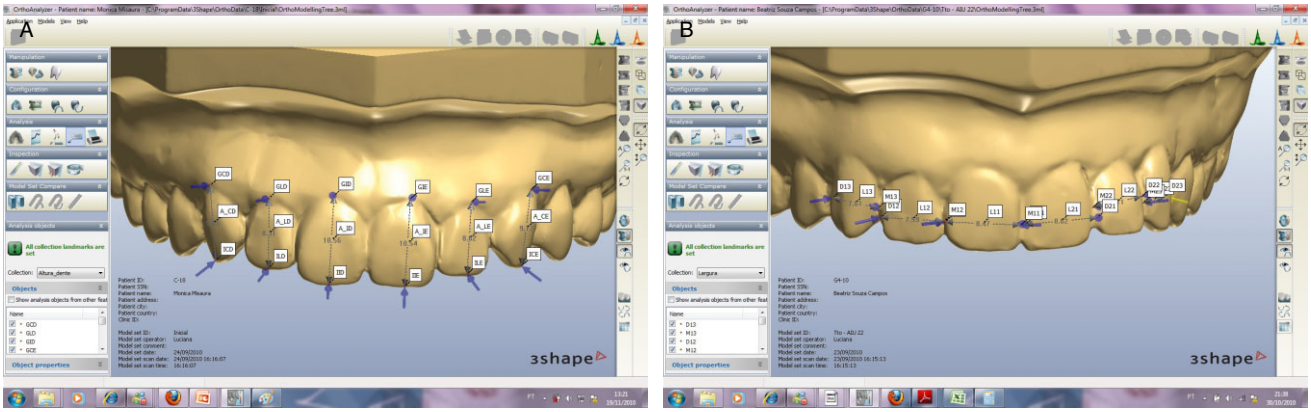

FIGURE 3. Reference points for teeth's (A) height and (B) width using the OrthoAnalyser software (3Shape A/S).

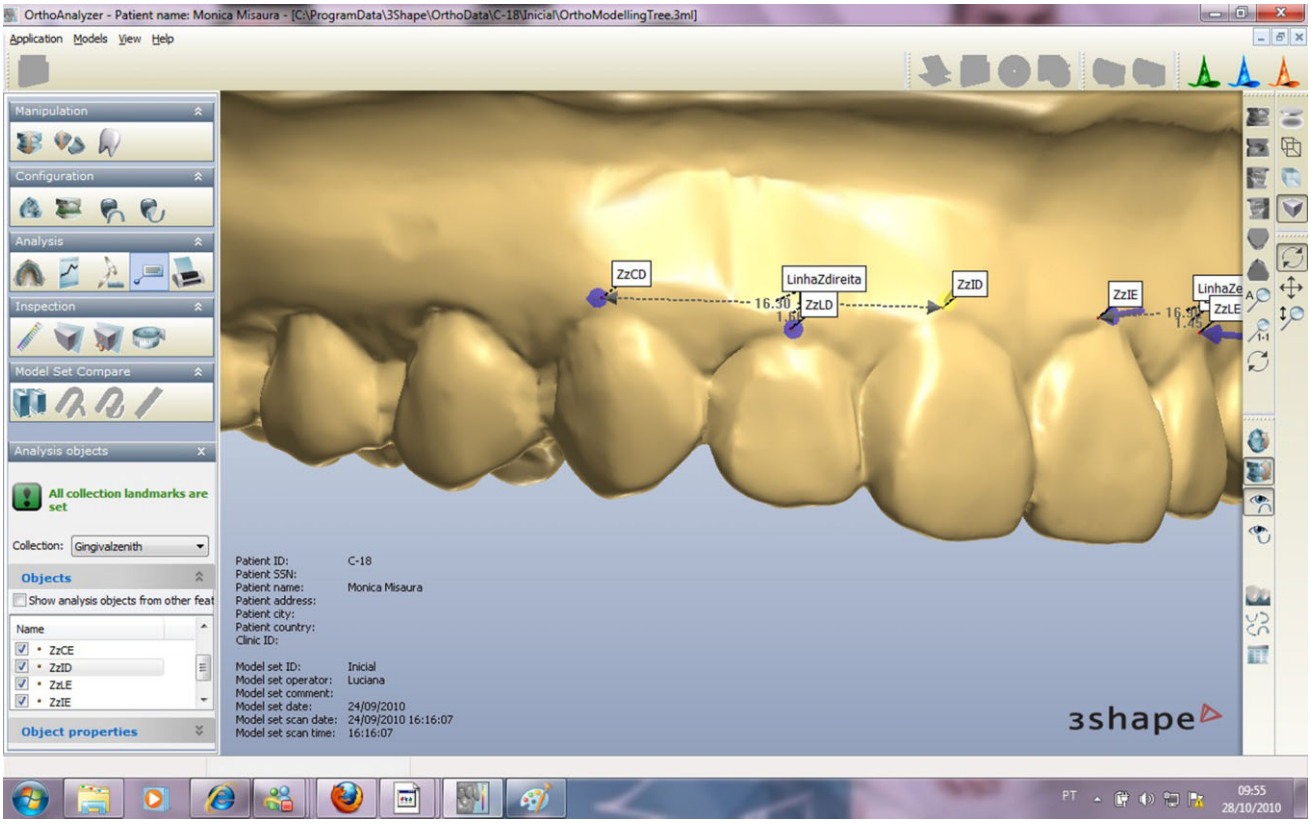

FIGURE 4. Reference points for gingival zenith evaluation using the OrthoAnalyser software.

mesial to the contact points, e.g., the percentage found for ACD between teeth #11/12 was determined in relation to the height of tooth #11. The percentage between teeth #11/21 was calculated in relation to the highest point found for the central incisor (tooth #21).

DISCUSSION

This is a pioneering study in the analysis of anterior dental esthetics, as it evaluates parameters such as WHR, GZ, and the ACD using electronic images obtained from dental casts in a sample composed by

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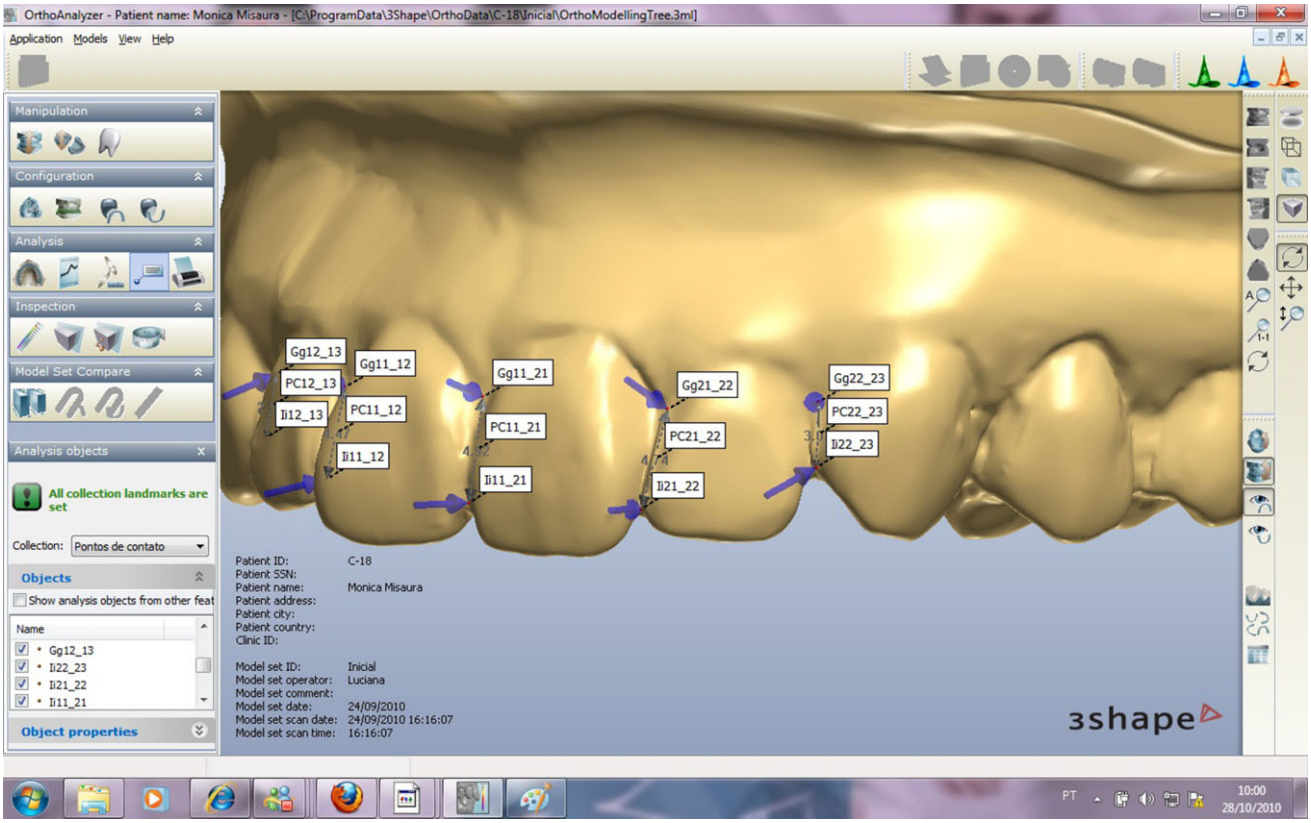

FIGURE 5. Reference points to evaluate the proximal contact areas using the OrthoAnalyser software.

TABLE 1. Comparison of width/height ratio data among groups (Kruskal–Wallis test, $p < 0.05$)

Side	Teeth	*p*-value
Right	CI	0.1577
	LI	0.2326
	C	0.3635
Left	CI	0.2892
	LI	>0.0500
	C	0.3828

C = canine; CI = central incisor; LI = lateral incisor.

treated MLIA patients compared with healthy volunteers.

Regarding the methodology, digital analysis of 3D images obtained from dental casts has many advantages over more traditional methods using calipers or compasses. They can be easily obtained, either from a previously made dental cast or from a patient's alginate impression.[40] It allows for multiple measurements from a single image while reducing observer's subjectivity when marking the reference points to be used during the analysis.[40] In addition, its use facilitates dental cast analysis,[36,40] analysis sharing, diagnosis and treatment planning,[40] and dental plaster cast storage.[36,40] However, studies using 3D imaging found in the literature are more commonly related to Bolton's analysis,[34–37] but not in the assessment of anterior dental esthetics of MILA patients. Although similar patient samples, treatment options, and procedures have already been used with MLIA patients,[41–46] there is little information on how esthetic parameters have been applied to these treatments.

Although no statistically significant differences were found in the comparison among groups, WHR descriptive analysis revealed some important peculiarities to each group (Table 1). WHR mean values (Table 2) found for central incisors in all groups

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TABLE 2. Mean, SD, normality (SW) and Spearman coefficient (R) for width/height ratio data ($p < 0.05$)

		Mean	SD	SW	R
Recontouring group	RCI	0.851545	0.07626	0.2838	0.8906
	RLI	0.819939	0.11572	0.7333	0.9319
	RC	0.815467	0.11966	0.2487	0.934
	LCI	0.84644	0.09536	0.6032	0.9381
	LLI	0.837017	0.10386	0.9653	0.9174
	LC	0.835679	0.10213	0.7144	0.9092
Implant group	RCI	0.854215	0.10669	0.4439	0.8667
	RLI	0.777166	0.11686	0.4439	0.7697
	RC	0.8041	0.09288	0.042	0.8424
	LCI	0.855503	0.11764	0.8763	0.697
	LLI	0.75677	0.09637	0.7815	0.6364
	LC	0.792952	0.09619	0.5676	0.7455
Control group	RCI	0.910771	0.1018	0.0093	0.8704
	RLI	0.847132	0.11956	0.1059	0.8304
	RC	0.855371	0.0797	0.561	0.8052
	LCI	0.899436	0.09622	0.0139	0.687
	LLI	0.83497	0.11032	0.0648	0.7183
	LC	0.844126	0.09704	0.2182	0.7704

LC = left canine; LCI = left central incisor; LLI = left lateral incisor; RC = right canine; RCI = right central incisor; RLI = right lateral incisor.

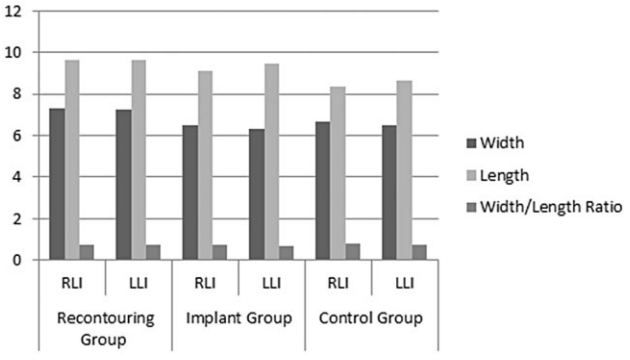

FIGURE 6. Width, height, and width/height ratio mean values of lateral incisors. LLI = left lateral incisors; RLI = right lateral incisors.

(85–91%) are similar to those described by Sterret and colleagues.[33] Likewise, for the canines, WHR mean values (79–84%) were within the range described by Hasanreisoglu and colleagues.[31] Regarding lateral incisors, RG and CG mean values were in agreement with ranges (80–85%) reported by Hasanreisoglu and colleagues[31] and Gillen and colleagues,[34] whereas IG presented WHR values ranging between 75% and 80%, which is in accordance with Zlataric and colleagues[30] and Sterret and colleagues.[33]

Overall, WHR mean values found for CG were always larger than those found in the other groups. Nevertheless, when WHR mean values from lateral incisors were compared, RG presented the largest values for width and height. This difference is due to

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TABLE 3. Mean value, SD, normality (SW) and Spearman coefficient (R) for gingival zenith data ($p < 0.05$)

		Recontouring group	Implant group	Control group
RLI	Mean	–0.1506	0.344	0.5833
	SD	2.3099	1.3083	1.0089
	SW	0.0009	0.0134	0.004
	R	0.6901	0.9273	0.9745
LLI	Mean	–0.8389	0.131	0.8296
	SD	2.0422	1.04	0.8531
	SW	0.0001	0.1677	0.0124
	R	0.9897	0.9666	0.9378

LLI = left lateral incisor; RLI = right lateral incisor.

TABLE 4. Comparison of gingival zenith data between recontouring group (RG) and control group (CG) (Kruskal–Wallis test, $p < 0.05$)

Side	Variable	*p*-value
Right	LI	0.7724
Left	LI	0.0165

LI = lateral incisor.

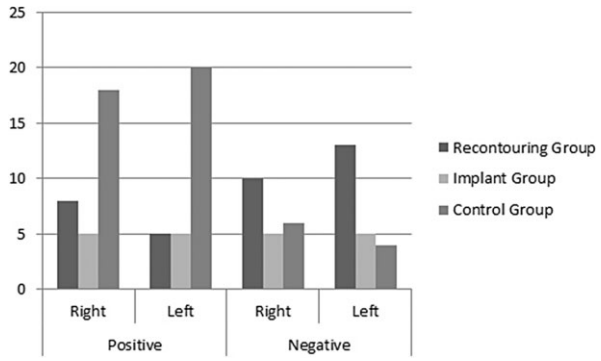

FIGURE 7. Prevalence of patients with positive and negative gingival zeniths.

the fact that, in practice, recontoured canines were being compared with natural lateral incisors. That is also the reason why WHR mean values found for RG were larger than those found for IG, despite the fact that the orthodontic approach prior to treatment adjusted the agenesis site to the approximate width of natural lateral incisors.[19,31,33,46]

When compared with CG, IG presented similar WHR mean values for width, but divergent values for height (Table 6). This may have resulted from possible limitations of the implant technique. Although the width of the agenesis site could be adjusted to the width of a lateral incisor, the height may not always be reestablished in proportion to that dimension. These limitations are related to crestal bone height and keratinized tissue thickness of the gingiva around implants, which may vary according to the type of platform or abutment, the relationship between implant and adjacent teeth, implant/abutment junction location in relation to the crestal bone, and gingival biotype among others.[47–49]

Moreover, even though there were no significant differences among natural lateral incisors, recontoured canines, and implant-supported prostheses, the overall smaller WHR mean values found for IG and RG may also be explained by the morphological simplification that patients with dental agenesis may present in other teeth.[50] McKeown and colleagues[50] compared teeth dimensions in patients with hypodontia with their relatives and a control group. Those authors found that teeth measurements presented higher values for the control group, followed by the relatives group with

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TABLE 5. Mean value, SD, normality (SW) and Spearman coefficient for apparent contact dimension ($p < 0.05$)

		Mean	SD	SW	R
Recontourig group	12/13	3.035	1.703561	0.1134	0.8496
	11/12	3.981111	1.743802	0.022	0.8512
	11/21	5.128889	2.034337	0.0036	0.9889
	21/22	4.512222	0.808729	0.572	0.6429
	22/23	3.089444	1.150936	0.291	0.9313
Implant group	12/13	4.208	1.336004	0.5358	0.5549
	11/12	6.114	0.917475	0.5887	0.9394
	11/21	6.102	1.650238	0.293	0.8788
	21/22	5.665	1.052534	0.0214	0.7212
	22/23	4.875	0.805154	0.878	0.794
Control group	12/13	2.564167	1.032649	0.0775	0.8586
	11/12	3.287083	1.276621	0.01	0.8218
	11/21	4.855833	1.256935	<0.0001	0.7641
	21/22	3.719583	1.241134	0.2435	0.9374
	22/23	2.601667	1.146559	0.2391	0.8712

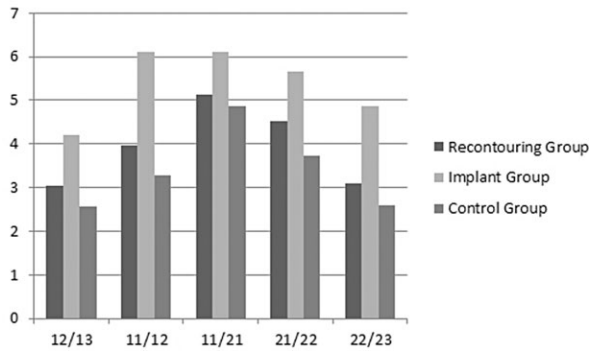

FIGURE 8. Proximal contact areas' mean values.

TABLE 6. Comparison of apparent contact dimension among groups (Kruskal–Wallis, $p < 0.05$)

Variable	*p*-value
12/13	0.0030
11/12	<0.0001
11/21	0.0816
21/22	0.0001
22/23	<0.0001

intermediary values, and the hypodontia group with the lowest values.

GZ position quantitative and qualitative evaluation of the lateral incisors in relation to the gingival triangle is not currently found in the literature. Chu and colleagues[28] and Mattos and Santana[29] were pioneers in conducting esthetic analysis using this principle.

However, their objective was to evaluate GZ position in relation to anterior teeth long axis. In this study, MLIA patients were compared with a control group, providing an opportunity to evaluate this esthetic principle as well as its behavior in cases of multidisciplinary rehabilitation.

Teeth GZs were marked following the pattern established in the literature,[10,23,28,29] which defines that

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TABLE 7. Proximal contact areas' mean values in relation to teeth's height

	Teeth	Mean	Variable	Mean	%
Recontouring group	RC	9.695	12/13	3.035	32.23
	RLI	9.64833333	11/12	3.981111	36.95
	RCI	10.775	11/21	5.128889	46.97
	LCI	10.91			
	LLI	9.64888889	21/22	4.512222	41.33
	LC	9.52055556	22/23	3.089444	31.95
Implant group	RC	9.698	12/13	4.208	46.20
	RLI	9.094	11/12	6.114	56.73
	RCI	10.771	11/21	6.102	56.63
	LCI	10.618			
	LLI	9.481	21/22	5.665	53.34
	LC	10.211	22/23	4.875	51.37
Control group	RC	9.5	12/13	2.564167	30.22
	RLI	8.47666667	11/12	3.287083	32.89
	RCI	9.97708333	11/21	4.855833	48.30
	LCI	10.0466667			
	LLI	8.5875	21/22	3.719583	36.95
	LC	9.61041667	22/23	2.601667	30.30

LC = left canine; LCI = left central incisor; LLI = left lateral incisor; RC = right canine; RCI = right central incisor; RLI = right lateral incisor.

the GZ is the most apical point of the gingival contour. This is generally located distal to the long axis for incisors and canines, whereas it is usually coincident with the long axis for lateral incisors. In accordance with the literature,[9,23,24] the esthetic gingival triangle for central incisors and canines are usually found at the same level, whereas for lateral incisors it is below this level. The presence of negative mean values in RG confirmed that the mesial movement of the canines promoted the formation of an inverted triangle in most patients. This may be explained by the difference between GZ of canines and premolars, in relation to the teeth that they are replacing (lateral incisors and canines). As a result, even though these differences may have been reduced with orthodontic space closure prior to teeth recontouring, the discrepancy between mean values found on the right and the left lateral incisors (Table 3), and the prevalence of LIZ with negative values (Figure 7), show that an esthetic triangle is not always possible. This also explains the statistically significant difference found in the comparison between RG and CG (Table 4).

Although statistically significant differences were not found in the comparison between IG and CG, GZ analysis suggests that differences in GZ positioning between implants (IG) and natural lateral incisors (CG) exists. In IG, the gingival triangle was formed closer to the referential (CZ/CIZ) line than in CG. This may be explained by the greater height presented by prostheses due to the limitations already discussed earlier.

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ACD evaluation in proximal areas is an important parameter because ACD restoration is responsible for gingival embrasures of the maxillary anterior teeth, the formation of black spaces, periodontal health, esthetics, and phonetics.[9,27,51,52] The mean values shown in Table 5 and Figure 8 indicate that these values decrease from the anterior to posterior teeth, being larger between central incisors (#11/21) than central and lateral incisors (#11/12 and 21/22), which in turn is larger than lateral incisors and canines (#12/13 and 22/23), in accordance to the current literature.[10,11,23,26,50] Only one exception was found in IG, in which teeth #11/12 presented a value larger than that found between teeth #11/21. These data and the analysis of ACD values for IG, which presented the highest values, show that, probably, the larger ACD values found for this group are due to the alveolar bone in the agenesis area, which is commonly at a lower level than in more normal conditions. According to Tarnow and colleagues,[25] in normal conditions, i.e., the distance between the tip of the gingival papilla and the alveolar bone crest is 5 mm, a full papilla is present, resulting in adequate ACD. In case of implants, this is not possible because of the changes present in the alveolar bone level, a scenario not always considered esthetic. However, in cases when patients with lateral incisors agenesis in whom the resulting condition is considered to be more satisfactory than the initial condition, this parameter may not be considered critical in an esthetic evaluation.[25] The mean values found for the agenesis groups (RG and IG) were always larger than those found for CG. IG presented values significantly higher than the other groups, which may be explained by the presence of more elongated prostheses in this group.

According to the literature, ACD between teeth #11/21 should correspond to 50% of central incisor height, whereas ACD between teeth #11/12 and 21/22 should correspond to 40% of central incisor height, and the ACD between teeth #12/13 and 22/23 should correspond to 30% of the lateral incisor height.[9,11,23,25] Data presented in Table 7 show that CG, as expected, was closest to these parameters, whereas IG was the most divergent, presenting the largest mean values when compared with the reference percentages. This discrepancy was always found in IG and explains the statistically significant differences found in the comparisons among groups (Table 6) for all variables (except for teeth #11/21).

The results of the present study, as well as those found in the literature, indicate that clinicians should use esthetic parameters in treatment planning during oral rehabilitation. One important limitation of this study was the number of patients involved. These analyses would benefit from a larger number of patients so that differences between groups could be better defined and patterns could be better established. MLIA patients should also be followed up for extended periods of time in order to assess the long-term esthetic results of treatment.

CONCLUSION

In conclusion, the results found in this study demonstrated that patients treated with space closure and teeth recontouring (RG) were closest to controls concerning WHR and ACD. However, RG was the most divergent of all groups regarding GZ. The negative GZ found in this group indicates that space closure and recontouring of the canines into lateral incisors and the premolars into canines does not reestablish the gingival triangle according to the current esthetic guidelines.

Patients treated with implant-supported prostheses (IG), on the other hand, presented smaller WHR values, which were particularly divergent in height. Although GZ in these patients was positive, it was closer to the reference line than controls, also affecting esthetics. Moreover, ACD mean values found for IC patients diverged the most when compared to CG, which esthetically represents more elongated teeth.

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