Original Article

Three-dimensional evaluation of facial asymmetry in association with unilateral functional crossbite in the primary, early, and late mixed dentition phases

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ABSTRACT

Objective: To assess the degree of facial asymmetry associated with subjects with unilateral functional crossbite (CB) in the primary, early/intermediate, and late mixed dentition phases in comparison with a group of subjects without CB.

Subjects and Methods: A group of 234 white subjects, 78 with CB (42 girls and 36 boys) and 156 without CB (73 girls and 83 boys), aged 3.9–11.9, grouped according to the dentition phase, were included. Three-dimensional laser scans of the subjects' faces were used to assess facial asymmetry. For each part of the face two-way multivariate analysis of covariance was performed to assess differences among the subjects, and an independent sample *t*-test was used to assess the significance of the differences between data sets.

Results: Within all dentition phases, the subjects with CB had statistically significantly greater facial asymmetry of the whole face than the subjects without CB, with the greatest values in the lower part of the face ($P < .05$). In the middle part of the face a significant difference was observed in the mixed dentition phases.

Conclusions: Children with unilateral functional CB exhibited a greater facial asymmetry than children without this malocclusion in all the dentition phases herein investigated. The greatest differences were seen for the lower part of the face. Further, facial asymmetry in the middle part of the face became clinically relevant in combination with the transition from primary to mixed dentition phase. (*Angle Orthod.* 2013;83:253–258.)

KEY WORDS: Three-dimensional; Facial asymmetry; Unilateral functional crossbite

INTRODUCTION

Unilateral functional crossbite (CB) is one of the most prevalent malocclusions in the primary and early mixed dentition phases. The prevalence increases from the primary to the mixed dentition phase and the malocclusion, if not treated, has a tendency to worsen throughout the development.[1,2] Unilateral functional CB commonly arises as a result of a narrow maxilla, which forces the mandible to displace laterally into an abnormal position because of the presence of tooth interferences.[2,3]

Treatment of unilateral functional CB in the primary dentition period is still questionable in respect to cost-effectiveness,[2,4,5] and it has been claimed that the main indication for correction in the primary dentition is the correction of functional asymmetry to prevent adverse skeletal mandibular growth.[2,6]

The functional asymmetry observed in unilateral functional CB can contribute to mandibular skeletal asymmetry because during the growth period continuous condylar displacement in the glenoid fossa induces differential growth of the condyles.[7,8] This symmetric function reflects different development of the elevator muscles on each side of the jaws, leading to a thinner masseter muscle on the CB side, which is already seen in the early mixed dentition.[9] Therefore,

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early corrections of functional problems should prevent adverse dental and facial development.[5,6,10,11]

Even though undesirable growth modifications in terms of skeletal asymmetry have been reported as a consequence of untreated functional CB,[8,10] further knowledge about the potential impact of untreated unilateral functional CB on facial growth is still needed. In particular, very little is known regarding the potential facial asymmetry consequent to untreated functional CB.

Therefore, the present controlled study was aimed at comparing the degree of facial asymmetry, as recorded though a three-dimensional (3D) laser scanning method, in growing subjects according to their dentition phase.

MATERIALS AND METHODS

Ethical approval for this study was gained from the Slovenian Ethical Committee of the Medical University in Ljubljana, Slovenia, and informed consent was obtained from the parents of all subjects.

A group of 234 white subjects, 78 with unilateral functional CB (42 girls and 36 boys) and 156 without malocclusion (73 girls and 83 boys), aged 3.9–11.9 years, were included. The subjects were grouped according to the presence or absence of unilateral functional CB and according to the dentition phase.

The subjects with CB were randomly selected from a pool of patients referred to the Department of Orthodontics, University Clinical Centre. Only the subjects with all the posterior teeth in CB on one side and a midline deviation of at least 2 mm, due to a functional mandibular shift, were included.

The functional mandibular shift was assessed clinically by an experienced orthodontist. The subjects without CB were randomly selected from a local school; only subjects without malocclusion and in good general health with no respiratory, deglutition, or mastication problems were included.

The appraisal of the dentition phase was carried out according to the following definitions[12]: (1) primary dentition, when all the primary teeth were erupted; (2) early mixed dentition, when the first permanent molars and incisors were erupting; (3) intermediate mixed dentition, when the permanent incisors and first molars had fully erupted, with presence of the primary canine, first molars, and second molars; (4) late mixed dentition, when the primary canines and molars had exfoliated, with eruption of the permanent canines and premolars.

The subjects were placed in one of three groups according to dentitional phase: primary, early/intermediate mixed, and late mixed dentition. Within each dentition phase, the number of subjects was 26 and 52 for the CB and no CB groups, respectively. The merged mean ages for the CB and no CB groups were 5.2 $\pm$ 0.5 years, 7.1 $\pm$ 0.5 years, and 10.4 $\pm$ 0.6 years in the primary, early/intermediate mixed, and late mixed dentition phases, respectively.

Assessment of Facial Asymmetry

Surface facial images were obtained using two Konica/Minolta Vivid 910 laser scanners (Konica Minolta Optics, Inc, Tokyo, Japan) angled to capture left and right sides of the face with significant overlap in the anterior part of the face to facilitate registration and merging of the two images to produce one facial image.[13] These devices are eye safe and have scanning time of about 2.5 seconds with a reported manufacturing accuracy of 0.3 mm. Natural head posture was adopted for this study as this has been shown to be clinically reproducible.[14] Each child was positioned on an adjustable stool and instructed to look into his or her eyes in a mirror placed in front of him or her between the laser cameras at a distance of approximately 1.3 m. The technique for positioning the patient and image capture has been validated and described elsewhere[13] and the use of laser cameras in growing subjects has been previously validated.[13]

The 3D data were imported to a reverse modeling software package (Rapidform 2006, INUS Technology Inc, Seoul, Korea). Each scan of the face (left and right images) was processed to remove unwanted data, registered, and merged to produce a complete facial image. Left and right scans were merged only if there was at least 70% matching between them in the overlap area with $\pm$0.5 mm tolerance.[15,16]

The facial image was aligned to the midsagittal (Y-Z) and transverse planes through the endocanthions of the eyes (X-Z).[17] The midsagittal plane of the original face was constructed by registering the original and mirrored facial image using the best-fit technique, resulting in a perfectly symmetric structure. The symmetry plane of this structure was used as the midsagittal plane of the original face. The face was oriented using a cylinder that fits all facial data points of the original-mirror symmetric facial structure. This fully automated procedure requires three landmarks to be set manually—left and right endocanthions and pogonion—which are used to identify the natural facial orientation in the virtual space.

The facial image was divided into three functional parts: (1) the upper part, defined as the part of the face above the endocanthion plane; (2) the middle part, from the endocanthion plane to the plane through the outer commissures of the lips; and (3) the lower part, below this plane (Figure 1). To check for left/right symmetry, the face was mirrored across the Y-Z plane

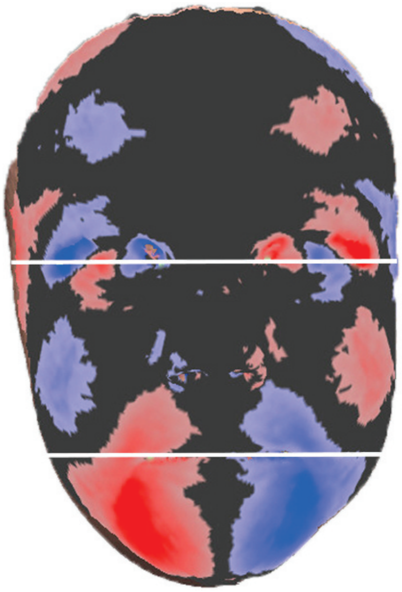

Figure 1. Assessment of facial asymmetry. Percentages of asymmetry were assessed on color deviation maps of the mirrored facial images for the upper, middle and lower parts of the face: black color indicates deviations within 0.5 mm that were considered symmetric; red color indicates the positive, while blue color the negative differences.

and the mirrored images were superimposed using the automatic best-fit procedure of the mirrored facial image surfaces.[17]

Asymmetry was assessed quantitatively as the average distances (in millimeters) between the mirrored images and as the percentage of mirrored images not coinciding within 0.5 mm (percentage of asymmetry, Figure 1). The greater the average distance was between the mirrored images, and the greater the percentage of asymmetry, the greater the asymmetry of the face was. The parameters were calculated for the whole face and for each part of the face separately. The assessment was performed by an experienced operator.

Sample-Size Calculation and Method Error Analysis

A sample size of at least 26 subjects per group was necessary to detect an effect size coefficient[18] of 0.8 for either of the asymmetry parameters (average distance or percentage of asymmetry) in any comparison between the groups, with an alpha set at 0.05 and a power of 0.80.[19] The effect size coefficient is the ratio of the difference between the recordings of the two groups, divided by the within-subject standard deviation (SD). An effect size of at least 0.8 is regarded as a large effect.[18]

The method error for each asymmetry parameter was calculated using the intraclass correlation coefficient (ICC) on a random sample of 10n replicate measurements. With the aim of quantifying the full method error of the recordings for both of these asymmetry parameters, the method of moments (MME) variance estimator was used.[20] Therefore, the mean error and 95% confidence intervals (CIs) between the repeated recordings were calculated using the MME variance estimator and expressed as percentages.[21] The MME variance estimator has the advantages of not being affected by any unknown bias, that is, systematic errors, between pairs of measurements.[20]

Statistical Analysis

The Statistical Package for Social Sciences program (SPSS Inc, Chicago, Ill) was used to perform the data analysis. Each data set was tested for the normality of the data by means of the Shapiro-Wilk test and by Q-Q normality plots; equality of variance was also tested by means of the Levene test and Q-Q normality plots of the residuals. Through this analysis, a root-square transformation of the data sets was required to meet the assumption for using parametric methods. For each part of the face, two-way multivariate analysis of covariance (MANCOVA) was performed to assess differences in the average distance and asymmetry among the different conditions. Dentition phase and group were entered as independent fixed factors, while age and sex were entered as covariates. When significant interactions were seen, an independent sample *t*-test was used to assess the significance of the differences between data sets. A P value less than .05 was accepted for rejection of the null hypothesis.

RESULTS

The ICC for the asymmetry parameters ranged from 0.67 to 0.95. Method errors as mean (95% CI) were 7.6% (3.6–12.7) and 3.9% (1.8–6.5) for the average distance and percentage of asymmetry, respectively. Within each dentition phase, the CB and no CB groups were balanced by age and sex ($P > .05$).

At the two-way MANCOVAs for the whole, middle, and lower parts of the face, the group was the only independent factor yielding a significant effect, with $F_{2;225}$ values ranging from 8.63 ($P < .001$) to 14.68 ($P < .001$) for the middle and lower parts of the face, respectively. In contrast, the dentition phase, and the corresponding interaction with the group, did not reach statistical significance in any of these models. Moreover, the two-way MANCOVA for the upper part of the face did not yield any significant interaction. Finally, at the univariate analyses, both the average distance between mirrored images and percentage of asymmetry yielded statistically significant effects for the whole, middle, and lower parts of the face (all $P < .001$). The

Table 1. Mean (±SD) Age of the Examined Groups and Facial Asymmetry Parameters for the Whole Face and Each Part of the Face Separately, According to the Dentition Phase[a]

Parameter	Portion	Group[b]	Dentition Phase: Primary	Dentition Phase: Early/Intermediate Mixed	Dentition Phase: Late Mixed
Age (y)	–	CB	5.1 ± 0.3	7.0 ± 0.9	10.2 ± 1.0
		No CB	5.2 ± 0.5	7.1 ± 0.7	10.6 ± 1.1
		Diff	NS	NS	NS
Average distance (mm)	Whole	CB	0.49 ± 0.12	0.49 ± 0.15	0.53 ± 0.20
		No CB	0.41 ± 0.09	0.40 ± 0.08	0.44 ± 0.13
		Diff	$P < .05$	$P < .01$	$P < .05$
	Upper	CB	0.43 ± 0.10	0.42 ± 0.11	0.48 ± 0.18
		No CB	0.42 ± 0.12	0.41 ± 0.11	0.41 ± 0.18
		Diff	NS	NS	NS
	Middle	CB	0.47 ± 0.16	0.50 ± 0.22	0.54 ± 0.23
		No CB	0.41 ± 0.15	0.38 ± 0.09	0.44 ± 0.17
		Diff	NS	$P < .05$	$P < .05$
	Lower	CB	0.66 ± 0.39	0.64 ± 0.36	0.63 ± 0.33
		No CB	0.41 ± 0.14	0.43 ± 0.17	0.50 ± 0.28
		Diff	$P < .01$	$P < .01$	$P < .05$
Asymmetry (%)	Whole	CB	35.3 ± 11.2	36.1 ± 9.9	39.1 ± 13.5
		No CB	29.3 ± 9.3	28.3 ± 8.5	31.5 ± 11.7
		Diff	$P < .05$	$P < .01$	$P < .05$
	Upper	CB	29.9 ± 9.0	30.3 ± 10.7	35.0 ± 14.2
		No CB	29.9 ± 11.8	28.5 ± 10.9	28.0 ± 14.9
		Diff	NS	NS	NS
	Middle	CB	35.6 ± 15.6	36.1 ± 16.0	39.6 ± 16.7
		No CB	28.9 ± 14.1	27.2 ± 11.8	31.9 ± 15.6
		Diff	NS	$P < .05$	$P < .05$
	Lower	CB	46.3 ± 24.9	47.8 ± 22.1	45.7 ± 19.2
		No CB	29.0 ± 13.0	30.5 ± 16.3	36.4 ± 20.5
		Diff	$P < .05$	$P < .01$	$P < .05$

[a] CB indicates crossbite; diff, significance of the difference between the groups; NS, difference not statistically significant.
[b] Within each dentition phase, there were 26 subjects and 52 subjects for the CB and no CB groups, respectively.

mean values and respective SDs for either asymmetry parameter of both groups are reported in Table 1. Facial asymmetry of the whole face and of the lower part was significantly greater in subjects with CB compared with subjects without CB within all the dentition phases ($P < .05$, at least). Although no significant difference was observed for the upper part of the face ($P > .05$), the subjects with CB had a significantly greater asymmetry of the middle part of the face in the mixed dentition phases ($P < .05$). The effects of the age and sex covariates did not reach statistical significance in all the models.

DISCUSSION

In the present cross-sectional controlled study, facial asymmetry of subjects with CB was assessed in the primary, early/intermediate mixed, and late mixed dentition phases and compared with facial asymmetry of a group of subjects without CB using a noninvasive 3D laser scanning method.

Recently, several 3D methods of analyzing facial changes have been developed, including surface laser scanning.[3,22–25] In the present study a landmark independent method, which has been previously reported to be a more accurate method for assessing asymmetry,[26] was used.

It has been previously reported that subjects with unilateral functional CB already exhibit greater facial asymmetry in the primary dentition phase than do subjects without CB.[2,3,6] Furthermore, it has been claimed that this facial asymmetry is the result of a functional mandibular shift that, if not treated, has a tendency to worsen during growth resulting in permanent skeletal asymmetry.[8,10]

According to the present results, no face was perfectly symmetric, as minor, nonpathologic facial asymmetry or normal asymmetry is relatively common.[27] Moreover, subjects with unilateral functional CB had a significantly greater facial asymmetry compared with the subjects without CB through all the dentition phases, as the average distances between the mirrored images and the percentages of facial asymmetry for the whole face were significantly higher in the CB group.

Although no significant differences were observed between the CB and no CB groups for the upper part of the face, subjects with CB had a significantly greater facial asymmetry in the middle part of the face at both the early/intermediate and late mixed dentition phases. The greatest degree of facial asymmetry was seen in the lower part of the face of all subjects, with significantly greater average distances between the mirrored images and percentages of facial asymmetry in subjects with CB at all the dentition phases, without any tendency of self-correction. It has been reported that the mandibular region has shown a larger degree of asymmetry[27,28] because several factors related to dental arches were assumed as causes of craniofacial asymmetries, including the presence of a functional mandibular shift, which was diagnosed in all the subjects with CB. This is in accordance with previous studies that report a greater facial asymmetry in subjects with unilateral functional CB, particularly in the lower part of the face.[3]

Previous studies have shown that sex and age do not affect facial asymmetry,[22,29] which is in accordance with the results of the present study. Furthermore, no significant differences were seen in the facial parameters within each group (CB and no CB) according to different dentition phases for the upper and lower facial parts. On the contrary, facial asymmetry in the middle part in subjects with CB compared with subjects without CB was significantly greater in the mixed dentition phases, whereas no significant differences were observed in the primary dentition phase (Table 1). Therefore, it seems that facial asymmetry does not worsen or improve in the CB or no CB group, except for the middle part of the face, where an increase of facial asymmetry was observed in the CB group at the mixed dentition phases.

Even though a longitudinal study is warranted, the results of the present cross-sectional study would be consistent with a non–self-correcting tendency of facial asymmetry in subjects with CB in the lower part of the face. Further, facial asymmetry in the middle part of the face becomes clinically relevant during the early/intermediate mixed dentition phase, that is, prepubertal period. This might be due to the fact that the peak of pubertal mandibular growth had not yet occurred in most of the subjects included in the present study. On the contrary, as the peak of maxillary growth is observed in the prepubertal period, the worsening of facial asymmetry in the middle part could be a result of adverse skeletal maxillary growth.

Clinical Implications

The use of 3D laser scanning enables an objective noninvasive assessment of facial asymmetry in growing subjects. The diagnostic potential of this method is mainly seen for the lower part of the face. Treatment in the primary dentition should be performed not only to correct functional asymmetry due to the lateral mandibular shift but also to prevent adverse maxillary growth in the prepubertal period with a consequent impairment of the maxillary symmetry.

CONCLUSIONS

- Children with unilateral functional CB exhibit a greater facial asymmetry than children without this malocclusion in all the dentition phases investigated with the greatest differences seen for the lower part of the face.
- However, when a functional CB is present, facial asymmetry in the middle part of the face would become clinically relevant in combination with the transition from primary to mixed dentition phase.

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