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Three-Dimensional Soft-Tissue Evaluation in Patients with Cleft Lip and Palate

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: In cleft lip and palate (CLP) patients, the shape of the facial soft tissues shows variety in 3 dimensions (3D). Two-dimensional (2D) photographs and radiographs are insufficient in the examination of these anomalies. The aim of this retrospective study was to examine the soft tissue and craniofacial characteristics of individuals with nonsyndromic unilateral cleft lip and palate (UCLP), bilateral cleft lip and palate (BCLP), skeletal Class III malocclusions, or skeletal Class I malocclusions using 3D facial imaging.

Material/Methods: The entire study group consisted of a total of 158 patients, aged 8–32 years: 29 of the patients had UCLP, 22 BCLP, 54 had skeletal Class III malocclusions, and 53 had skeletal Class I malocclusions. 3D stereophotogrammetric soft-tissue recordings of all patients were analyzed. ANOVA and the Kruskal-Wallis test were performed to compare the groups.

Results: Statistically significant differences were observed among the groups in terms of linear, angular, proportional. and volumetric measurements. While nasal differences were not observed in the Class III group, nose and upper-lip deformities were common in the CLP groups. Upper-lip projection was reduced in all 3 groups. In the Class III patients, the lower lip and chin were more prominent than in the other groups. The facial convexity angle was increased in the CLP and Class III groups. The upper-lip volume was decreased in the BCLP, the UCLP, and the Class III groups.

Conclusions: Patients with skeletal Class III or CLP anomalies showed significantly different soft-tissue characteristics than the Class I control group. 3D stereophotogrammetric facial imaging is an easy and noninvasive method that can be used in examination and recording of these facial deformities. It is possible to make volumetric measurements using this method.

MeSH Keywords: **Cleft Lip • Imaging, Three-Dimensional • Photogrammetry**

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Background

CLP is a multifactorial and congenital deformity that can be caused by both genetic and environmental factors, with a mean prevalence of 1 per 800 to 1000 live births [1,2]. The craniofacial growth and development of patients with CLP differ from normal individuals for various reasons. Some researchers state that these growth differences are due to surgical operations for closure of the defect, while some others reported that they were due to embryological or genetic differences [3–7].

In patients with CLP, imaging and assessment of the deformity play an important role in the effectiveness of the treatment, since the soft tissue has own characteristics in cleft patients. Assessment of the formation processes of facial deformities is an important component that can contribute to improving the quality of life of these patients. For this reason, many methods have been applied by researchers to assess the soft tissue symmetry and nasolabial form changes and to show the differences between unaffected people and CLP patients, before and after surgical and orthodontic treatments. The most commonly used traditional methods of imaging soft tissues are lateral cephalometric radiographs and facial photographs [8,9]. However, lateral cephalometric radiographs have certain limitations, including providing only profile assessments and having low resolution. Soft-tissue examination in detail and asymmetrical assessment cannot be made due to overlap with skeletal structures [10–12]. Another disadvantage of cephalometric radiographs is that the patient is exposed to radiation. Jacobs et al. evaluated the total radiation dose received from various radiographic imaging methods in cleft patients and non-cleft patients with or without orthodontic treatment. They found that cleft patients had higher total amounts of radiation from cephalometric radiography, computerized tomography (CT), and cone beam computerized tomography (CBCT) than non-cleft patients in each age group. According to the results of their studies, the total lifetime radiation doses of women with cleft palate in particular can be considered as dangerous [13]. Therefore, because of the risk of radiation, we focused on noninvasive 3D imaging modalities in CLP patients in the present study.

Even if taken from different angles, the photographs are insufficient to show the depth and shape features of the 3D structures [14]. During the comparison of different facial photographs, unreliable results can be obtained due to variables such as distance between the camera and the object, the camera angle, and head position [15]. It is also true that the appearance of a 3D object can be changed completely when viewed from different viewpoints [16]. In recent years, due to the disadvantages mentioned above, the popularity of 3D imaging systems for soft-tissue surface analysis has increased. 3D imaging techniques offer high accuracy and precise measurement capabilities, as well as the ability to view images from any angle to and analyze 3D videos [17]. 3D facial imaging techniques include 3D cephalometric radiography, laser scanning, structural light techniques, conventional CT, CBCT, stereophotogrammetry, 3D ultrasonography, and magnetic resonance imaging.

CBCT is a 3D diagnostic tool that is often used in cases requiring detailed examination, such as the localizing of impacted teeth and odontoma or the examination of patients with craniofacial anomalies [18]. Tulunoglu et al. compared cephalometric radiographs and CBCT images of patients with CLP and found that several skeletal and dental measurements could not be correlated with each other, and there were significant differences [19]. In another cleft study, Perillo et al. used the CBCT images of the UCLP patient during the examination of impacted teeth and treatment planning [20]. However, this technique is not successful enough to display soft tissues, real color, and skin texture. Another disadvantage is that the shooting time is long. Shooting time lasts approximately 30 to 40 s, during which inaccurate images may achieved on soft tissues due to involuntary muscle movements, such as breathing [21]. Due to these limitations of CBCT, stereophotogrammetry and laser scanning are the suitable techniques in soft-tissue imaging.

Today, the stereophotogrammetry technique has been accepted as the most promising one among all 3D soft-tissue imaging methods. This technique works by the principle that 2 or more cameras take images at the same time at different angles over an object, and the 3D image of the soft-tissue morphology is created with the aid of special computer software [22]. Although there have been several studies examining the facial soft-tissue characteristics by stereophotogrammetry in patients with CLP, no studies have compared patients with skeletal Class I malocclusions, skeletal Class III malocclusions, UCLP, and BCLP. Therefore, the aim of this study was to compare the soft-tissue properties of patients with nonsyndromic UCLP, BCLP, skeletal Class III malocclusions, and skeletal Class I malocclusions using stereophotogrammetry. The null hypothesis was that there is no difference between the facial soft-tissue images of UCLP, BCLP, skeletal Class III, and skeletal Class I patients examined by 3D stereophotogrammetry.

Material and Methods

This study was single-center and retrospective; patients who received treatment from the second author at the Department of Orthodontics were included. The study was approved by the University Ethics Committee. All CLP patients who underwent orthodontic treatment (a total of 125 patients aged 8–32 years old) were evaluated, first based on the inclusion criteria. Patients with total UCLP and BCLP were included. Ten of these patients were excluded from the study because 8 of them had

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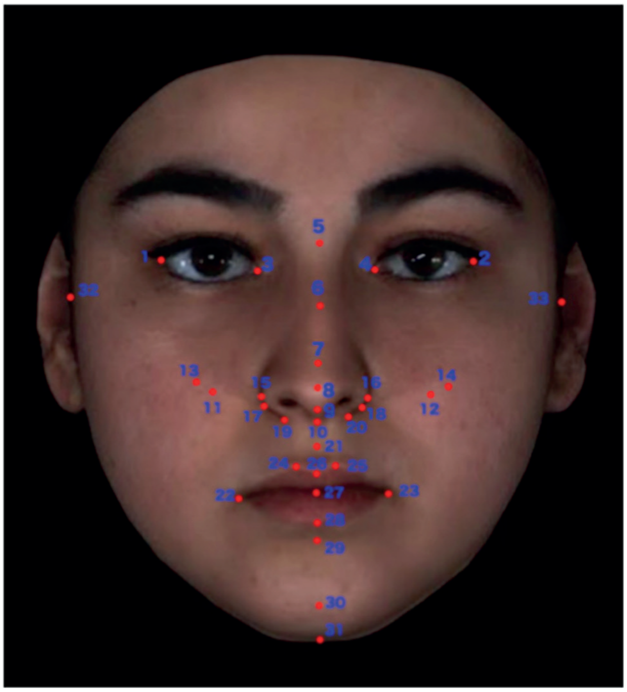

No	Landmark	Abbrevation
1.	Exochanton right	ExR
2.	Exochanton left	ExL
3.	Endochanton right	EnR
4.	Endochanton left	EnL
5.	Soft tissue nasion	N′
6.	Upper nasal dorsum convexity	NDC
7.	Nasal supratip	NS
8.	Pronasale	Prn
9.	Columella	C
10.	Subnasale	Sn
11.	Buccal contour point rigt	BcR
12.	Buccal contour point left	BcL
13.	Cheek point right	CkR
14.	Cheek point left	CkL
15.	Alare right	AlR
16.	Alare left	AlL
17.	Alare curvature right	AcR
18.	Alare curvature left	AcL
19.	Subalare right	SbalR
20.	Subalare left	SbalL
21.	Subspinale	Ss
22.	Cheilion right	ChR
23.	Cheilion left	ChL
24.	Christa philtri right	CphR
25.	Christa philtri left	CphL
26.	Labiale superior	Ls
27.	Stomion	Sto
28.	Labiale inferior	Li
29.	Sublabiale	Sl
30.	Soft tissue pogonion	Pg′
31.	Soft tissue menton	Me′
32.	Tragion right	TrR
33.	Tragion left	TrL

Figure 1. Reference points used in 3D facial soft-tissue evaluation.

an isolated cleft palate and 2 had no stereophotogrammetry records. Of the remaining 113 patients, 62 were not included in the study because they had previously undergone growth modification therapy or had underwent orthognathic surgery before obtaining the 3D images. As a result of these exclusions, 51 CLP patients were included in the study. These cleft groups were compared to the skeletal Class III group and the Class I control group. For this purpose, the skeletal Class III patients with maxillary retrognathia and the skeletal Class I patients having pretreatment 3D images were assessed as well. Lateral cephalometric radiographs were evaluated to determine skeletal anomalies. There were no more than 6 months between the date of the lateral cephalometric radiographs and the 3D image recordings. Both the ANB angle and the Wits values were assessed to design the skeletal Class I and Class III groups. In the skeletal Class I group, the ANB angle was between 0 and 4 and the Wits measurement was a positive value. In the skeletal Class III group, both the ANB angle and the Wits values were negative. Consequently, the study sample consisted of 158 patients aged 8–32 years old with nonsyndromic UCLP, BCLP, skeletal Class III malocclusions, or skeletal Class I malocclusions. Soft-tissue evaluations of all patients were performed using 3D stereophotogrammetric facial images.

In this study, 3D facial images were taken using the 3dMDface System (3dMD LLC, Atlanta, GA, USA). Images were taken in standard office lighting conditions and in the natural head position, which has high clinical reproducibility [23]. The analysis was performed using 3dMD Vultus® software (3dMD Vultus® software version 2.3.0.2, 3dMD, Atlanta, GA, USA). All the 3D facial images were reoriented for standardization and all the sections of the images that were not included in the analyses were cut off so as to have similarity in all subjects.

The landmarks used in this study are shown in Figure 1. In our study, a total of 34 linear, 11 angular, 5 proportional, and 6 volumetric measurements were made on the 3dMD Vultus software. The linear, angular, proportional, areal, and volumetric measurements are shown in Figures 2–4. Some of the linear measurements we made were the distance between certain landmarks on face, and some were the perpendicular distances of certain landmarks to coronal, axial, and N'-Prn plane. The coronal plane (CP) was defined as that which passed through the outer canthus of both the eyes, and the axial plane (AP) was defined as that which passed through the inner canthus of both the eyes. Supratip convexity was measured as the perpendicular distance from the supratip point of the nose (the most convex point of the upper part of the nose tip) to the N'-Prn plane. The hump was measured as the distance from the upper dorsum convexity point of the nose (the most convex point of the upper arch of the nose) to the N'-Prn plane. Volumetric measurements were made between the vertical

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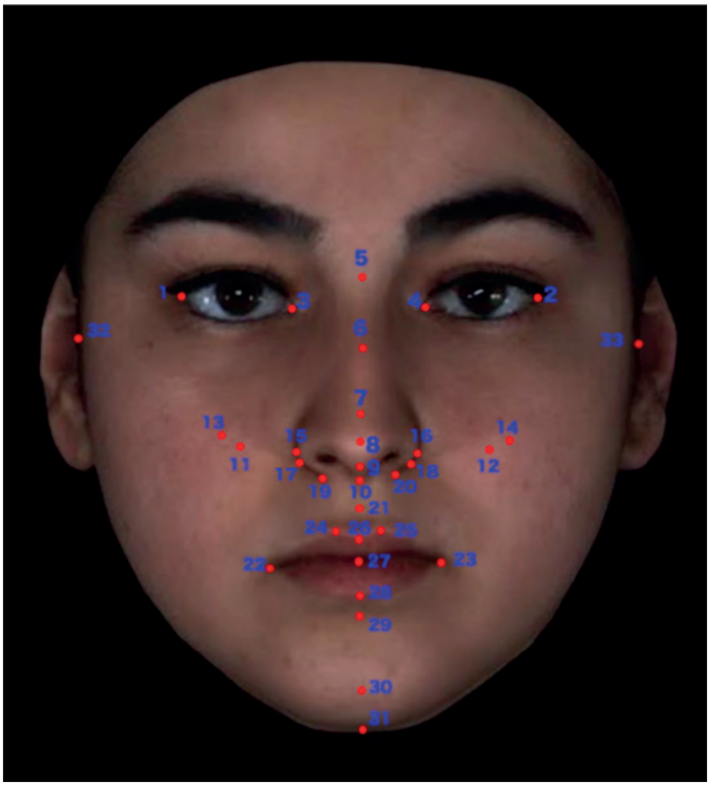

	Measurements	Landmarks
Linear measurements (mm)	N′-Me′	5–31
	N-Sn	5–10
	Sn-Me′	10–31
	AIR-AIL	15–16
	AcR-AcL	17–18
	SbalR-SbalL	19–20
	CphR-CphL	24–25
	ChR-ChL	22–23
	Ch-Ac	17–22
	Ls-Sn	10–26
	Ls-Sto	10–27
	Li-Sto	27–28
	Sn-Prn	8–10
	N′-Prn	5–8
	Prn-Sto	8–27
	Ac-Prn	8–17
	Ac-Sn	10–17
	Cph-Sn	10–24
	Sn-Sto	10–27
	Sto-Me′	27–31
Angular Measurements	N′-Sn-Pg′ °	5–10–30
	N′-Prn-Pg′ °	5–8–30
	Bc-N′-Sn °	11–5–10
	N′-Pg′-Ls °	5–30–26
	ChR-Ls-ChL °	22–26–23
	ChR-Li-ChL °	22–28–23
	AIR-N′-AIL °	15–5–16
	AIR-Prm-AIL °	15–8–16
	Li-SI-Pg′ °	28–29–30
	C-Sn-Ls °	9–10–26
	Prn-N′-Sn °	8–5–10
Proportional Measurements	Sn-Prn/Ac-Prm	8–10/8–17
	Sn-Prn/AIR-AIL	8–10/15–16
	N′-Sn/N′-Me′	5–10/5–31
	Sn-Me′/N′-Me′	10–31/5–31
	Sn-Sto/Sto-Me′	10–27/27–31

Figure 2. Linear, angular, and proportional measurements used in 3D facial soft-tissue evaluation.

and horizontal planes, passing through certain landmarks as shown in Figure 4.

The average values of the right and left sides were calculated and using a single value in the BCLP, skeletal Class III, and skeletal Class I groups, while in the UCLP group the measurements on the cleft side were used for the analyses.

To determine the individual error of measurement, 50 subjects were selected randomly from all groups for a second 3dMD analysis. The second measurements were made 15 days after the first measurements. All of the second measurements were compared with the first measurements to assess the reliability of analysis using Cronbach's alpha reliability test (r). All r values were in the range of 0.913–1, suggesting that the first and second measurements were almost identical or had negligible errors of measurements.

SPSS software, version 23.0, was used to perform the statistical analyses. The Cronbach's alpha reliability test was used for method errors and the Shapiro-Wilk test was used to determine whether the data were normally distributed. In normally distributed data, the ANOVA test was used for testing the differences among groups. Where significant differences between the groups were demonstrated, the Bonferroni (post hoc) test was used between paired groups. In non-normally distributed data, the Kruskal-Wallis test and the Mann-Whitney U test was performed among the paired groups. The significance was determined to be $p<0.05$ in ANOVA, Bonferroni, and the Kruskal-Wallis tests, and $p<0.008$ in the Mann-Whitney U test.

Results

The mean age of the UCLP group was 15.45±5.15 years (minimum 8.27, maximum 29.11), the BCLP group was 16.18 ± 5.89 years (minimum 9.3, maximum 32), the skeletal Class I group was 15.66±4.01 years (minimum 8.17, maximum 29.33) and the skeletal Class III group was 15.09±4.18 years (minimum 8.87, maximum 31.66). No significant differences were found among the groups in terms of chronological age ($p>0.05$). Comparisons of linear measurements are shown in Table 1 and results of the proportional, angular, and volumetric measurements are shown in Table 2.

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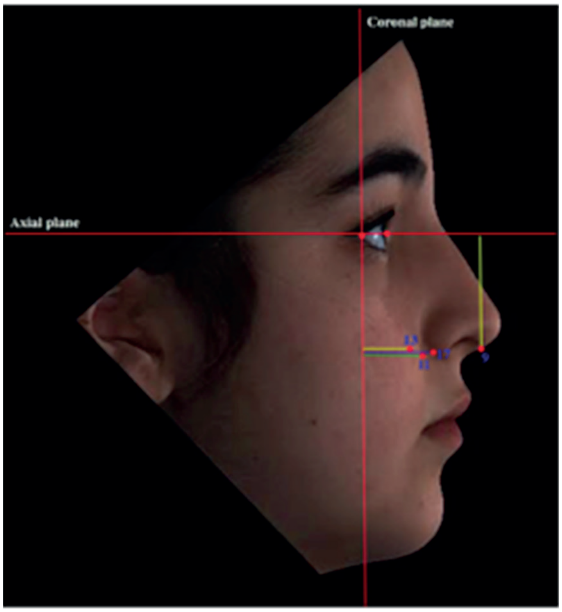

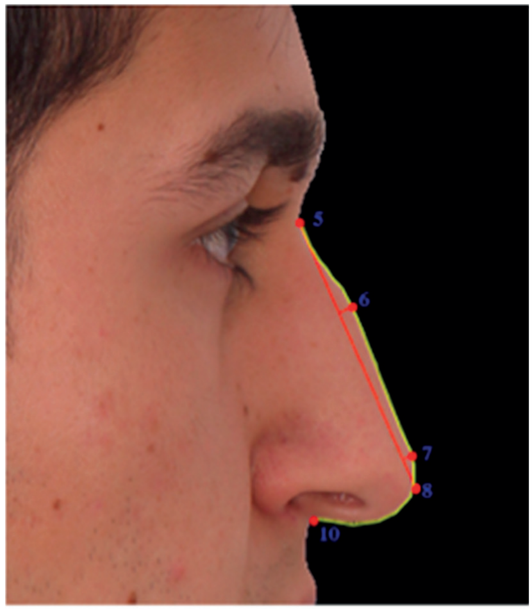

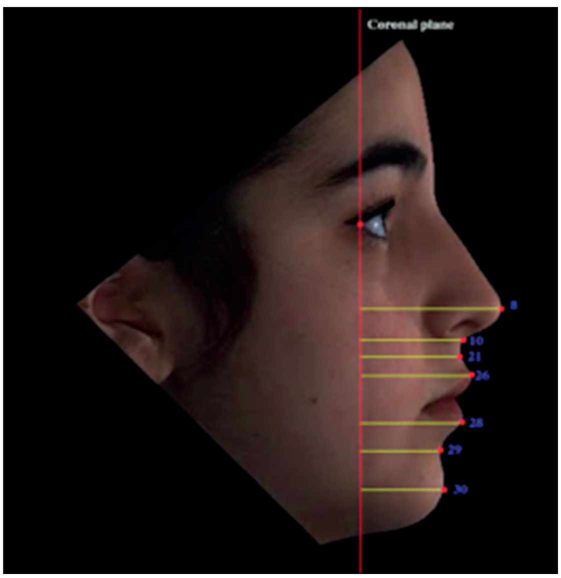

	Measurements	Landmarks
Linear measurements (mm)	Supratip	6⊥5–8
	Hump	7⊥5–8
	C-Axial P.	9-Axial P.
	Bc-Coronal P.	11-Coronal P.
	Ck-Coronal P.	13-Coronal P.
	Ac-Coronal P.	17-Coronal P.
	Prn-Coronal P.	8-Coronal P.
	Sn-Coronal P.	10-Coronal P.
	Ss-Coronal P.	21-Coronal P.
	Ls-Coronal P.	26-Coronal P.
	Li-Coronal P.	28-Coronal P.
	Sl-Coronal P.	29-Coronal P.
	Pg'Coronal P.	30-Coronal P.
	N'-Sn (topographic)	5–8

Figure 3. Linear and topographic measurements used in 3D facial soft-tissue evaluation.

When the frontal nasal measurements were evaluated in the UCLP group, the nasal width (AlR-AlL), the nasal base width (AcR-AcL), and the subalar width (SbalR-SbalL) were increased significantly in comparison to the Class I group and were decreased significantly in comparison to the BCLP group. The UCLP group had a significantly shorter upper lip r (Sn-Sto) and shorter upper lip vermillion length (Ls-Sto) as compared to the Class I group. The distances from the Sn, Ss, and Ls points to the coronal plane decreased with respect to the control group; however, these distances were similar to the BCLP group. The soft-tissue convexity angle (N'-Sn-Pg '), the total facial convexity angle (N'-Prn-Pg'), the upper lip angle (ChR-Ls-ChL), the upper nasal angle (AlR-N'-AlL), the nasal tip angle (AlR-Prn-AlL), and the nasal convexity angle (Prn-N'-Sn) were found to be larger than in the control group. The total facial convexity angle, the upper nasal angle, and the nasal type angle were significantly lower than in the BCLP group. The H angle (N'-Pg'-Ls) and the nasolabial angle (C-Sn-Ls) were narrower as compared to the control group. In the UCLP group, the ratio of the Sn-Prn/Ac-Prn was higher than that of the control group, which was similar to the BCLP group. However, the ratio of Sn-Sto/Sto-Me' was lower than that of the control group. In the UCLP group,

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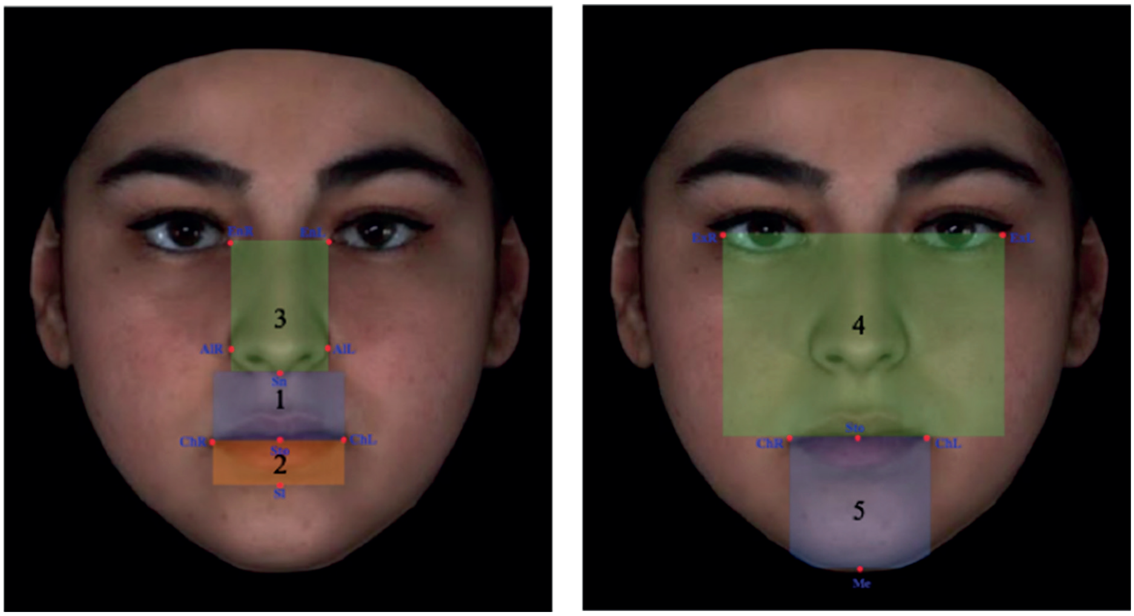

	Measurements	Arca
Volumetric mesuremetsi (cc)	Upper lip volume	1
	Lower lip volume	2
	Nasal volume	3
	Upper lip and paranasal volume	4
	Upper lip and paranasal volume except nasal volume	4 (except 3)
	Lower lip and chin volume	5

Figure 4. Volumetric measurements used in 3D facial soft-tissue evaluation.

the upper-lip surface volume, the upper lip, and the paranasal surface volume and the middle face surface volume decreased with respect to the control group and similar to the Class III and the BCLP groups.

In the BCLP group, the nasal width (AlR-AlL), the nasal base width (AcR-AcL), and the subalar width (SbalR-SbalL) increased in comparison to all other groups. The philtrum length (Ls-Sn), when compared to both the Class III and UCLP groups, had decreased in the BCLP group. Compared to the control group, the nasal bridge (N'-Prn) and the upper-lip length (Sn-Sto) were decreased in the BCLP group. The distances from the Prn, Sn, Ss, and Ls points to the coronal plane decreased with respect to the control group, while they were found to be similar to the UCLP group. In the BCLP group, the soft-tissue convexity angle (N'-Sn-Pg'), the upper-lip angle (ChR-Ls-ChL), and the nasal convexity angle (Prn-N'-Sn) were larger than that of the control group. However, the H angle was smaller than that of the control group. In the BCLP group, the total facial convexity angle (N'-Prn-Pg'), the upper nasal angle (AlR-N'-AlL), the nasal tip angle (AlR-Prn-AlL), and the nasal convexity angle (Prn-N'-Sn) was wider than in all the other groups.

The Class III group had a significantly shorter upper-lip vermillion length (Ls-Sto) as compared to the control group. In the Class III group, the distances from the Ac, Prn, Sn, and Ss points to the coronal plane decreased with respect to the control group, but were similar to the UCLP and BCLP groups. The distances from the Li, Sl, and Pg' points to the coronal plane increased in comparison to all other control groups. The soft-tissue convexity angle (N'-Sn-Pg'), the total facial convexity angle (N'-Prn-Pg'), the upper-lip angle (ChR-Ls-ChR), the mentolabial angle (Li-Sl-Pg'), the nasolabial angle (C-Sn-Ls), and the nasal convexity angle (Prn-N'-Sn) were larger than in the control group. However, the H angle (N'-Pg'-Ls) was reduced when compared to the control group. In the Class III group, the upper-lip surface volume, the upper lip and the paranasal surface volume, and the middle-face surface volume increased with respect to the control group, while they were found to be similar to the UCLP and BCLP groups.

Discussion

In this study, the dimensions of the nose, lips, cheeks, and chin were analyzed in 3D for different cleft types and skeletal malocclusions. Significant differences were found between the

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Table 1. Comparison of linear measurements made on facial soft tissues according to groups.

	Measuremets	UCLP (n=29)	BCLP (n=22)	CLASS III (n=54)	CLASS I (n=53)	p **	p *
Linear measurement (mm)	N'-Me'	116.16±9.09	117.87±7.49	114.19±9.23	116.24±7.86	0.338	
	N'-Sn	50.32±4.82	51.36±3.64	48.86±5.09	50.74±4.16	0.083	
	Sn-Me'	67.91±5.77	68.18±5.86	67.35±6.35	69.06±5.43	0.509	
	AlR-AlL	36.72±5.04B	39.45±4.24C	33.27±3.41A	33.55±2.82A	**0.000**	
	AcR-AcL	36.05±4.46B	40.02±4.06C	32.49±3.13A	32.29±2.59A	**0.000**	
	SbalR-SbalL	26.37±3.96B	29.41±3.56C	20.43±2.74A	21.22±2.44A	**0.000**	
	CphR-CphL	11.97±2.8	13.09±4.31	11.38±2.3	11.33±1.72		0.281
	ChR-ChL	45.8±5.67	47.89±4.95	46.48±4.42	46.26±3.65	0.405	
	Ch-Ac	27.59±3.05	27.32±2.35	27.85±2.46	28.65±2.22		0.101
	Ls-Sn	13.12±2.97AB	11.23±3.4B	14.24±2.79A	14.98±2.47A	**0.000**	
	Ls-Sto	6.78±2.59B	7.73±3.41AB	6.96±1.75B	8.42±1.27A		**0.000**
	Li-Sto	8.12±2.17	8.53±1.73	8.39±1.84	9.28±1.84	0.054	
	Sn-Prn	19.59±3.25	19.62±3.13	18.3±2.03	17.71±1.8		0.089
	N'-Prn	41.93±4.59AB	40.69±4.25B	41.97±5.45AB	44.3±4.69A	**0.013**	
	Prn-Sto	35.55±4.33	35.96±3.96	35.65±3.75	36.19±3.3		0.079
	Ac-Prn	30.74±3.97	31.36±3.26	30.35±2.99	30.18±2.8		0.699
	Ac-Sn	21.1±3.15	23.06±2.26	20.39±1.99	20.22±1.67		0.067
	Cph-Sn	13.85±2.58	12.01±2.89	13.73±2.5	14.43±2.47		0.121
	Sn-Sto	18.96±3.43B	18.31±3.81B	20.26±2.86AB	21.76±2.41A	**0.000**	
	Sto-Me'	49.86±5.29	50.65±5.12	47.51±4.74	47.74±3.93	0.054	
	Supratip	1.35±0.74	1.36±0.69	1.25±0.71	1.48±0.63		0.248
	Hump	0.4±1.35	0.5±1.3	0.05±1.27	0.18±1.27		0.356
	C-Axial P.	40.11±4.88	40.45±5.05	40.23±5.15	40.19±4.13	0.995	
	Bc-Coronal P.	11.14±3.45	10.83±3.15	10.99±2.88	11.98±3.03	0.295	
	Ck-Coronal P.	9.02±2.75	9.21±2.92	9.02±2.93	9.84±2.56		0.327
	Ac-Koronal D.	14.37±3.36AB	13.21±2.99AB	12.49±3.13B	14.75±3.13A	**0.002**	
	Prn-Coronal D.	36.55±4.56AB	35.98±4.38B	37.43±4.44AB	39.41±4.48A		**0.007**
	Sn-Koronal D.	21.35±3.12B	21.55±4.16B	23.11±3.5B	25.53±3.81A	**0.000**	
	Ss-Koronal D.	20.66±3.29B	20.38±3.43B	21.64±3.73B	23.92±3.64A	**0.000**	
	Ls-Koronal D.	21.94±3.66C	20.42±4.01C	24.05±4.14B	26.31±4.12A	**0.000**	
	Li-Koronal D.	21.53±4.13A	21.95±5.15A	23.81±4.18B	21.94±4.42A		**0.048**
	Sl-Koronal D.	14.58±4.79A	15.24±5.32A	18.25±4.34B	15.45±4.03A		**0.000**
	Pg'-Koronal D.	15.56±4.79A	17.02±6.15A	19.29±4.77B	16.25±4.22A		**0.001**
	Topografik N'-Sn	64±7.54	63.52±7.13	62.32±7.16	64.04±6.22	0.574	

Statistically significant differences are written in **bold**. p ** – ANOVA, binary comparison Bonferroni test; p * – Kruskal-Wallis test, binary comparison Mann-Whitney U test.

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Table 2. Comparison of angular, proportional and volumetric measurements made on facial soft tissues according to groups.

	Measuremets	UCLP (n=29)	BCLP (n=22)	CLASS III (n=54)	CLASS I (n=53)	p **	p *
Angular measurements	N'-Sn-Pg' °	168.72±5.09B	170.89±5.91B	169.53±5.28B	161.94±4.87A	**0.000**	
	N'-Prn-Pg' °	136.15±6.23B	140.27±6.41C	136.27±4.3B	131.84±4.31A	**0.000**	
	Bc-N'-Sn °	37.29±2.9	37.57±2.14	38.28±1.86	37.43±2.05		0.059
	N'-Pg'-Ls °	9.36±4.7B	7.01±4.07B	8.28±4.69B	14.47±3.28A	**0.000**	
	ChR-Ls-ChL °	115.45±9.71B	117.32±8.65B	114.38±5.91B	105.64±4.22A	**0.000**	
	ChR-Li-ChL °	115.45±9.71	117.32±8.65	114.93±5.91	116.31±5.46	0.062	
	AlR-N'-AlL °	47.64±5.58B	51.44±4.5C	45.06±4.32AB	43.63±3.96A	**0.000**	
	AlR-Prn-AlL °	90.28±7.63B	95.78±8.39C	80.85±8.23A	82.86±6.68A	**0.000**	
	Li-Sl-Pg' °	139.76±13.93AB	137.23±16.66AB	144.2±11.87B	135.26±11.65A		**0.005**
	C-Sn-Ls °	106.05±10.19B	117.12±15.94C	106.9±10.59B	112.56±10.14A	**0.002**	
	Prn-N'-Sn °	22.11±3.41B	21.41±3.13B	21.53±1.97B	19.94±2.04A	**0.001**	
Proportional measurements	Sn-Prn/Ac-Prn	0.64±0.08B	0.65±0.06B	0.6±0.04A	0.59±0.04A	**0.000**	
	Sn-Prn/AlR-AlL	0.55±0.08	0.52±0.07	0.56±0.08	0.53±0.05		0.113
	N'-Sn/N'-Me'	0.43±0.02	0.44±0.02	0.43±0.03	0.44±0.02		0.264
	Sn-Me'/N'-Me'	0.58±0.02	0.58±0.03	0.59±0.03	0.59±0.02		0.079
	Sn-Sto/Sto-Me'	0.39±0.08B	0.37±0.08B	0.43±0.06A	0.46±0.05A	**0.000**	
Volumetric measurements (cc)	Upper lip volume	2.43±1.03B	2.52±1.11B	2.86±0.98B	3.77±0.95A		**0.000**
	Lower lip volume	3.08±1.28	3.44±1.21	3.45±1.31	3.26±0.93		0.641
	Nasal volume	12.44±3.81	13.31±4.09	11.37±3.1	11.93±2.96		0.054
	Upper lip and paranasal volume	27.7±5.83B	28.44±4.28B	25.73±4.46B	31.11±5.25A	**0.000**	
	Upper lip and paranasal volume except nasal volume	15.19±4.01B	16.12±3.62B	14.36±2.41B	19.17±3.78A	**0.000**	
	Lower lip and chin volume	4.55±2.46	5.93±3.16	5.37±2.26	5.29±1.3		0.164

Statistically significant differences are in **bold**. p ** – ANOVA, binary comparison Bonferroni test; p * – Kruskal-Wallis test, binary comparison Mann-Whitney U test.

groups in terms of linear, angular, proportional, and volumetric measurements. Nasolabial changes seen in cleft and skeletal Class III patients were especially remarkable.

Patients with CLP have different facial appearances from their normal peers [24,25]. It was reported that interocular width, nasal floor width, lip width, lower face height, nose length, and lip shape were different from normal individuals [24] and various facial asymmetries are seen [26,27]. Many factors influence the severity of these deformities, which especially affect the mid-facial region. These factors may include the type of cleft, race, sex, the techniques used in the repair of the cleft, and the timing of the surgical procedures performed [1,28]. At present, the aesthetic expectations of both clinicians and patients from orthodontic treatment have been increasing; therefore, evaluation of the effectiveness of both surgical and orthodontic treatments has become more important.

To evaluate the facial soft tissue, 2D photographs and traditional cephalometry have been replaced by 3D facial imaging systems [29]. In studies performed with conventional cephalometric radiographs, remodeling changes of the bone tissue formed by growth or orthodontic treatment can be examined only by distance to a certain plane. However, using 3D

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approaches, soft-tissue reflection of bone remodeling can be evaluated in a wider surface. Because of its practical use, stereophotogrammetry has become the preferred craniofacial and dentofacial 3D face-imaging system [30]. Facial images taken with the 3dMDface system include the entire face, including between the ears and below the chin. In this system, which has a total of 6 cameras (3 on the right and 3 on the left), the image acquisition time is 1.5 milliseconds [31]. 3D stereophotogrammetry produces high-resolution 3D images that can generate a sense of reality. Thus, the identification of soft-tissue points is facilitated, and facial measurements are precise and reproducible [32]. In studies investigating the accuracy of landmarks and measurements using stereophotogrammetry, it was concluded that the system was reliable and was a suitable technique for facial soft-tissue analysis [22,32–39]. Previous studies have also shown that stereophotogrammetry is an appropriate method in the detection of facial deformities and postoperative changes in patients with CLP [39–43]. However, there is no consensus in the literature about measurements made on 3D facial images. Many different anthropometric points and measurements have been used in the evaluation of soft tissues of CLP patients [12,24,43–47]. The landmarks used in this study were mainly based on the Farkas system [48]. In addition to Farkas measurements, some new measurements were added in order to better evaluate the shape of the nasolabial complex.

Nasolabial deformities are one of the most basic problems seen in CLP patients. It has been stated that the alar base shape was even more flat due to insufficient bone support in the affected areas [49]. In studies conducted in patients with UCLP, the nose is generally asymmetric; the tip of the nose is deformed, straightened and deviated towards the unaffected side. It has been reported that the nose width increases and the columella is wider and shorter at the cleft side [47,50,51]. Similar to previous studies, we found that the measurements of the nasal width, the nasal floor width, and the subalar distance in the UCLP patients were significantly higher than those of the Class I control groups [45,47,49]. A number of studies reported that the increase in nasal width is the most striking finding regarding the nose in patients with BCLP, and the increase in the ratio of nose width to lip width was reported to negatively affect the appearance [24,52]. According to our findings, the nasal width, the nasal floor width, and the subalar distance in the BCLP group were wider than in the other groups. These findings were consistent with the study conducted by Bugaigish et al. [45]. These results might have occurred because of inadequate bone support, which is made more inadequate due to clefts on both sides in patients with BCLP; therefore, the nasal base was more flattened than in patients with UCLP.

According to our results, the BCLP group had a longer nasal bridge length than in all the other groups, and no significant differences were found among the Class I control group, the Class III group, and the UCLP group. Consistent with our findings, Othman et al. and Zreaqat et al. have also reported that there was no significant difference in nasal bridge lengths in their studies comparing UCLP patients and control groups [47,53]. Bugaighis et al. reported that the nasal bridge length was significantly shorter in the BCLP groups as compared to the Class I control group [50].

The severity and types of cleft and the surgical procedures applied to the closure of the cleft affect the shape of the lips. A lip that is 3–4 mm less than its normal length has been defined as a short lip [54]. It is known that lip lengths vary depending on the type of surgical procedure performed. While the Millard advancement technique leads to a shorter upper-lip length, the Tennison repair leads to a longer upper-lip length [55]. However, it was difficult to standardize the surgeries, since all patients involved in this study were outside patients and there was no standardization of lip and palate closure in terms of technique and timing. Therefore, in the present study we found several differences in upper-lip form among the groups. While the Class I, Class III, and UCLP patients had similar philtrum height, BCLP patients had a significantly shorter philtrum, consistent with previous studies [44,45,53]. However, according to the distance of the Prn point from the CP, the nasal projection decreased in the Class III, UCLP, and BCLP patients, but only the BCLP group was significantly lower. This may be due to the fact that the tip of the nose was more affected in the repair of BCLP.

In a previous anthropometric study that compared UCLP and BCLP patients with control subjects, Duffy et al. found no significant difference in upper-lip vermillion height [24]. In contrast to these studies, we found a shorter upper-lip vermillion in the Class III and UCLP groups. It is thought that the difference of lips closure techniques has a variable effect on upper-lip vermillion and causes a decrease in thickness. The UCLP sample size in Duffy's study might not be large enough to detect such a difference. The UCLP group in the study by Bugaigish et al. showed similar results with our findings [45]. Zreaqat et al., Bugaigish et al., and Othman et al. reported that the upper-lip length in UCLP and BCLP patients was significantly shorter than those of the control group [45,47,53]. None of these studies made any comparison between UCLP and BCLP patients. In the present study, we also found that the upper-lip length was shorter in the UCLP and BCLP patients. However, no significant difference was found between the UCLP and BCLP groups.

In patients with CLP, the maxillary region and the entire midfacial region are considered to be problematic regions as well [56,57]. It was reported that inadequate mid-facial growth can be seen due to both the defect itself and the surgical

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procedures performed [58]. When the previous studies were evaluated, it was observed that angular measurements were frequently made during the sagittal evaluation of the midface, the maxilla, and the mandible. However, angular measurements may not give accurate results because the positions of the landmarks affect each other. For example, the soft-tissue convexity angle will be inadequate to diagnose the bimaxillary retrusion that is commonly seen in BCLP patients. For this reason, in our study, the distances from certain points on the face to a reference plane (coronal plane) were measured, so that the examination of the sagittal relation and the profile image is more accurate.

We measured the distances from the CP to the buccal contour (Bc), cheek (Ck), alar curvature (Ac), pronasale (Prn), subnasale (Sn), subspinale (Ss), labiale superior (Ls), labiale inferior (Li), sublabiale (Sl), and soft-tissue pogonion (Pg') points to determine and compare the projections of the midface, nose, and lower jaw area. The cheek projection was similar among the groups, while the alar curvature projection was reduced in the Class III, UCLP, and BCLP patients as compared to the Class I control group. However, only the difference between the Class III group and the control group was found to be statistically significant. The inadequate development of the midfacial area of the UCLP and BCLP patients could not be clearly seen with these measurements because their orbital areas may also be affected by the defects [24].

To determine the upper lip projection, the distances from the Sn, Ss, and Ls points to the CP were measured. The upper-lip projection was found to be less prominent in all study groups other than the Class I control group. This result can be attributed to the surgical repair of the lips in patients with UCLP and BCLP and maxillary insufficiency in patients with skeletal Class III malocclusion. The distance from the Ls point to the CP was significantly decreased in the Class III group as compared to the UCLP and BCLP groups. This may be due to the increased maxillomandibular discrepancy in the Class III group.

There is no consensus in the literature as to whether the lower-lip and jaw areas of UCLP and BCLP patients are affected by the cleft. The present study found that the lower-lip and chin projection were similar to the Class I control group in the UCLP and BCLP groups. In the Class III group, all of these measurements are significantly higher than that of the UCLP, BCLP, and Class I groups. In their study comparing skeletal Class III patients and normal subjects using 3D facial images, Sforza et al. reported that the lower face was more prominent in skeletal Class III patients [59].

The most frequently observed significant feature in patients with maxillary deficiency was concavity of the face. According to the angular measurements, the total facial convexity angle and the soft-tissue convexity angle were significantly higher in the Class III, UCLP, and BCLP groups as compared to the Class I control group. The total facial convexity angle in the BCLP group was significantly higher than that of all the other groups. It was not surprising that this measure, which was affected by nasal changes, was more markedly increased in BCLP patients whose nasal tip was more flattened. Our findings are similar to those of Bugaighis et al. [45].

The Class III, UCLP, and BCLP groups had a significantly higher upper-lip angle. This might be because of the variation of the lip width or position of the Ls point. According to our findings, lip width measurements were similar among the groups and the differences between them were not statistically significant. Therefore, it is thought that the upper-lip angle was higher in all 3 groups because of the position of the Ls point. The similarity of the lower-lip angle between all groups also support this idea. The upper nasal angle and the nasal tip angle had higher values in the UCLP and BCLP groups as compared to the Class I control group. However, it is noteworthy that these angles increased more in the BCLP group. The increase in the width of the alar base due to inadequate bone support properties of the cleft type in the patients with BCLP [24,45,60] might have caused an increase in these angles. For this reason, the nose seems to be wider and flattened, especially in patients with BCLP.

Sforza et al. stated that the mentolabial angle in skeletal Class III patients was significantly increased as compared to normal subjects [59]. In agreement with Sforza et al., we found that the mentolabial angle was significantly higher only in the Class III group as compared to the Class I control group. Mandibular prognathism causing an increase in the mentolabial angle is not very common in UCLP and BCLP patients. Patients with UCLP and BCLP usually show skeletal Class III malocclusion due to maxillary retrognathia. Therefore, a severe increase in mentolabial angle is not expected in UCLP and BCLP patients, but there may be some increase due to the dental compensation seen in the lower incisor teeth. Our results also supported the idea that there was a slight increase in the mentolabial angle of the UCLP and BCLP patients as compared to the Class I control group, but this increase was not statistically significant. Similar to our findings, a previous study found that the mentolabial angle was similar in the control groups and the UCLP patients [61].

The nasolabial angle is mostly affected by orthodontic and surgical procedures. This angle, which is often evaluated during the planning of orthodontic treatment, has an important role in facial aesthetics. According to the findings of the present study, the nasolabial angle decreased in the Class III and UCLP patients as compared to the Class I control group. This was consistent with the findings of other studies in the literature [62,63].

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However, the nasolabial angle increased in the BCLP group. It may be postulated that the retruded upper incisor teeth and the position of the premaxilla might have caused the increased nasolabial angle in these patients [62,64,65].

It has been observed that mostly linear and angular measurements are performed in the 3D face analysis for studies on CLP patients. In the present study, we included proportional and volumetric measurements as well as linear and angular measurements. In our proportional measurements, the Sn-Prn/Ac-Prn ratio was increased in the UCLP and BCLP groups as compared to the Class I control group and the Class III group. In the present study, we found no statistically significant difference between the Sn-Prn and Ac-Prn measurements among all groups. However, the Sn-Prn length was slightly increased in the UCLP and BCLP groups, and this could be the cause of these findings. Another noteworthy finding from the proportional measurements was the ratio of upper-lip length to lower-lip length. This ratio was decreased in the UCLP and BCLP patients. Because the lower-lip length was similar among all groups, it was thought that this result was due to the shorter length of the upper lip in the UCLP and BCLP patients [45,47,53,66].

Various facial volumetric measurements have been introduced [43,46,67]. In the present study, the upper-lip surface volume was significantly lower in the Class III, UCLP, and BCLP groups as compared to the Class I control group. The sagittal and transversal maxillary deficiency seen in these 3 groups and the surgical operations on the UCLP and BCLP patients might have caused the decrease of the upper-lip surface volume. Ferrario et al. showed that the upper-lip surface volume was slightly reduced in UCLP and BCLP patients, but the findings were not statistically significant [66]. The sample size in Ferrario's study was 18 (13 UCLP, 5 BCLP) and might not have been large enough to detect a change. Other volume measurements in our study, such as the upper-lip and paranasal surface volume – with and without the nasal surface volume – were less than in the Class I control group in the Class III, UCLP, and BCLP groups. In the skeletal Class III, UCLP, and BCLP patients, the sagittally and vertically developmental deficiency of the maxilla [68–70] leads to a decrease in the upper-lip and paranasal surface volume.

One of the limitations of this study was the similarity of the age range to that of previous studies [49,71,72]. However, the minimum, maximum, and mean ages of the groups were similar and allowed them to be compared. For further studies, designing subgroups-based growth periods will enable more accurate results from the evaluation of the nasolabial area.

Conclusions

The nasolabial changes seen in UCLP and BCLP patients were especially remarkable. The nose width, nasal floor width, and subalar width were increased significantly in the UCLP and BCLP patients, and this increase was more severe in the BCLP patients. The upper lip was found to be affected in the Class III, UCLP, and BCLP patients. Measurements that related to vertical upper-lip lengths generally did not differ significantly among the Class III, UCLP, and BCLP groups. In these groups the upper lip was shorter than in the Class I control group. However, it was surprising that the nasal surface volume was similar among these groups.

The use of 3DMD images will facilitate the assessment of craniofacial anomalies by orthodontists, maxillofacial surgeons, and plastic surgeons. This study aimed to provide the basis for a further longitudinal study that analyzes the similarities and differences between different cleft types and skeletal Class III malocclusion. Further studies in which patients are divided into subgroups according to skeletal maturation periods are important for a more accurate and detailed understanding of the facial soft tissues of craniofacial anomalies such as Skeletal Class III, UCLP, and BCLP.

References:

1. Cornel MC, Spreen JA, Meijer I et al: Some epidemiological data on oral clefts in the northern Netherlands, 1981–1988. J Craniomaxillofacial Surg, 1992; 20: 147–52
2. Dixon MJ, Marazita ML, Beaty TH et al: Cleft lip and palate: Understanding genetic and environmental influences. Nat Rev Genet, 2011; 12: 167–78
3. Bishara, SE: Cephalometric evaluation of facial growth in operated and non-operated individuals with isolated clefts of the palate. Cleft Palate J, 1973; 10: 239–46
4. Zheng Z-W, Fang Y-M, Lin C-X: Isolated influences of surgery repair on maxillofacial growth in complete unilateral cleft lip and palate. J Oral Maxillofacial Surg, 2016; 74: 1649–57
5. Ross R, Coupe T: Craniofacial morphology in six pairs of monozygotic twins discordant for cleft lip and palate. J Can Dent Assoc, 1965; 31: 149–57
6. Johnson GP: Craniofacial analysis of patients with complete clefts of the lip and palate. Cleft Palate J, 1980; 17: 17–23
7. Bardach J: Facial growth after cleft lip repair: an experimental study. Cleft Palate J, 1979; 16: 372–84
8. McCance A, Moss J, Wright W et al: A three-dimensional soft tissue analysis of 16 skeletal class III patients following bimaxillary surgery. Br J Oral Maxillofac Surg, 1992; 30: 221–32
9. Edler R, Rahim MA, Wertheim D et al: The use of facial anthropometrics in aesthetic assessment. Cleft Palate Craniofac J, 2010; 47: 48–57
10. Honrado CP, WF Larrabee Jr.: Update in three-dimensional imaging in facial plastic surgery. Curr Opin Otolaryngol Head Neck Surg, 2004; 12: 327–31
11. Mccance AM, Moss P, Fright WR et al: Three-dimensional analysis techniques – Part 3: Color-coded system for three-dimensional measurement of bone and ratio of soft tissue to bone: the analysis. Cleft Palate Craniofac J, 1997; 34: 52–57
12. Hood C, Hosey M, Bock M et al: Facial characterization of infants with cleft lip and palate using a three-dimensional capture technique. Cleft Palate Craniofac J, 2004; 41: 27–35

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13. Jacobs R, Pauwels R, Scarfe WC et al: Pediatric cleft palate patients show a 3-to 5-fold increase in cumulative radiation exposure from dental radiology compared with an age-and gender-matched population: A retrospective cohort study. Clin Oral Investig, 2018; 22: 1783–93
14. Da Silveira AC, DawJL, Kusnoto B et al: Craniofacial applications of three-dimensional laser surface scanning. J Craniofac Surg, 2003; 14: 449–56
15. Lane C, Harrell W: Completing the 3-dimensional picture. Am J Orthod Dentofacial Orthop, 2008; 133: 612–20
16. Lowe, DG: Three-dimensional object recognition from single two-dimensional images. Artificial Intelligence, 1987; 31: 355–95
17. Giovanoli, P, Tzou C-H, Ploner M et al: Three-dimensional video-analysis of facial movements in healthy volunteers. Br J Plast Surg, 2003; 56: 644–52
18. Isola G, Cicciù M, Fiorillo L et al: Association between odontoma and impacted teeth. J Craniofac Surg, 2017; 28: 755–58
19. Tulunoglu O, Esenlik E, Gulsen A et al: A comparison of three-dimensional and two-dimensional cephalometric evaluations of children with cleft lip and palate. Eur J Dent, 2011; 5: 451–48
20. Perillo L, Vitale M, d'Apuzzo F et al: Interdisciplinary approach for a patient with unilateral cleft lip and palate. Am J Orthod Dentofacial Orthop, 2018; 153: 883–94
21. Kau C, Richmond S, Palomo J et al: Current products and practice: Three-dimensional cone beam computerized tomography in orthodontics. J Orthodont, 2005; 32: 282–93
22. De Menezes M, Rosati R, Ferrario VF et al: Accuracy and reproducibility of a 3-dimensional stereophotogrammetric imaging system. J Oral Maxillofac Surg, 2010; 68: 2129–35
23. Chiu C, Clark R: Reproducibility of natural head position. J Dentistry, 1991; 19: 130–31
24. Duffy S, Noar J, Evans R et al: Three-dimensional analysis of the child cleft face. Cleft Palate Craniofac J, 2000; 37: 137–44
25. Ferrario VF, Sforza C, Dellavia D et al: A quantitative three-dimensional assessment of abnormal variations in facial soft tissues of adult patients with cleft lip and palate. Cleft Palate Craniofac J, 2003; 40: 544–49
26. Hood C, Bock M, Hosey M et al: Facial asymmetry-3D assessment of infants with cleft lip & palate. Int J Paediatr Dent, 2003; 13: 404–10
27. Zemann W, Santler G, Kärcher H: Analysis of midface asymmetry in patients with cleft lip, alveolus and palate at the age of 3 months using 3D-COSMOS measuring system. J Craniomaxillofacial Surg, 2002; 30: 148–52
28. Ross RB: Facial growth in cleft lip and palate. Plastic Surgery, 1990; 4: 2553–80
29. Moss J, Coombes A, Linney A et al: Methods of three dimensional analysis of patients with asymmetry of the face. Proc Finn Dent Soc, 1991; 87: 139–49
30. Mutsvangwa TE, Smit J, Hoyme HE et al: Design, construction, and testing of a stereo-photogrammetric tool for the diagnosis of fetal alcohol syndrome in infants. IEEE Trans Med Imaging, 2009; 28: 1448–58
31. Kau CH, Richmond S, Incrapera A et al: Three-dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery. Int J Med Robot, 2007; 3: 97–110
32. Aldridge K, Boyadjiev SA, Capone GT et al: Precision and error of three-dimensional phenotypic measures acquired from 3dMD photogrammetric images. Am J Med Genetics. Part A, 2005; 138: 247–53
33. Ghoddousi H, Edler R, Haers P et al: Comparison of three methods of facial measurement. Int J Oral Maxillofac Surg, 2007; 36: 250–58
34. Honrado CP, Lee S, Bloomquist DS et al: Quantitative assessment of nasal changes after maxillomandibular surgery using a 3-dimensional digital imaging system. Arch Facial Plast Surg, 2006; 8: 26–35
35. Lübbers H-T, Medinger L, Kruse A et al: Precision and accuracy of the 3dMD photogrammetric system in craniomaxillofacial application. J Craniofac Surg, 2010; 21: 763–67
36. Plooij J, Swennen G, Rangel F et al: Evaluation of reproducibility and reliability of 3D soft tissue analysis using 3D stereophotogrammetry. Int J Oral Maxillofac Surg, 2009; 38: 267–73
37. Weinberg SM, Naidoo S, Govier DP et al: Anthropometric precision and accuracy of digital three-dimensional photogrammetry: Comparing the Genex and 3dMD imaging systems with one another and with direct anthropometry. J Craniofac Surg, 2006; 17: 477–83
38. Wong JY, Oh AK, Ohta E et al: Validity and reliability of craniofacial anthropometric measurement of 3D digital photogrammetric images. Cleft Palate Craniofac J, 2008; 45: 232–39
39. Ayoub A, Garrahy A, Hood C et al: Validation of a vision-based, three-dimensional facial imaging system. Cleft Palate Craniofac J, 2003; 40: 523–29
40. Bagante I, Akota I: Cleft-related nose deformation evaluation and measurement methods. Literature review. Stomatologija, 2015; 17: 75–83
41. Bell A, Lo T-WR, Brown D et al: Three-dimensional assessment of facial appearance following surgical repair of unilateral cleft lip and palate. Cleft Palate Craniofac J, 2014; 51: 462–71
42. Krisztian N, Mommaerts MY: Analysis of the cleft-lip nose in submental-vertical view, Part I – reliability of a new measurement instrument. J Craniomaxillofacial Surg, 2007; 35: 265–77
43. Van Loon B, Maal T, Plooij J et al: 3D Stereophotogrammetric assessment of pre-and postoperative volumetric changes in the cleft lip and palate nose. Int J Oral Maxillofac Surg, 2010; 39: 534–40
44. Ayoub A, Bell A, Simmons D et al: 3D assessment of lip scarring and residual dysmorphology following surgical repair of cleft lip and palate: A preliminary study. Cleft Palate Craniofac J, 2011; 48: 379–87
45. Bugaighis I, Mattick C, Tiddeman B et al: 3D facial morphometry in children with oral clefts. Cleft Palate Craniofac J, 2014; 51: 452–61
46. Ferrario VF, Sforza C, Dellavia C et al: A quantitative three-dimensional assessment of soft tissue facial asymmetry of cleft lip and palate adult patients. J Craniofac Surg, 2003; 14: 739–46
47. Zreaqat M, Hassan R, Halim A: Facial dimensions of Malay children with repaired unilateral cleft lip and palate: A three dimensional analysis. Int J Oral Maxillofac Surg, 2012; 41: 783–88
48. Farkas LG: Anthropometry of the Head and Face. 1994, Raven Pr
49. Bagante I, Zepa I, Akota I: 3D assessment of nasolabial appearance in patients with complete unilateral cleft lip and palate. Cleft Palate Craniofac J, 2018; 55(2): 220–25
50. Bugaighis I, Mattick C, Tiddeman B et al: 3D asymmetry of operated children with oral clefts. Orthod Craniofac Res, 2014; 17: 27–37
51. Garrahy A: 3D assessment of dentofacial deformity in children with oral clefts. Thesis, University of Glasgow, 2002
52. Vegter F, Mulder JW, Hage JJ: Major residual deformities in cleft patients: A new anthropometric approach. Cleft Palate Craniofac J, 1997; 34: 106–10
53. Othman SA, Ahmad R, Asi SM et al: Three-dimensional quantitative evaluation of facial morphology in adults with unilateral cleft lip and palate, and patients without clefts. Br J Oral Maxillofac Surg, 2014; 52: 208–13
54. Stal S, Hollier L: Secondary deformities of the cleft lip, nose, and palate. Mathes Plastic Surgery, 2006; 4: 339–51
55. Serafin D, Georgiade NG: Pediatric plastic surgery. CV Mosby, 1984
56. Capelozza Filho L, Normando A, da Silva Filho OG: Isolated influences of lip and palate surgery on facial growth: comparison of operated and unoperated male adults with UCLP. Cleft Palate Craniofac J, 1996; 33: 51–56
57. Diah E, Lo L-J, Huang C-S et al: Maxillary growth of adult patients with unoperated cleft: answers to the debates. J Plast Reconstr Aesthet Surg, 2007; 60: 407–13
58. Dadáková M, Cagáňová V, Dupej J et al: Three-dimensional evaluation of facial morphology in pre-school cleft patients following neonatal cheiloplasty. J Craniomaxillofacial Surg, 2016; 44: 1109–16
59. Sforza C, Peretta R, Grandi G et al: Three-dimensional facial morphometry in skeletal Class III patients: A non-invasive study of soft-tissue changes before and after orthognathic surgery. Br J Oral Maxillofac Surg, 2007; 45: 138–44
60. Farkas LG, Forrest CR, Phillips JH: Comparison of the morphology of the" cleft face" and the normal face: Defining the anthropometric differences. J Craniofac Surg, 2000; 11: 76–82
61. Memikoğlu U, Akçam O, Arman A: A cephalometric evaluation of lower lip in patients with unilateral cleft lip and palate. Cleft Palate Craniofac J, 2004; 41: 485–89
62. Paradowska-Stolarz AM, Kawala B: The nasolabial angle among patients with total cleft lip and palate. Adv Clin Exp Med, 2015; 24: 481–85
63. Pietruski P, Majak M, Pawlowska E et al: A novel computer system for the evaluation of nasolabial morphology, symmetry and aesthetics after cleft lip and palate treatment. Part 2: Comparative anthropometric analysis of patients with repaired unilateral complete cleft lip and palate and healthy individuals. J Craniomaxillofacial Surg, 2017; 45: 505–14
64. Mars M, Houston WJ: A preliminary study of facial growth and morphology in unoperated male unilateral cleft lip and palate subjects over 13 years of age. Cleft Palate J, 1990; 27: 7–10

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65. Yücel-Eroğlu E, Gulsen A, Uner O: Head posture in cleft lip and palate patients with oronasal fistula and its relationship with craniofacial morphology. Cleft Palate Craniofac J, 2007; 44: 402–11
66. Ferrario VF, Sforza C, Tartaglia GM et al: Three-dimensional lip morphometry in adults operated on for cleft lip and palate. Plast Reconstr Surg, 2003; 111: 2149–56
67. Stauber I, Vairaktaris E, Holst A et al: Three-dimensional analysis of facial symmetry in cleft lip and palate patients using optical surface data. J Orofac Orthop, 2008; 69: 268–82
68. Berkowitz S: Some questions, a few answers in maxillo-mandibular surgery. The role of muscle and growth. Clin Plast Surg, 1982; 9: 603–33
69. Corbo M, Dujardin T, De Maertelaer V et al: Dentocraniofacial morphology of 21 patients with unilateral cleft lip and palate: A cephalometric study. Cleft Palate Craniofac J, 2005; 42: 618–24
70. Guyer EC, Ellis EE III, McNamara JA Jr. et al: Components of Class III malocclusion in juveniles and adolescents. Angle Orthod, 1986; 56: 7–30
71. Krimmel M, Schuck N, Bacher M et al: Facial surface changes after cleft alveolar bone grafting. J Oral Maxillofac Surg, 2011; 69: 80–83
72. Schwenzer-Zimmerer K, Chaitidis D, Boerner I et al: Systematic contact-free 3D topometry of the soft tissue profile in cleft lips. Cleft Palate Craniofac J, 2008; 45: 607–13

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