AL-ANBAR MEDICAL JOURNAL
Anb. Med. J. 19(1): 24–29, 2023

Evaluation of Orthodontic Treatment Success in Terms of Symmetry in Patients with Class III Malocclusion after Maxillary Expansion and Protraction

Nisreen M. Saleh,[1] Neslihan Ebru Senisik,[2] and Luay Ali Zaidan[1,*]

[1] *Ramadi First Sector for Healthcare, Al-Anbar Health Directorate, Ramadi, Anbar, Iraq.*
[2] *Department of Orthodontics, Faculty of Dentistry, Suleyman Demirel University, Isparta, Turkey.*
(Received : 28 February 2022; Accepted : 5 May 2022; First published online: 19 May 2022)

ABSTRACT

Background: Facial asymmetries are common in patients with skeletal class III malocclusion and posterior crossbite. Maxillary expansion and protraction (ME & P) and then fixed orthodontic treatment may affect positively on these asymmetries.
Objectives: We aimed to investigate the effects of applying ME & P by the rapid maxillary expansion (RME) and face mask and then fixed orthodontic treatment on soft tissue asymmetries in adolescent patients with skeletal class III malocclusion and posterior crossbite. For this purpose, the 3D facial imaging system of stereophotogrammetric (3dMD) recordings was analyzed quantitatively in the pre-treatment (T0), ME & P (T1), and post-fixed orthodontic treatment periods (T2).
Materials and methods: The study included 28 (11 females, 17 males) individuals with skeletal class III malocclusion and posterior cross-bite (5 patients with bilateral and 23 patients with unilateral cross-bite) and soft tissue facial convexity angle of $175.11^{o} \pm 1.06^{o}$ with a mean age of 9.37 ± 0.54 years. Three-dimensional photographs were taken from the individuals before the ME & P (T0), 6 months after the ME & P procedure and before starting fixed orthodontic treatment (T1), and after removing all orthodontic appliances from the mouth at the end of the fixed orthodontic treatment (T2). 3dMD Vultus® software was used to evaluate the data of 34 linear and 16 volumetric as a total of 50 measurements in soft tissue analysis.
Results: The right-left volume differences, the Root Mean Square (RMS) values, and linear width measurements in the upper, mid, and lower face regions when evaluated at the T1-T0, T2-T1, and T2-T0 period intervals, were found to a decrease in these values and improvement of asymmetry.
Conclusion: The asymmetry in the soft tissue in all face regions was corrected with ME & P and fixed orthodontic treatment. The most obvious asymmetry improvement occurs in the lower face area. It should be taken into consideration that asymmetry will improve with RME and face mask application and fixed orthodontic treatment in adolescents with Class III malocclusion and posterior cross-bite and treatment planning should be done according to that.
Keywords: Facial asymmetries; Stereophotogrammetry; Class III malocclusion; Posterior cross-bite; Maxillary expansion and protraction.

DOI: 10.33091/amj.2023.177947

INTRODUCTION

Orthodontic irregularities can be seen in three dimensions of space; sagittal, vertical, and transverse direction. Although Class III malocclusions are less common in the population, they can be easily noticed by patients and their parents in terms of aesthetics and function. Class III malocclusions are one of the most difficult orthodontic anomalies to treat [1]. The global distributions of Class III malocclusion were 5.93% [2] while for the Turkish population according to a study [3] were 252 subjects of 1507 (16.7%) orthodontic patients.

While correcting the sagittal and transversal mismatches of the Class III problem, RME is used to harmonize the upper and lower jawbones and teeth, and a face mask is used to bring the posteriorly located upper jaw forward and the ante-

* Corresponding author: E-mail: luayali82@gmail.com
Phone number: +9647826420407

http://doi.org/10.33091/amj.2023.177947

riorly located lower jaw slightly backward. After the jaws are brought to the appropriate position, the irregularities in the teeth are corrected with a fixed orthodontic treatment [4].

For a long time, balance and aesthetics in facial appearance is at the forefront of orthodontic practice [5]. Teeth and surrounding tissues play an important role in facial aesthetics. Irregularities in these structures negatively affect facial aesthetics. Therefore, hard and soft tissues may be greatly affected and asymmetries may occur [6].

It has been reported that temporomandibular joint problems or facial asymmetry may occur if sagittal and transverse dentofacial anomalies are not treated at an early age [7]. Maxillary narrowing or premature contact (early tooth contact) may cause functional mandibular problems [8].

Facial asymmetry is a three-dimensional problem frequently seen in patients with facial and chin irregularities. Dimensional differences in symmetrical anatomical structures such as cheeks, eyes, and ears have been shown between the right and left halves of the face, but this situation has been reported to be aesthetically acceptable [9]. Even a face with good aesthetics is not completely symmetrical [10]. When the literature is examined, most of the information given about the asymmetry of the face has reported that the right half of the face is wider than the left half [10].

In the past, facial asymmetry has been evaluated with 2D radiographs or photographs in many studies on hard and soft tissues [11]. However, since facial asymmetry is a three-dimensional problem and there is a lack of measurement of the dimensional depth of anatomical points in the 2-dimensional methods used for evaluation, all three aspects of space should be evaluated within the same measurements to make an ideal evaluation [12]. Nowadays, cone-beam computed tomography (CBCT) is justified to solve the assessment of the face in the pediatric population before orthodontic procedures [13]. Digital stereophotogrammetry is one of the methods by which the dimensions of facial soft tissues can be measured, which is a three-dimensional photographic scanning technique, that has recently been used to prevent the damage caused by ionizing radiation resulting from the use of conventional 3D radiographic methods (such as computerized tomography) [14].

Although there is a study using 3D imaging methods, examining the change of asymmetry-symmetry status in soft tissue before and after orthognathic surgery in adult patients with class III malocclusion [15], there is no study that evaluates soft tissue asymmetry-symmetry in adolescent patients with class III malocclusion and posterior crossbite at pre-treatment and post-treatment with the stereophotogrammetric recording technique. Hence, we aimed to use the 3D facial imaging system of stereophotogrammetric (3dMD) recordings to quantitatively analyze the pre-treatment (T0), ME & P (T1), and post-fixed orthodontic treatment periods (T2) in adolescent patients with skeletal class III malocclusion and posterior crossbite.

MATERIALS AND METHODS

This retrospective study was approved by the Ethics Committee of Suleyman Demirel University Health Sciences Institute (reference number 314, 15.10.2020). The reason, purpose, approach, and methods of this research were examined and found appropriate, and it was decided that there was no ethical or scientific objection to the research in the orthodontic clinic.

Inclusion criteria include individuals with skeletal class III malocclusion, posterior crossbite, negative overjet, and concave profile with maxillary deficiency or mandibular excess or a combination of both. Previously applied ME & P followed by fixed orthodontic treatment and finished the active orthodontic treatment, presence of 3D facial photographs at the beginning of the treatment (T0), after ME & P retention (T1), and at the end of fixed orthodontic treatment (T2). While, the patients with any craniofacial anomalies or a history of trauma affecting compliance with the investigator, undergone any facial aesthetic operation such as rhinoplasty before or during the treatment, systemic disease, and the presence of a neuromuscular disorder were excluded from the study.

In our study, the mean age of onset was 9.37 ± 0.54 years for, those who applied to Suleyman Demirel University, Faculty of Dentistry, Department of Orthodontics for treatment, with maxillary retrognathia or mandibular prognathism or a combination of both. The study was conducted on 28 volunteer individuals, 11 girls and 17 boys, with an initial soft tissue facial convexity angle of $175.11^{o} \pm 1.06^{o}$, 5 bilateral and 23 unilateral posterior crossbites, with 3D facial imaging materials at pre-treatment, after treatment with facemask-RME and at the end of fixed appliance.

This study made 3dMD Vultus® (3dMD Vultus® software Version 2,3,0,2, 3dMD, Atlanta, GA, USA) with the "symmetry axis creation feature" presented in the program. In our study, instead of an axis of symmetry based on anthropometric points, the symmetry axis obtained by using the "mirror image method of the face", which is a feature of the program was used. During registration, the program uses its algorithm as in Figure 1. After obtaining the axis of symmetry, right and left face parts can be obtained from the facial surfaces. The right full face is obtained by taking the mirror image of the right face part, and the left full face is obtained by taking the mirror image of the left face part. It is possible to overlap the surfaces of these later created right and left full faces, obtain their differences, and determine their asymmetry quantitatively.

Reference points used in three-dimensional soft tissue evaluation

1-Nasion (N), 2,3-External Canthal Right/Left (EC R-EC L), 4,5-Internal Canthal Right/Left (IC R-IC L), 6-Right Tragion (Tr R), 7-Left Tragion (Tr L), 8-Pronasale (Prn), 9-Right Buccal Contour Point (Bc R), 10-Left Buccal Contour Point (Bc L), 11,12-Alar Right/Left (Al R-Al L), 13,14-Alar Curvature Right/Left (Ac R-Ac L), 15,16-Subalar Right/Left (Sbal R-Sbal L), 17,18-Subnasal Right/Left (Sn R-Sn L), 19-Subnasale (Sn), 20,21-Crista Philtrum Right/Left (Cph R-

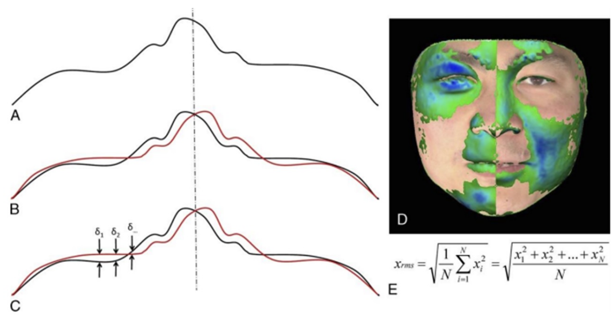

Figure 1. Symmetry axis creation feature.

http://doi.org/10.33091/amj.2023.177947

Cph L), 22-Labiale superior (Ls), 23,24-Lip margins (Chelion) Right/Left (Ch R-Ch L), 25-Labiale inferior (Li), 26-Sublabial (Sl), 27-Pogonion (Pg) and 28-Gnathion (Gn).

In this study, we divided the whole face into three areas (upper, middle, and lower). But to examine the symmetry/asymmetry of the face in more detail, we divided the face into additional five smaller areas which are (nasal, paranasal, upper lip, lower lip, and the lower lip and chin) to be 8 different surface areas.

Measurements used in the study

Twenty-eight linear, 8 volumetric, and 8 RMS measurements were made in the current study. For linear measurements, points were determined on the three-dimensional photographs opened in the 3DMD Vultus program, and linear measurements were measured in millimeters. For volumetric measurements, 8 different face areas were created on the right and left sides of the photographs opened in the 3DMD Vultus program, and volumetric difference measurements were made. The 3DMD Vultus program feature was used for volume measurements. After determining the symmetry plane for RMS measurements, RMS deviation values were obtained by overlapping certain regions of 2 full faces, right and left separately, with 3DMD Vultus software.

Statistical Analyses

Millimetric, volumetric and RMS measurements of one-third of the patients were repeated at all times to determine the error rate in the determination of the reference points used in the study. Cronbach's alpha reliability coefficients were calculated for baseline measurements and method error control. This coefficient was found to be close to 1 for all measurements. IBM SPSS Statistics 20.0 (Statistical Package for Social Sciences, New York, USA) program was used to evaluate the data of 34 linear and 16 volumetric total of 50 measurements. The conformity of the variables to the normal distribution was examined using Kolmogorov-Smirnov/Shapiro-Wilk tests. Descriptive statistics were given using the mean-standard deviation. The linear millimetric measurement findings of the examined reference points were tested with repeated measures analysis of variance (Repeated ANOVA) to test the significance of time-dependent changes in volumetric measurements and 89 RMS measurements. Pairwise comparisons of the LSD test were used. In cases where the Sphericity assumption was not met, it was interpreted according to the Greenhouse-Geisser correction.

RESULTS

In this study, the volumetric difference and RMS value of the right-left areas (upper face, midface, lower face, nasal, paranasal, upper lip, lower lip, and lower lip and chin) decreased during the transition from the T0 period to the T1 period and from the T1 period to the T2 period, and this decrease showed a statistically significant difference between the treatment periods (P-value < 0.05) (Table 1 and 2). Thus, according to the volume difference findings, there was a statistically significant decrease in the T1-T0, T2-T1, and T2-T0 period intervals.

All linear width measurements (nose width, nasal base width, philtrum width, lip width, subalar width, and subnasal width) measured in the midface region increased during the transition from the T0 period to the T1 period but decreased very slightly in the T2 period, and all these changes were statistically significant differences (P-value < 0.05) (Table 3).

In the midface area all right and left linear distances of symmetrical points (right alar curvature, left alar curvature, right alar point, left alar point, right buccal contour, left buccal contour, right chelion, left chelion, right crista philtra, left crista philtra, right subalar, left subalar, right subnasal, left subnasal, right tragion and left tragion) to the symmetry

Table 1. The variation of the volumetric difference between the right and left facial areas was created according to the facial symmetry axis and the treatment periods.*

Right-left volume difference (cc)	T0 Mean±SD	T1 Mean±SD	T2 Mean±SD
Upper face area	2.45 0.86	2.04 0.73	1.90 0.73
Midface area	3.35±0.70	2.89±0.79	2.70±0.77
Paranasal area	2.27±0.94	1.88±0.76	1.58±0.60
Nasal area	1.66±0.57	1.34±0.46	1.17±0.44
Upper lip area	0.68±0.41	0.45±0.29	0.34±0.24
Lower face area	6.10±0.83	4.63±0.70	3.81±0.71
Lower lip and chin area	4.47±1.08	3.34±0.81	2.63±0.87
Lower lip area	0.92±0.50	0.59±0.36	0.47±0.38

* P-value=0.00

Table 2. Variation of the RMS measurements of the right and left facial areas created according to the facial symmetry axis according to the treatment periods.*

Right-left RMS	T0 Mean±SD	T1 Mean±SD	T2 Mean±SD
Upper face area	1.03±0.45	0.79±0.36	0.70±0.36
Midface area	1.95±0.65	1.49±0.37	1.27±0.33
Paranasal area	1.64±0.63	1.20±0.63	0.90±0.58
Nasal area	1.05±0.51	0.76±0.45	0.61±0.35
Upper lip area	0.93±0.48	0.71±0.40	0.60±0.36
Lower face area	2.29±0.92	1.63±0.57	1.29±0.44
Lower lip and chin area	1.38±0.45	0.96±0.40	0.78±0.33
Lower lip area	0.88±0.49	0.58±0.32	0.46±0.27

* P-value=0.00

Table 3. Evaluation of the linear width measurements of the nose and upper lip according to the treatment periods.*

Linear distance (mm)	T0 Mean±SD (mm)	T1 Mean±SD (mm)	T2 Mean±SD (mm)
Al R-al L (nasal width)	31.90±2.24	34.34±2.51	33.20±2.19
Ac R-ac L (nasal floor width)	28.98±2.61	31.37±2.38	30.14±2.24
Cph R-Cph L (philtrum width)	11.41±1.20	13.07±0.86	12.32±0.82
Ch R-ch L(lip width)	44.40±2.26	46.52±2.15	45.68±2.64
Sal R-sbal L (subalar width)	14.18±1.34	15.52±1.71	14.46±1.60
Sn R-sn L(subnasal width)	7.91±0.88	9.16±0.99	8.40±0.74

* P-value=0.00

http://doi.org/10.33091/amj.2023.177947

axis increased during the transition from T0 to T1 period, but decreased slightly in T2 period, and these changes were statistically significant (P-value < 0.05) (Table 4).

The numerical and proportional data of the positions of the unsymmetrical anthropometric points of the patients on the right side left side and midline according to the symmetry axis at the examined times (Table 5).

DISCUSSION

There are various studies in the literature for the evaluation of craniofacial asymmetries with 3D imaging such as CT. However, only hard tissue asymmetry was evaluated in most of the studies performed with tomography [16, 17]. Owing to the high radiation dose and cost of the CT method to the patient, the imaging method with CBCT is preferred over traditional CT. It has been reported that the scanning times of the devices used in the CBCT method vary between 10 and 70 [18]. The disadvantage of this method is an inaccurately reflected soft tissue compared to stereophotogrammetry which records also in less time. In addition, since the soft tissues cannot reflect the real skin color and structure in the recordings taken in CBCT, the resolution is lower and additional software is needed to process the images.

Recently, real face color and structure can be recorded with the most up-to-date technologies such as stereophotogrammetry and laser scanners [19]. The laser scanning technology is one of the 3D imaging methods and is widely used in the research, but the scanning time is between 2-20 seconds, and accurate measurements are limited because the head movements that may occur during this period may distort the recorded images. In studies, it has been reported that the images taken with the laser scanner cannot fully convey the structural differences in the soft tissue and the resting position of the head cannot be fully preserved. In laser scanners, laser light reflects uncontrollably from the skin, so it has been reported that recorded images may be distorted [20]. To overcome these disadvantages of laser scanners, stereophotogrammetry has been developed. Compared to laser scanners, clearer and more precise images are recorded with stereophotogrammetry, especially from the recessed-protruding surfaces of the face [21]. The deficiencies of the previously used methods were eliminated by stereophotogrammetry, and quantitative and reliable anthropometric point data were [22]. The stereophotogrammetry method is advantageous because it provides the most realistic measurement and can record images quickly [23].

The reason why we made our measurements by separating the face into different areas in this study is that the sensitivity of the evaluations made on the whole face is low. For this reason, serious asymmetries can be overlooked [24]. The Root Mean Square Errors (RMS) value, which we used in the study and determined the asymmetry, is the amount of surface differences that occur between two different surfaces after the overlapping of the surface areas. This value reveals the quantitative value of the asymmetry. The larger the selected area, the higher the probability of an increase in the margin of error [25].

As far as is known, no study has been found that evaluates asymmetry in the upper facial region of the soft tissue after the application of ME & P and fixed orthodontic treatment in individuals with class III malocclusion in the adolescent period. Although the upper face region is known to be the region least affected by facial asymmetries [26], a small amount of

Table 4. Evaluation of the anthropometric points with the symmetry axis of the face in the midface region, the linear distance measurement data to the symmetry axis according to the treatment periods.*

Linear distance (mm)	T0 Mean±SD (mm)	T1 Mean±SD (mm)	T2 Mean±SD (mm)
Ac R (right alar curvature)	20.89±1.23	23.13±1.22	21.85±1.16
Ac L (left alar curvature)	20.21±1.34	22.51±1.11	21.36±1.12
Al R (right alar point)	22.45±1.17	24.26±1.37	22.94±1.13
Al L (left alar point)	21.44±0.95	23.55±0.86	22.28±0.82
Bc R (right buccal contour)	42.27±0.66	43.80±0.88	42.62±0.87
Bc L (left buccal contour)	41.23±0.75	43.33±0.81	42.11±0.71
Ch R (right chelion)	25.75±2.36	27.20±2.61	25.86±2.54
Ch L (left chelion)	24.86±2.44	26.80±2.56	25.21±2.62
CphR (right crista philtra)	7.25±0.52	8.30±0.71	7.42±0.46
CphL (left crista philtra)	7.12±0.52	7.95±0.59	7.37±0.46
SbalR (right subalar point)	6.08±0.61	7.19±0.73	6.46±0.66
SbalL (left subalar point)	5.99±0.65	7.16±0.71	6.47±0.56
SnR (right subnasal)	7.00±1.16	8.25±1.13	7.37±1.02
SnL (left subnasal)	7.04±1.19	8.18±1.06	7.42±1.04
TrR (right tragion)	122.33±4.47	123.71±4.96	122.80±4.62
TrL (left tragion)	121.32±4.48	123.47±4.44	122.21±4.37

* P-value=0.00

Table 5. Descriptive table of the position findings of the anthropometric points that are unsymmetrical according to the symmetry axis in the mid and lower face regions and used in soft tissue evaluation.

Anthropometric points	Position	T0 N(%)	T1 N(%)	T2 N(%)
Prn (pro nasal)	Middle	3(10,7)	6(21,4)	10(35,7)
	Right	17(60.7)	15(53.6)	12(42.9)
	Left	8(28.6)	7(25.0)	6(21.4)
Sn (subnasal)	Middle	3(10.7)	8(28.6)	9(32.1)
	Right	16(57.1)	12(42.9)	11(39.3)
	Left	9(32.1)	8(28.6)	8(28.6)
Ls (labial superior)	Middle	7(25.0)	11(39.3)	12(42.9)
	Right	12(42.9)	10(35.7)	9(32.1)
	Left	9(32.1)	7(25.0)	7(25.0)
Sl (sublabial)	Middle	2(7.1)	11(39.3)	12(42.9)
	Right	11(39.3)	8(28.6)	7(25.0)
	Left	15(53.6)	9(32.1)	9(32.1)
Pg (pogonion)	Middle	2(7.1)	5(17.9)	5(17.9)
	Right	10(35.7)	9(32.1)	9(32.1)
	Left	16(57.1)	14(50.0)	14(50.0)
Gn (gnathion)	Middle	2(7.1)	5(17.9)	5(17.9)
	Right	10(35.7)	9(32.1)	9(32.1)
	Left	16(57.1)	14(50.0)	14(50.0)

http://doi.org/10.33091/amj.2023.177947

asymmetry in the upper face region was found in our study, and this asymmetry was found in both the right-left upper facial area volumetric difference and RMS measurements and it decreased significantly in response to both treatment and the effect of growth and development [13].

The reason for the increase in linear width measurements after ME & P compared to pre-treatment (T1-T0) is the skeletal and dental expansion and protraction with RME and face mask. The decrease in the T2-T1 period may be due to relapse after skeletal expansion and advancement. Soft tissues surrounding the skeletal structures are one of the most important factors of the relapse mechanism. The facial muscles, masticatory muscles, and fascia are partially elastic and are stretched by the forces applied during expansion and advancement. However, there is no clear information about how much the adaptation of these ligaments, muscles, and fascia stretched with treatment will be after treatment [27]. It is noteworthy that linear width measurements increased after total treatment compared to pre-treatment (T2-T0) despite relapse in tissues. Our study findings are in line with the findings of various studies reporting soft tissue measurement results in the mid-face region after ME & P [25, 28, 29].

The most effective factor in defining facial asymmetry is the deviation of the mandibular chin. Hwang et al [30] stated that the deviation of the chin tip was caused by the difference in ramus height. However, they also reported that there are other possible causes for jaw deviation, such as differences in mandibular corpus length. Severt and Proffitt [26] stated that asymmetry is mostly seen in the lower third of the face. However, they found that 85% of the jaw deviation in patients with dentofacial deformity had a leftward deviation. In our findings, n = 16/28 (57.1%) showed parallelism with the above findings, since the pogonion and gnathion points of the patients were mostly located on the left side as shown in Table 5.

The fact that the sizes of the areas where we evaluated the asymmetry differences were different from each other prevented us from comparing these surface area sizes with each other. The inability to make this comparison is a limitation of this study since there is no control group with similar characteristics to the study group. During the statistical evaluation of the data of this study, firstly, the individuals were evaluated by considering their gender. Because the gender differences were statistically insignificant, the data for boys and girls were pooled.

CONCLUSION

We can conclude from the current study that 1) the volume differences and RMS values in all 8 face regions have decreased. Combined treatment reflecting the combined effect of ME & P (T1) and fixed orthodontic treatment (T2) is effective in asymmetry improvement. 2) Nasal width, nasal base width, philtrum width, lip width, subalar width, and subnasal width, which are all linear measurements in the midface region; it has been evaluated at starting of treatment (T0), ME & P (T1) and fixed orthodontic treatment (T2) and it found to be increased at ME & P (T0-T1) and decreased during fixed orthodontic treatment (T1-T2) but as a total treatment period (T0-T2) it found to be increased. 3) The positions and the linear distances of the non-symmetrical anthropometric points used in soft tissue evaluation in the mid-face region and lower face region to the axis of symmetry approached the axis of symmetry in all periods. The most obvious approach in the midface region was at the subnasal point while in the lower face region was at (pogonion, gnathion). This position and distance change indicates that the asymmetries are effectively corrected. Moreover, the most obvious asymmetry improvement occurs in the lower face area and this is because after ME & P the mandible is located in the correct position after being released from premature contact caused by the crossbite.

ETHICAL DECLARATIONS

Acknoweldgements

None.

Ethics Approval and Consent to Participate

Written approval had been gained from the Ethics Committee of Suleyman Demirel University Health Sciences Institute (reference number 314, 15-10-2020). Study data/information was used for the research purpose only. Informed consents from every participant was taken.

Consent for Publication

Not applicable (no individual personal data included).

Availability of Data and Material

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that there is no conflict of interest.

Funding

No funding.

Authors' Contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

REFERENCES

[1] M. P. F. Martino and R. Joubert. Surgical-orthodontic retreatment of a severe skeletal class iii malocclusion following an orthodontic camouflage. *Dental Press J. Orthod.*, 26, 2021.

[2] M. S. ALHAMMADI *et al.* Global distribution of malocclusion traits: A systematic review. *Dental press journal of orthodontics*, 23(40):e1–40, 2018.

http://doi.org/10.33091/amj.2023.177947

[3] M. Celikogluand, S. Akpinar, and I. Yavuz. The pattern of malocclusion in a sample of orthodontic patients from Turkey. *Med Oral Patol Oral Cir Bucal*, 15(5):e791–6, 2010.

[4] R. M. Moyers R. Early treatment, handbook of orthodontics. *4th ed. Chicago, Yearbook Medical Pub Inc*, 1988.

[5] S. E. Bishara, P. S. Burkey, and J. G. Kharouf. Dental and facial asymmetries: a review. *The Angle Orthodontist*, 64(2):89–98, 1994.

[6] H. A. Kiyak. Patients and parents expectations from early treatment. *American journal of orthodontics dentofacial orthopedics*, 129(4):S50–S54, 2006.

[7] W. R. Proffit. The timing of early treatment: an overview. *American journal of orthodontics dentofacial orthopedics*, 129(4):S47–S49, 2006.

[8] K. Ishizaki, K. Suzuki, T. Mito, E. M. Tanaka, and S. Sato. Morphologic, functional, and occlusal characterization of mandibular lateral displacement malocclusion. *American Journal of Orthodontics Dentofacial Orthopedics*, 137(4):454. e1–454. e9, 2010.

[9] M. Alqattan, J. Djordjevic, A. I. Zhurov, and S. Richmond. Comparison between landmark and surface-based three-dimensional analyses of facial asymmetry in adults. *European Journal of Orthodontics*, 137(1):1–12, 2015.

[10] A. M. Launonen *et al.* Craniofacial asymmetry from one to three years of age: A prospective cohort study with 3d imaging. *J. Clin. Med.*, 9(1):70, 2020.

[11] T. S. Douglas. Image processing for craniofacial landmark identification and measurement: a review of photogrammetry and cephalometry. *Computerized Medical Imaging Graphics*, 28(7):401–409, 2004.

[12] K. F. O'Grady and O. M. Antonyshyn. Facial asymmetry: three-dimensional analysis using laser surface scanning. *Plastic reconstructive surgery*, 104(4):928–937, 1999.

[13] S. T. Häner, G. Kanavakis, F. Matthey, and N. J. S. r. Gkantidis. Valid 3d surface superimposition references to assess facial changes during growth. *Sci Rep*, 11:16456, 2021.

[14] O. Erten and B. N. Yilmaz. Three-dimensional imaging in orthodontics. *Turk J Orthod.*, 31(3):86–94, 2018.

[15] D. G. F. Da Pozzo, G. A. Beltramini, C. Dolci, A. B. Giann, and C. Sforza. Sthe effect of orthognathic surgery on soft-tissue facial asymmetry: a longitudinal three-dimensional analysis. *J. Craniofac. Surg*, 31(6):1578–1582, 2020.

[16] M. Maeda *et al.* 3d-ct evaluation of facial asymmetry in patients with maxillofacial deformities. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, Endodontology*, 102(3):382–390, 2006.

[17] S. C. White and E.-K. Pae. Patient image selection criteria for cone beam computed tomography imaging. *Seminars in Orthodontics*, 15(1):19–28, 2009.

[18] W. C. Scarfe, A. G. Farman, M. D. Levin, and D. Gane. Essentials of maxillofacial cone beam computed tomography. *The Alpha Omegan*, 103(2):62–67, 2010.

[19] C. H. Kau, S. Richmond, A. Incrapera, J. English, and J. J. Xia. Three-dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery. *Int J Med Robot*, 3(2):97–110, 2007.

[20] G. McAvinchey, F. Maxim, B. Nix, J. Djordjevic, R. Linklater, and G. Landini. The perception of facial asymmetry using 3-dimensional simulated images. *The Angle Orthodontist*, 84(6):957–965, 2014.

[21] D. Germec-Cakan, H. I. Canter, B. Nur, and T. Arun. Comparison of facial soft tissue measurements on three-dimensional images and models obtained with different methods. *Journal of Craniofacial Surgery*, 21(5):1393–1399, 2010.

[22] P. Metzler *et al.* Craniofacial landmarks in young children: how reliable are measurements based on 3-dimensional imaging? *Journal of Craniofacial Surgery*, 23(6):1790–1795, 2012.

[23] P. Metzler, E. J. Geiger, C. C. Chang, and D. M. Steinbacher. Surgically assisted maxillary expansion imparts three-dimensional nasal change. *Journal of Oral Maxillofacial Surgery*, 72(10):2005–2014, 2010.

[24] T. Verhoeven *et al.* Three dimensional evaluation of facial asymmetry after mandibular reconstruction: validation of a new method using stereophotogrammetry. *International journal of oral maxillofacial surgery*, 42(1):19–25, 2013.

[25] E. Staderini, R. Patiniand M. De Luca, and P. Gallenzi. Three-dimensional stereophotogrammetric analysis of nasolabial soft tissue effects of rapid maxillary expansion: A systematic review of clinical trials. *Acta Otorhinolaryngologica Italica*, 38(5):399–408, 2018.

[26] T. Severt and W. Proffit. The prevalence of facial asymmetry in the dentofacial deformities population at the university of north carolina. *The International journal of adult orthodontics orthognathic surgery*, 12(3):171–176, 1997.

[27] K. Ueki *et al.* Changes in the lip closing force of patients with class iii malocclusion before and after orthognathic surgery. *International journal of oral maxillofacial surgery*, 41(7):835–838, 2012.

[28] G. Kurt, T. Uysal, and A. Yagci. Soft and hard tissue profile changes after rapid maxillary expansion and face mask therapy. *World journal of orthodontics*, 11(4):e10–8, 2010.

[29] V. Moshkelgosha, A. Raoof, A. Sardarian, and P. Salehi. Photogrammetric comparison of facial soft tissue profile before and after protraction facemask therapy in class iii children (6-11 years old). *Journal of Dentistry*, 18(1):7–16, 2017.

[30] H.-S. Hwang, C. H. Hwang, K.-H. Lee, and B.-C. Kang. Maxillofacial 3-dimensional image analysis for the diagnosis of facial asymmetry. *American journal of orthodontics dentofacial orthopedics*, 130(6):779–785, 2006.