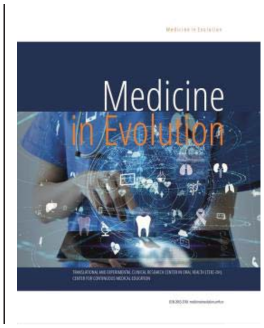
Facial Asymmetry Assessment in Orthodontic Patients with Posteroanterior Cephalometric Analysis



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Abstract

This study aimed to evaluate facial asymmetry parameters using posteroanterior (PA) cephalometric analysis in 15 orthodontic patients diagnosed with transverse dento-skeletal anomalies. Patients were selected based on the indication for frontal cephalometry at the Clinic of U.M.F. "Victor Babeş" Timişoara, with a distribution of 60% female and 40% male, aged between 15 and 37 years. Parameters were evaluated using the Ricketts and Grummons cephalometric analyses. Measurements were performed digitally using AudaxCeph software (versions 5.0 and 6.0), minimizing manual tracing errors. Statistical analysis included means, standard deviations, and independent t-tests, which revealed no significant gender differences but significant differences between age groups. Five cases demonstrated marked asymmetry. Statistically significant differences were observed between low and high asymmetry groups for maxillomandibular line deviation, facial symmetry, and nasal width.

Keywords: facial asymmetry, cephalometry, orthodontics, posteroanterior analysis

INTRODUCTION

The facial symmetry is an important component of a person's attractiveness, representing one of the determining factors in its evaluation. In reality, there is currently no perfect bilateral body symmetry in living human organisms. Any two congruent mirror images that exist in nature usually show right-left variations. People frequently show functional and morphological asymmetries in the shape of the right hand compared to the left, as well as a preference for one eye or one foot over the other. Functional asymmetry id favorable to aesthetic symmetry, but fluctuating asymmetry is common and more natural, even if some patients consider it noticeable.

The original concept of symmetry of the human face was first illustrated by the artist Leonardo da Vinci through the study of human anatomy. Based on mathematical and geometrical analysis, he put togheter in collaboration with Luca Pacioli in the asthetic traise "De Divina Proporzione", where for the first time it was invoked the role of the "golden proportion" [1].

Facial asymmetry in humans can arise from a complex interplay of genetic and environmental factors influencing bilateral development. Van Valen categorized asymmetries into three types: directional, antisymmetric, and fluctuating. Fluctuating asymmetry, which reflects an individual's reduced ability to develop identical bilateral structures, has been reported in craniofacial morphology and both primary and permanent dentition. While directional and antisymmetry are typically considered part of normal development, fluctuating asymmetry may signal underlying developmental instability. In clinical practice, the terms lateroocclusion and laterognathism help differentiate between apparent facial asymmetries of functional origin and true skeletal asymmetries, respectively. The former often arises from mandibular deviations related to occlusal disturbances, whereas true asymmetries are frequently associated with congenital skeletal conditions such as syndromes, hypoplasias, or hyperplasias [2].

The orofacial region undergoes dynamic growth and remodeling throughout life, leading to changes in both skeletal and soft tissues. Bone deposition, resorption, and soft tissue adaptation shape facial structures over time, creating age-related differences in facial form and occlusion. Facial asymmetry arises when the midline of the face is deviated, often due to abnormal jaw growth, and can affect features such as the jawline and dental alignment. While mild asymmetries are usually unnoticed, more pronounced deviations may impact both function and aesthetics [3]. The external appearance of the patient depends on the constitutional composition of his skeleton, the position of the facial bones in relation to the cranial base; the relationship between the upper and lower jaws; the way they intercuspate, the thickness of the soft tissue that lies over the facial skeleton and the size of the nose, lips and chin as well [4].

Facial analysis, alongside bite examination, guides diagnosis and treatment planning by highlighting key aesthetic features [5].

Occlusal harmony is guided by facial aesthetics, influencing orthodontic or surgical choices. Posteroanterior cephalograms aid in evaluating craniofacial symmetry, with digital analysis improving accuracy by automating measurements [6] .

To make an objective differentiation between minor and major asymmetry, quantification of it is recommended. This makes it possible to demonstrate the amount of asymmetry for diagnostic purposes, to observe the development of asymmetry during growth and to evaluate the results of treatment. On the other hand, qualitative analysis allows differentiation between problems of skeletal, dental or soft tissue origin thus suggesting the diagnosis, planning and design of mechanical treatment [7].

Various methods of assessing facial morphology have been used in the literature. The posteroanterior cephalogram has been considered one of the most valuable diagnostic aid for assessing asymmetry, to study the goals of treatment, as well as to evaluate improvements in facial or dental proportions. Grummons and Kappeyne Van De Coppello developed a major analysis system for assessing facial asymmetries. The main purpose of Grummons' analysis was to determine asymmetry rather than actual discrepancies to identify individual differences, and normative data were not presented in this system [8].

This study aimed to assess the effectiveness of cephalometric analysis—particularly posteroanterior techniques—in evaluating facial asymmetry and supporting accurate diagnosis. By analyzing specific parameters, the goal was to identify key indicators of asymmetry and enhance diagnostic precision and treatment planning in orthodontic patients.

MATERIALS AND METHODS

This retrospective, observational, and analytical study initially included 50 Romanian patients aged between 15 and 37 years, who presented at the "Victor Babeş" University of Medicine and Pharmacy, Timișoara, between 2013 and 2020. All patients underwent clinical and radiological assessments for diagnostic purposes, including facial and intraoral photographs, study models, orthopantomograms, and frontal cephalometric radiographs. All procedures were conducted in accordance with the Declaration of Helsinki and were approved by the Ethics Committee of the "Victor Babeş" University of Medicine and Pharmacy, Timișoara (Approval Code: Aviz CECS al UMFTVB 13/26.03.2021). Informed consent was obtained from all participants prior to inclusion in the study.

Posteroanterior (PA) cephalograms were acquired using the Cranex 3D (Soredex) device at the Dentavis Radiology Center in Timișoara. Patient positioning included head stabilization, use of a cephalometric light to align the Frankfurt plane, and incorporation of a calibration ruler on both sides of the image. All images were captured with the teeth in maximum intercuspation.

Out of the 50 initial PA cephalograms, 35 were excluded based on predefined exclusion criteria. The final sample included 15 cases. Digital linear, angular, and volumetric measurements were performed using AudaxCeph software—version 5.0 for Ricketts analysis and version 6.0 for the Grummons and Kappeyne Van De Coppello analysis.. The parameters and the results are illustrated in figure 1 and described in the table1.

The study focused on 15 dental and skeletal parameters described by Ricketts, as well as additional asymmetry-related landmarks used by Grummons, including:

CoR/CoL – condylion (the most superior point on the mandibular condyle);

Cg – Galli crest;

OccR/OccL – the point where the first molars occlude;

A1 – The most marginal point at the incisal level of the upper central;

B1 - The most marginal point at the incisal level of the lower central;

To evaluate the discrepancies of facial asymmetry, four components of the PA analysis described by Grummons and Kappeyne Van De Kopello were used, which present left-right values, which were generated by the AudaxCeph version 6.0 program, after tracing the analysis, locating the anthropometric points and plotting the bone counts, as you cand see in figure 2.

The reference planes that you can see in Figure 1 are defined as follows and grouped into the following cranial relationships, which they describe:

Dental relationships are represented by:

<u>Left and right molar relationships</u> (A6-B6/6B-6A): measures the distance between the upper and lower first molars at the most lateral point on the buccal surface of each.

Intermolar width – is measured from the occlusal surface of the lower first molar to its analogue and is helpful in determining the etiology of reverse occlusion.

Intercanine width – from the cusp tip of the right lower canine to the left. The distance has a normal value of 22.7mm at the age of 7 years (in unerupted teeth) and increases by 0.8mm/year until the age of 13 years when it reaches the normal adult value (27.5mm).

The **skeletal** relationships are defined by the following measured planes:

Right and left maxillomandibular width – represents the distance measured from the Jugal process (JL/JR) to the frontofacial plane (ZL-AG/ZR-GA).

Maxillomandibular midline: the angle formed between the ANS-Me plane perpendicular to the ZA-AZ plane (Facial width). The variation of this angle is significant in determination of the deviation of the mandibular midline from the mid-sagittal plane. If asymmetry is present, this could be the consequence of functional or skeletal problems.

Maxillary width (JL-JR) – its value indicates the transverse development and should be taken into account for planning and evaluating palatal expansion.

Mandibular width (AG-GA) – its value compared to the normal value described by Ricketts shows whether the mandible is developed correctly or not.

Dento-skeletal relationships: are mainly defined by the distance from the lower first molar to the JR-GA/JL-AG plane.

Cranio-facial relationship: is defined by the angle formed between the ZA-AG-ZL/AZ-GA-ZR reference points.

Symmetry is calculated by the difference between the values of the two angles - on the left and on the right - and has a mean value of 0°, and the standard deviation is +/- 2°.

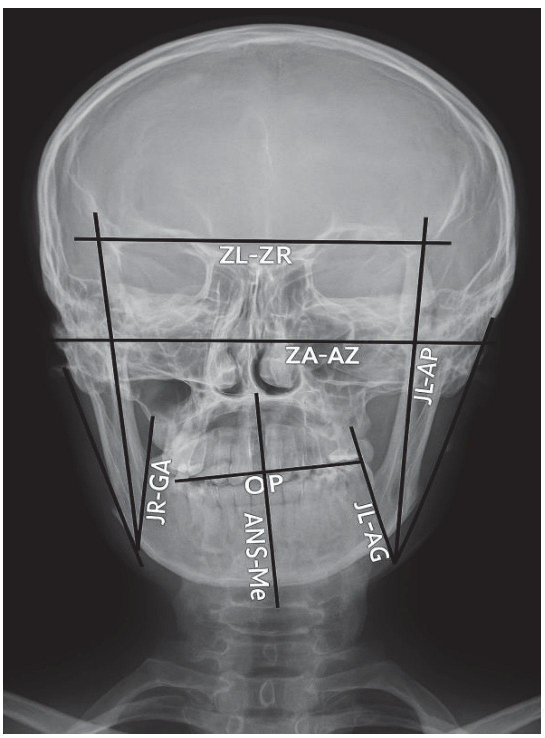

Figure 1. Results representation of the PA-Riketts measurement exported in pdf

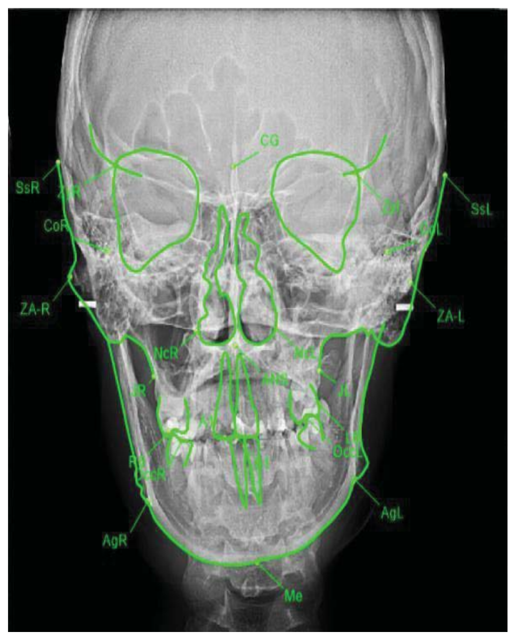

Figure 2. Cephalometric parameters and bone contouring in Grummons analysis

Table 1. Abbreviations and Anatomical Reference Points Used in Craniofacial Analysis

Abbreviation	*Anatomical Reference Point*
ZL/ZR	Innermost point on the fronto-zygomatic suture
ZA/AZ	Outermost (lateral) point of the zygomatic arch
ANS	Anterior nasal spine
CN/NC	Outermost point of the nasal cavity
JL/JR	Highest point on the maxillary alveolar process
AG/GA	Deepest point of the antegonial depression
Me	Lowest point of the mandibular symphysis
A6 / 6A	Outermost point on the vestibular surface of the upper first molar
B6 / 6B	Outermost point on the vestibular surface of the lower first molar
B3 / 3B	Cusp tip of the canine
CoR / CoL	Highest point on the mandibular condyle
Cg	Crista Galli
OccR / OccL	Point of occlusion of the first molars
A1	Most marginal point at the incisal edge of the upper central incisor
B1	Most marginal point at the incisal edge of the lower central incisor

RESULTS

The obtained data were grouped in the MS Office Excel 16.0 program and statistical analyses were performed in the SPSS 24.0 program (SPSS, Chicago, IL). For the 15 selected analyses, the mean value and standard deviation were calculated, then they were divided into 2 age groups: the first between 15-22 years and the second group between 24-37 years. The independent T-test was calculated to analyze the differences between sexes, for the 2 age groups. Pearson correlation coefficients were also calculated for both types of analyses.

The data were obtained from 15 PA cephalometric analyses, of which 40% were men and 60% were women, aged between 15 and 37 years. The mean age was 23 +/- 1 year, with the same mean value for women and 21 +/- 1 year for men.

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After interpreting the measurements resulting from the Ricketts PA analysis, we observed that 5 patients had a significantly deviated maxillo-mandibular midline. Each subject presented, along with this significant deviation, reverse occlusion of mainly skeletal etiology, being accompanied in some cases by dental etiology. This anomaly in the transverse plane determined, moreover, the facial asymmetry of the evaluated patients.

The values measured in the Ricketts PA analysis were subjected to descriptive statistics that present the mean value (Mean Statistic), mean error value (Mean Std.Error) and standard deviation (Std. Deviation Statistic).

Table 2. Descriptive statistics of the measurements of the PA- Ricketts parameters

Descriptive statistics of the measurements of the PA-Ricketts parameters

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Right molar relation	15	-.93	.539	2.086
Left molar relation	15	-.53	.456	1.767
Intermolar distance	15	53.40	.999	3.869
Intercanine distance	15	24.20	.509	1.971
Left maxillomadibular width	15	12.20	.763	2.957

Right maxillomandibular width	15	11.73	.771	2.987
Maxillomandibular line deviation	15	2.93	.714	2.764
Face symmetry	15	1.87	.446	1.727
Nasal width	15	28.87	.506	1.959
Maxilar width	15	56.93	1.110	4.301
Mandibular width	15	78.53	1.095	4.240
Valid N (listwise)			15	

The subjects were grouped into 2 groups, according to age: The first group was from 15 to 21 years old, and the second from 22 to 37 years old. The average values of the measurements of the 2 groups were then compared and represented by a diagram (Table 3). As we can see, differences between the age groups were in the maxillary, mandibular width and the angles of the internal structures measured in the maxilla (Max) and mandible (Mand), where the average value in the younger group was higher than in the mature group. In the intermolar and intercanine distances and the proportion of internal structures (Prop) the values are almost equal, the younger group exceeding the mature group by only a few decimals. In the values of the left and right maxillo-mandibular widths, the average values can be observed with a few decimals higher in the age group from 22 to 37 years old.

To study the correlation between each of the 15 PA (Ricketts) analyses, Pearson correlation coefficients were calculated (Table 3). The coefficient with the highest value was between the mandibular and left maxillomandibular widths (r = 0.929), and the one with the lowest value was found between the maxillary and left maxillomandibular widths (r = 0.01). Significant correlations were found between the intermolar and intercanine distances (r =32

0.607) at p=0.05. For the p=0.01 level, the significant coefficients with the highest value were found between the mandibular width (Ag-Ag) and the right maxillo-mandibular width (r=0.644), and the significant coefficients with the lowest value were found to be between the maxillary width (JL-JR) and the left maxillo-mandibular width (r= -0.752).

Table 3. Correlation between each of the 15 PA (Ricketts) analyses, Pearson correlation coefficients

Correlations

		Relaţia molară dreaptă	Relaţia molară stângă	Distanţa intermolară	Distanţa intercanină	Lăţimea maxilo-mandibulară stângă	Lăţimea maxilo-mandibulară dreaptă	Lăţimea nazală	Lăţimea maxilară	Lăţimea mandibulară
Relaţia molară dreaptă	Pearson Correlation	1	-.183	-.101	-.281	-.280	-.008	.125	.152	-.158
	Sig. (2-tailed)		.513	.721	.310	.312	.976	.658	.589	.575
	N	15	15	15	15	15	15	15	15	15
Relaţia molară stângă	Pearson Correlation	-.183	1	-.081	.094	.350	.066	-.187	-.259	-.026
	Sig. (2-tailed)	.513		.773	.738	.201	.816	.504	.352	.927
	N	15	15	15	15	15	15	15	15	15
Distanţa intermolară	Pearson Correlation	-.101	-.081	1	.607*	-.232	-.194	.187	.410	-.088
	Sig. (2-tailed)	.721	.773		.016	.405	.488	.506	.130	.755
	N	15	15	15	15	15	15	15	15	15
Distanţa intercanină	Pearson Correlation	-.281	.094	.607*	1	-.032	-.209	-.085	.187	-.082
	Sig. (2-tailed)	.310	.738	.016		.910	.456	.763	.504	.771
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilo-mandibulară stângă	Pearson Correlation	-.280	.350	-.232	-.032	1	.209	-.242	-.752**	.025
	Sig. (2-tailed)	.312	.201	.405	.910		.456	.386	.001	.929
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilo-mandibulară dreaptă	Pearson Correlation	-.008	.066	-.194	-.209	.209	1	-.434	-.469	.644**
	Sig. (2-tailed)	.976	.816	.488	.456	.456		.106	.078	.010
	N	15	15	15	15	15	15	15	15	15
Lăţimea nazală	Pearson Correlation	.125	-.187	.187	-.085	-.242	-.434	1	.330	-.275
	Sig. (2-tailed)	.658	.504	.506	.763	.386	.106		.230	.322
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilară	Pearson Correlation	.152	-.259	.410	.187	-.752**	-.469	.330	1	.143
	Sig. (2-tailed)	.589	.352	.130	.504	.001	.078	.230		.611
	N	15	15	15	15	15	15	15	15	15
Lăţimea mandibulară	Pearson Correlation	-.158	-.026	-.088	-.082	.025	.644**	-.275	.143	1
	Sig. (2-tailed)	.575	.927	.755	.771	.929	.010	.322	.611	
	N	15	15	15	15	15	15	15	15	15

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSIONS

A minor and major asymmetry is an important factor in quantifying asymmetry. For diagnostic and clinical purposes during growth, but also in adults and to evaluate the results of treatment, quantification is indispensable to visualize the amount of asymmetry. This is best observed and evaluated in the Grummons analysis. For the analysis of asymmetry to be qualitative, skeletal, dental or soft tissue origin problems help in the diagnosis and treatment planning. Comprehensive analysis of facial asymmetry, horizontal planes, mandibular morphology, maxillomandibular relationship, and evaluation of linear asymmetry parameters are important in many fields of medicine and dentistry, especially among plastic and reconstructive surgeons, dentoalveolar and maxillofacial surgeons, orthodontists, and maxillofacial prosthodontists [9]. Alexa et al. (2022) highlighted the relevance of accurate skeletal asymmetry evaluation through imaging techniques, supporting the continued use of posteroanterior cephalometric analyses for identifying mandibular deviations and guiding clinical interventions [10].

Cephalometric analysis procedures have been used to determine the dental, skeletal, lateral, and facial components of normal and malocclusion in individuals from different populations, using different types of analysis [11,12]. For severe cases, laterolateral cephalometric analysis is helpful in establishing orthodontic diagnosis, treatment planning, and follow-up. However, an accurate diagnosis of differences in a horizontal plane, mandibular morphology, maxillomandibular relationship and assessment of linear asymmetry may also require an estimate of postero-anterior cephalometry.

After evaluating the measurements obtained from the Ricketts analysis, we observed in the five patients a degree of increased asymmetry, due to the very inclined maxillo-mandibular midline and in one case the asymmetry of the upper face exceeding the critical value of 4. Each of these patients had unilateral reverse occlusion, some also bilateral of skeletal etiology, to which was also joined reverse occlusion of dental origin. The deviation of the maxillo-mandibular midline was towards the side where the reverse occlusion was present. In all these patients the maxillary width (JL-JR) presented significantly lower values, compared to the normal value. In some of these cases, the width of the piriform apertures (NC-CN) was also smaller than the normal value for the corresponding age. The mandibular width (AG-GA) was in most cases significantly increased compared to the normal value. In two of these patients, the mandibular width was also observed to be smaller than the average value, thus the maxilla and mandible were compressed. In these cases, it is necessary to intervene as soon as possible with expansion treatment, if growth still allows this.

These findings align with previous literature on the distribution of facial asymmetries. Severt and Proffit reported that facial asymmetry affects the upper, middle, and lower thirds of the face in approximately 5%, 36%, and 74% of cases, respectively, with the lower third being most commonly involved. This predominance in the lower facial region may be attributed to the prolonged period of mandibular growth. Additionally, Chew et al. found that 35.8% of patients with dentofacial deformities exhibited asymmetry, most frequently among those with Class III occlusal relationships [13,14] .

In patients with lateral reverse occlusion and midline deviation, orthodontic treatment aims to rehabilitate the asymmetry of muscle activity between the side with reverse occlusion and the other side, but also the changed position of the condyle caused by the deviation of the mandible. The muscular type of lateral reverse occlusion occurs as a result of the adjustment of the orofacial muscles at the first contact of some teeth. This premature contact determines the lateral deviation of the mandible, which is placed in a compensatory adaptive position. The mandible is displaced towards one side of the face, causing a distortion of the harmony of the patient's face. This type of lateral reverse occlusion is also called forced reverse occlusion, and usually the first contact is in the canine area [15]. The mandible is positioned diagonally to the maxilla, as it moves in a sagittal and transverse position [16] .

Multiple studies [17–19] have confirmed that cephalometric radiography remains a cornerstone of orthodontic diagnosis and treatment planning. When facial asymmetry is clinically suspected, the use of posteroanterior cephalograms offers a reliable means to assess its presence and severity, guiding practitioners toward more accurate and individualized therapeutic approaches.

CONCLUSIONS

In conclusion, we consider posteroanterior (PA) cephalometric radiography to be one of the most accessible and valuable tools for identifying and assessing transverse skeletal and dental imbalances. The information it provides is essential for establishing a differential diagnosis in cases of lateral reverse occlusion—whether of dentoalveolar or skeletal origin—and for evaluating transverse deficiencies of the maxilla, mandibular overdevelopment, or a combination of both.

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Conflicts of Interest

The authors declare no conflict of interest. The study was supported by the “Victor Babeş” University of Medicine and Pharmacy, Timişoara. The institution had no role in the study design, data collection and analysis, manuscript preparation, or decision to publish the results.

Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki, and the research protocol was approved by the Ethics Committee of the “Victor Babeş” University of Medicine and Pharmacy, Timişoara (Approval Code: Aviz CECS al UMFTVB Nr. 13/26.03.2021). All subjects gave their informed consent for inclusion before participating in the study.

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