Original Article

The Alternative Use of a Nonconventional Orthopantomograms Analysis Technique for Facial Skeletal Assessment

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Abstract

Context: Cephalometric analysis to assess facial skeletal patterns does not come without limitations. Complementary radiographic analysis has been suggested by many authors to better analyze facial patterns and discrepancies. **Aims:** This study aims to find correlations between the vertical and sagittal relationships of cephalograms and orthopantomograms (OPG), use the OPG to assess facial symmetry, and test the efficacy of a novel OPG analysis technique in the skeletal facial analysis. **Settings and Design:** Cephalograms, OPG, and facial pictures were taken from 23 volunteers from the orthodontic clinic at RAKCODS (13 males and 10 females). **Subjects and Methods:** Symmetry was assessed in the OPG. The traditional cephalometric analysis was performed and correlated to an experimental OPG technique. Facial convexity (pictures) and cephalometric measurements were used to identify participants with normal facial skeletal patterns. Preliminary standards for the OPG analysis technique were determined from this normal subgroup. **Statistical Analysis Used:** Pearson's correlation was used to assess the relation between angles. means and standard deviations were calculated to establish norms. **Results:** Significant correlations were observed between the cephalometric analyses and the OPG technique. Perfect symmetry was uncommon. Sagittal, vertical, and transverse preliminary norms were established. **Conclusions:** Perfect symmetry is uncommon, which makes lateral cephalometric analysis insufficient to analyze facial skeletal patterns. Complementary frontal assessment may improve the accuracy of orthodontic diagnosis. The OPG technique introduced in this study correlates with traditional cephalometric analysis and can be a potential adjunct to cephalometric analysis. Further studies using a larger sample should be used to establish more reliable measurement standards.

Keywords: Cephalometry, orthodontics, orthopantomogram, skeletal pattern

Introduction

Facial skeletal patterns are just as important to orthodontic treatment as interarch and intraarch dental relationships. Several radiographic techniques are used to determine the facial skeletal pattern of a patient. Cephalometry has been the quintessential tool to determine facial skeletal patterns. Cephalometric analysis is performed in a two-dimensional image with overlapping structures, which assumes that the patient is symmetric.[1] Despite this shortcoming, it has the most well-documented clinical success in facial skeletal pattern determination. A variety of measurements have been applied to cephalometric analysis. In the 1950s, Cecil Steiner developed what is considered to be one of the first cephalometric analysis techniques that are still used to this day. It mainly uses the A point, nasion, B point angle to measure the skeletal jaw discrepancy.[2] Ricketts later modified the technique to introduce the Frankfort horizontal plane (FH) as the reference plane rather than the sella to nasion plane (SN) used in Steiner's analysis.[3] Other techniques developed throughout the years include McNamara's, Down's, Sassouni's, and Witt's analyses. They are all based on a series of bone landmarks that can be associated to represent craniofacial proportions. Measurements are tested in patients with esthetically pleasing faces and ideal dental relations to establish norms.[4]

Ideal analysis of facial skeletal patterns should assess facial bones in all three planes of space. The use of cone beam computed tomography (CBCT) is currently being explored for such investigations. CBCT produces a three-dimensional image thus allowing further image processing using software

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for orthodontic measurements.[5] However, CBCT is more expensive than other conventional radiographic equipment, delivers higher doses of radiation, and is susceptible to the production of image artifacts due to some restorations.[5-7] An alternative to three-dimensional analysis using CBCT could be the use of orthopantomograms (OPG) to complement findings from cephalograms. Orthopantamography gives a broad coverage with minimum overlapping of bilateral structures and is the most readily available radiographic tool in dental clinics.[8,9] OPG can also facilitate the assessment of impacted teeth, periodontal bone support, and missing or supernumerary teeth.[10] Disadvantages of OPG include image distorted, unequal magnification, and the inability to display fine anatomic details.[10,11]

Previous studies on the use OPG for skeletal pattern analysis have focused on symmetry.[12,13] The Levandoski analysis has introduced landmarks for linear facial skeletal analysis in OPG. In addition, angular measurements for angular analysis of the OPG have been suggested.[14] These studies have used conventional OPG techniques where the patient is biting on a plastic guide, and the mandible is displaced toward an edge-to-edge position. This may allow for the analysis of symmetry but not for analysis of interarch relationships which are of great relevance to orthodontic diagnosis.

The aim of this study is to assess vertical and anteroposterior skeletal relationships using OPG. A modified modality of OPG will be used to overcome the deficiencies observed in prior studies. Correlation between traditional cephalometric analysis measurements and novel OPG analysis measurements will be assessed for validation. Symmetry will be examined to justify the need of bilateral facial skeletal analysis. Finally, the new measurements will be applied to a standardized sample of participants with normal facial skeletal relationships to obtain preliminary norms.

Subjects and Methods

Subjects

Twenty-three participants of both genders between the age of 20 and 26 (13 males and 10 females) were selected from the orthodontic clinic at RAK College of Dental Sciences for participation in this study. The study methodology was approved by the RAK Medical and Health Science University-Research Ethics Committee-10-2016-UG-D and respects the Helsinki Declaration of 1975, as revised in 2000. The risks of radiation exposure and the purpose and methodology of the study were explained, and written consent was obtained from each participant. Cephalometric and panoramic radiographs and facial pictures were taken as part of the participant's initial diagnosis materials. All first appointment patients were considered for the study. Participants were excluded if: central incisors and/or permanent first molars were missing, facial asymmetry due to craniofacial syndromes or a history of facial trauma was present, participants suffered severe medical illnesses, participants were undergoing chemotherapy and/or radiotherapy, or were pregnant.

Radiographic procedures

Lateral cephalograms were taken under standard conditions using Gendex Orthoralix 9200 DDE Digital Cephalometric + Panoramic X-ray (Model: GEN-XRAY25, Manufacturer: Gendex Panoramic, USA). A new OPG technique was devised. Instead of the participant biting on the bite block, the edges of the maxillary central incisors rested on the bite block during maximum intercuspation. The participant was positioned so that the FH plane was parallel to the floor, and the facial midline was used to align the participant's head sagittally. The head of the patient was stabilized using the radiographic machine's head stabilizer. This technique ensured that the menton (Me) always showed on the radiographs, which may not occur in conventional techniques and that occlusal relationships were present in the OPG [Figure 1]. Since the radiograph was taken in maximum intercuspation, the vertical relationship could be measured. The condylar position was also the same as that in the lateral cephalometric radiograph; thus, the correlation tests could be done more accurately. After that, facial profile pictures from the right side were taken for every patient. All radiographs and photos were taken by the same operator to ensure standardization.

Radiographic analysis

All the collected materials were analyzed using Autodesk AutoCAD 2016. Steiner's and Ricketts analysis were used for the analysis of the cephalograms to test the correlation with their corresponding OPG angles and to identify the participants with normal facial proportions. The landmarks used and angles measured as shown in Figure 2. The cephalometric values used as norms to identify the sagittal and vertical skeletal patterns are shown in Table 1. Facial photographs were used to measure the facial convexity angle. Normal patients were those who presented 165–175° angles. The participants who were within the normal standards of cephalometric analysis and facial convexity were included in the subgroup that was later used to establish preliminary standards for OPG analysis.

OPG analysis was done using bone landmarks [Figure 3] and an experimental set of angles that would measure symmetry and sagittal and vertical relationships [Figure 4]. The main

Figure 1: Panoramic radiograph taken in maximum intercuspation

Table 1: Cephalometric norms

Angle	Normal values (°)
SNA	82±3
SNB	79±3
ANB	3±2
FH-NA	90±4
FH-NPg	87±4
SN-MP	32±5
FH-MP	24±3
Y-axis - SN	66±3
Y-axis - FH	59±3
U1-SN	103±6
U1-NA	22±6
L1-MP	90±5
L1-NB	25±7
U1-L1	135±11

reference line used was a line from orbitale to the AE (Or/AE), which represents the cranial base. The sagittal position of the maxilla was measured as the angle formed from Or/AE to the anterior nasal spine (Or/AE-ANS). The sagittal position of the mandible was measured as the angle formed from Or/AE to Me and the angle formed from Or/AE to Go. The sagittal position of the dentition in the maxilla and the mandible were measured as angles from molar to ANS to Me and Mo to Me to ANS, respectively. Facial height was measured between Or/AE and the mandibular plane. The height of the lower facial third was measured as an angle from the ANS to Mo to Me. The gonial angle was measured as an angle from the AE to Go to Me. The steepness of the mandible was measured as an angle from the gonial angles on each side of the mandible and Me (GoR-Me-GoL). The transverse dimensions of the maxillary and mandibular arches were measured as the angles between Mo on each side of the arch and the ANS (MoR-ANS-MoL) and Me (MoR-Me-MoL), respectively.

Symmetry was assessed between the right and left articular eminence (AE), J point (J), sigmoid notch point (Snp), and gonion (Go). The angles formed by the line joining the right and left landmark and the facial midline were measured [Figure 4]. The points were considered symmetric when 90° angles were formed to the right and left of the midline. The degree of asymmetry was calculated as the difference between the two angles.

Statistical analysis

Pearson's correlation was used to assess the relation between the cephalometric angles and the corresponding OPG angles of all the participants in the sample. $P < 0.05$ were considered statistically significant. The subgroup of normal patients underwent complete OPG analysis using the newly devised technique. Measurements were made from both sides of the face where applicable and used as independent values for one parameter. The means and standard deviations for the OPG measurements of this subgroup were calculated to establish norms.

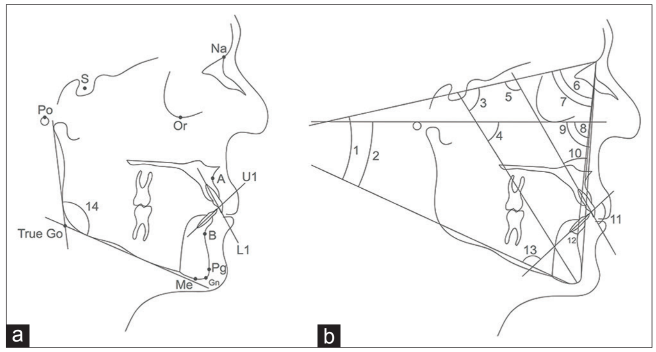

Figure 2: Landmarks and angles used for cephalometric analysis. (a) Bone landmarks (S, Sella; Na, Nasion; Po, Porion; Or, Orbital; A, Point A; B, Point B; Pg, Pogonion; Gn, Gnathion; Me, Mention; Go, True Gonion; U1, Upper Incisor; L1, Lower Incisor). (b) Cephalometric angles from Rickett's and Steiner's analyses (1, SN-MP; 2, FH-MP; 3, Y-axis-SN; 4, Y-axis-FH; 5, U1-SN; 6, SNA; 7, SNB; 8, FH-NA; 9, FH-NPg; 10, U1-NA; 11, U1-L1; 12, L1-NB; 13, L1-MP; 14, Gonial Angle)

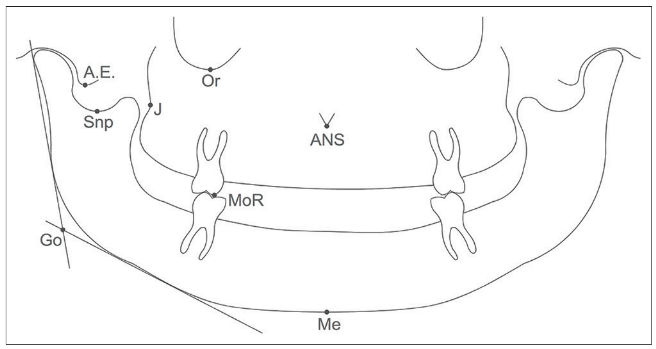

Figure 3: Bone landmarks used in the orthopantomograms analysis. (AE, Articular Eminence; Or, Orbital; Snp, Sigmoid Notch Point; J, J-point; ANS, Anterior Nasal Spine; Go, True Gonion; Me, Menton; MoR, Mesiobuccal Cusp of the Maxillary Right First Molar)

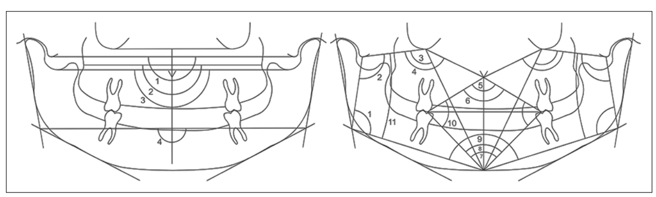

Figure 4: Angles used for orthopantomograms analysis. (A) Analysis of symmetry (1, Or-Midline; 2, AE-Midline; 3, J-Midline; 4, Snp-Midline; 5, Go-Midline). (B) Analysis of sagittal, vertical and transverse skeletal patterns (1, AE-Go-Me; 2, Or/AE-Go; 3, Or/AE-Me; 4, Or/AE-ANS; 5, MoR-ANS-MoL; 6, MoR-ANS-Me; 7, MoR-Me-MoL; 8, MoR-Me-ANS; 9, GoR-Me-GoL; 10, ANS-MoR-Me; 11, Or/AE-MP)

Results

Average symmetry measurements of 0.49–4.09, 0.33–3.09, 0.91–4.81, and 0.15–4.42 were observed for AE, J, Snp and Go, respectively [Table 2]. Only 1 (4.5%) participant presented absolute symmetry on all measurements included in this study. The subgroup of normal patients also presented a similar degree of asymmetry [Table 2]. Significant differences between the symmetry of AE, J, Snp and Go were not observed.

Significant correlations were observed between the sagittal measurements for the maxilla and mandible on the OPG analysis and Ricketts cephalometric analysis [Table 3]. A significant correlation was observed between the sagittal measurement of the mandible but not the maxilla when comparing the OPG analysis and Steiner's cephalometric analysis. The OPG analysis angles used to measure the vertical facial proportion were significantly correlated with the angles corresponding to Ricketts analysis but not to those corresponding to Steiner's analysis. The highest level of significance was found between the gonial angle measured in the OPG and cephalometric analyses.

A total of 8 (35%) participants in the sample were found to be within normal values of sagittal and vertical proportions after assessing the cephalometric analysis parameters in cephalograms and the convexity angles in facial profile pictures. The normal values for the OPG analysis measurements are shown in Table 4. Five sagittal measurements are suggested to determine the anteroposterior position of the maxilla and mandible. Four measurements are suggested for the assessment of facial height; and two measurements are suggested for measurement of transverse relationships of the arches. From these 14 angles, four can be directly compared with existing cephalometric analysis parameters [Table 4 and Figure 5]. Statistically reliable standard deviations were found for all the measurements. Differences are observed for the standards of the total sample of normal patients and for subgroups of males and females. The normal values for the OPG analysis should be gender dependent.

Table 2: Measurements of symmetry parameters

Parameters	Mean±SD	Minimum	Maximum
Total sample (n=23)			
AE - AE	2.286±1.799	0.486	4.085
J point - J point	1.714±1.380	0.334	3.094
Snp - Snp	2.857±1.952	0.905	4.809
Go - Go	2.286±2.138	0.148	4.424
Normal sample (n=8)			
AE - AE	2.50±1.77	0.73	4.27
J point - J point	2.50±2.56	0.06	5.06
Snp - Snp	3.00±1.85	1.15	4.85
Go - Go	2.75±2.38	0.38	5.13

SD: Standard deviation

Discussion

Significant correlations were found between the measurements from traditional cephalometric analyses and a novel OPG analysis technique. It was also found that symmetry is not

Table 3: Correlation tests of cephalometric and panoramic radiographic analysis

	Cephalometry	OPG analysis	Hemiface	r	P	Significance
Sagittal	FH-NA#	Or/AE-ANS	Right side	0.43	0.0401	*
			Left side	0.49	0.0184	*
			Mean	0.47	0.0235	*
	FH-NPg#	Or/AE-Me	Right side	0.46	0.0271	*
			Left side	0.48	0.0194	*
			Mean	0.49	0.0189	*
	SNA##	Or/AE-ANS	Right side	0.23	0.3020	NS
			Left side	0.32	0.1411	NS
			Mean	0.28	0.2019	NS
	SNB##	Or/AE-Me	Right side	0.44	0.0378	*
			Left side	0.44	0.0370	*
			Mean	0.45	0.0316	*
Vertical	FH-MP#	Or/AE-MP	Right side	0.61	0.0019	**
			Left side	0.55	0.0063	**
			Mean	0.63	0.0014	**
	Y-axis - FH#	Or/AE-MP	Right side	0.58	0.0037	**
			Left side	0.50	0.0141	*
			Mean	0.58	0.0034	**
	SN-MP##	Or/AE-MP	Right side	0.38	0.0722	NS
			Left side	0.43	0.0384	*
			Mean	0.44	0.0375	*
	Y-axis - SN##	Or/AE-MP	Right side	0.24	0.2611	NS
			Left side	0.28	0.1948	NS
			Mean	0.28	0.1948	NS
	Gonial angle	AE-Go-Me	Right side	0.77	0.0002	***
			Left side	0.81	0.0001	***
			Mean	0.87	0.0001	***

*P<0.05, **P<0.01, ***P<0.001, #Ricketts Cephalometric parameter, ##Steiner's Cephalometric parameter. NS: Not significant

Table 4: Preliminary panoramic analysis norms

Dimension	Angle	Mean±SD		
		Overall	Male	Female
Sagittal	Or/AE-ANS*	138±4	140±3	136±5
	Or/AE-Me*	105±3	107±3	102±1
	Or/AE-Go	108±6	105±3	114±7
	Mo-ANS-Me	59±4	60±3	58±4
	Mo-Me-ANS	40±4	40±4	40±2
Vertical	Or/AE-MP*	25±3	24±1	27±4
	ANS-Mo-Me	80±5	80±5	82±5
	AE-Go-Me*	97±5	99±2	93±7
	GoR-Me-GoL	147±8	144±7	152±8
Transverse	MoR-ANS-MoL	119±6	121±6	116±7
	MoR-Me-MoL	80±8	80±9	81±4

*Reciprocal measurements from cephalometric and OPG analyses.
SD: Standard deviation, OPG: Orthopantomograms

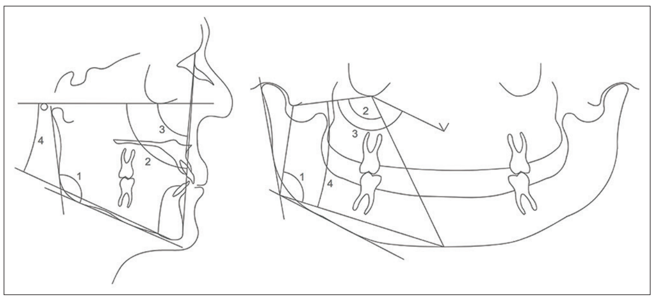

Figure 5: Comparison of cephalometric and orthopantomograms angles used for correlation analysis. Corresponding angles: 1, Gonial Angle to Gonial Angle; 2, FH-NPg to Or/AE-Me; 3, FH-NA to Or/AE-ANS; 4, FH-MP to Or/AE-MP

frequent even in individuals where normal sagittal proportions are determined based on cephalometric and facial analysis. A preliminary set of panoramic radiographic norms for facial analysis have been established using the novel OPG analysis technique.

Previous studies using the OPG for skeletal facial analysis have assessed samples of patients belonging to one skeletal classification rather than a random sample, single pathologies, facial symmetry alone, mandible alone, and/or different landmarks.[13-16] It has also been suggested that panoramic radiographs cannot be reliable enough to give accurate information as compared due to predictability concerns;[14] however, more extensive studies have shown that bone structures are not significantly distorted in the OPG.[17-19] This novel OPG analysis technique has been designed to overcome these deficiencies. Reliability can be improved by the use of angular rather than linear measurements and avoiding translocation of the mandible. Maximum intercuspation in the OPG allows the condyle to be positioned within the glenoid fossa as in the cephalogram, consequently, a more direct comparison of the cephalometric and OPG analyses. With the condyle in its natural resting position, the Me is less likely to be cut out of the image and can be better identified in the OPG. Furthermore, the facial height is not abnormally elongated. The choice of anatomic landmarks used in this OPG analysis technique was more similar to that of cephalometric analysis, differing mainly in the Or/AE plane. This new plane corresponds to the SN plane and FH plane in the Steiner's and Ricketts analysis, respectively; but, has greater resemblance to the FH plane. Therefore, the newly devised OPG analysis correlates more to the cephalometric analysis where the primary reference to the cranial base is the FH plane rather than the SN plane. The gonial angle, which is not measured relative to the cranial base showed the highest correspondence. The ability to accurately measure the gonial angle in OPGs had been discussed before.[20,21]

The most relevant disadvantage of cephalometric analysis for facial skeletal analysis and orthodontic diagnosis is the overlapping of bilateral structures and the assumption that the studied participants are symmetrical.[1] In cases where bone landmarks are duplicated in the cephalogram, measurements are usually averaged to compensate for the underlying asymmetry of the face. However, averaging does not provide reliable values.[22] This study shows that symmetry should not be expected in any patient and that analysis of both facial hemispheres is recommended. This could increase operational time but improve accuracy of diagnosis and treatment planning.

The clinical application of radiographic analyses of facial skeletal patterns requires a set of measurement values that are considered to be present in a normal population. Studies summarizing the measurements values observed on participants with ideal facial proportions have been used for this purpose for decades.[4,23,24] They require standardized age, gender, and ethnicity to determine the norms applicable to a specific population.[25,26] The normal sample in this study was chosen based on the already existing normal cephalometric measurements and facial convexity angle. A preliminary set of normal measurement values has been obtained from the normal patients in the studied sample. Even though the preliminary mean and SD values are promising, the number of normal participants within this study sample was limited and not sufficient to establish norms to be used in a clinical setup. Therefore, future research must include larger, standardized samples to formulate a more conclusive set of norms.

The results of this study provide reliable information on the use of OPG for sagittal, vertical, and transverse analysis of the facial skeletal patterns. This technique can be used as a complement to cephalometric analysis without the additional exposure to radiation required for CBCT or can be used as an alternative in clinical setups where panoramic radiographs are the only available tools for facial skeletal diagnosis.

Conclusions

Facial skeletal symmetry is rarely observed and can affect the reliability of cephalometric analysis. Bilateral facial skeletal assessment and asymmetry analysis can be done in a panoramic radiograph to the benefit of orthodontic diagnosis and treatment planning. The novel OPG analysis technique presented in this study is comparable to traditional cephalometric analysis techniques and has the potential to assess sagittal, vertical, and transverse facial skeletal relationships in an OPG.

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Conflicts of interest

There are no conflicts of interest.

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