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Cranial symmetry assessment through cone-beam CT images

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Abstract

Objective: The aim of the present study was to compare the right and the left sides of symmetrical individuals´ skull through images generated by cone-beam computed tomography (cbct).

Methods: The sample consisted of 35 scans from the 3d-i-cat (imaging sciences international inc., hatfield, usa) of 13 male and 22 female individuals, aged between 8 and 64, who showed acceptable facial symmetry. The images were entered into the invivodental 5.0 software (anatomage, san jose, usa) and positioned analogously to the patient´s head posture to get a lateral cephalometric radiography. Go-me, go-cd, s-cd, co-gn, and co-a linear distances (mm); mego.cd, fma, and gogn.sn angles (degrees), as well as five condyle-glenoid fossa linear distances (mm) were the bilateral variables analyzed.

Results: Statistically significant difference between the right and the left sides was only verified when s-cd (mm) was assessed.

Conclusion: therefore, there is no need to obtain bilateral values of these variables (except s-cd) to assess the skull of individuals with no evident asymmetries. In relation to s-cd variable, the difficulty to mark the sella point (s) in a 3-dimensional study created inexistent discrepancies between the right and the left condyles position.

Key words: Cephalometry; skull; facial asymmetry; tomography.

Avaliação da simetria craniana através de imagens de TC cone beam

Resumo

Objetivo: O objetivo do presente estudo foi comparar os lados direito e esquerdo de indivíduos que apresentavam simetria craniana através de 2 imagens geradas pela tomografia computadorizada cone beam (TCCB).

Métodos: A amostra consistiu de 35 imagens obtidas pelo tomógrafo 3D-i-CAT (Imaging Sciences International Inc., Hatfield, USA), sendo 13 de indivíduos do gênero masculino e 22 do gênero feminino, com idades variando de 8 a 64 anos, que apresentavam simetria facial aceitável. As imagens foram manipuladas com a ajuda do programa invivodental 5.0 (Anatomage, San Jose, USA) e posicionadas de forma análoga à postura da cabeça para a obtenção da radiografia cefalométrica de perfil. As distâncias lineares Go-Me, Go-Cd, S-Cd, Co-Gn e Co-A (mm); os ângulos mego.Cd, FMA e gogn.SN (graus), e cinco distâncias lineares côndilo-fossa glenóide foram as variáveis analisadas.

Resultados: Uma diferença estatística significante entre os lados foi encontrada apenas para a variável S-Cd (mm).

Conclusão: Portanto, não há necessidade de se obter valores bilaterais para essas variáveis (exceto S-Cd) para avaliar o crânio de indivíduos sem assimetrias evidentes. Com relação à variável S-Cd, a dificuldade para se marcar o ponto S (sela) num estudo tridimensional criou discrepâncias inexistentes entre as posições dos côndilos direito e esquerdo.

Palavras-chave: Cefalometria; crânio; assimetria facial; tomografia.

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Introduction

Cone-beam computed tomography (CBCT) is a diagnostic element that allows the imaging and the visualization of structures under different angles. Many exams currently used are expected to be replaced by three-dimensional images [1,2], as they are more accurate than the conventional methods [3,4], with lower radiation when compared with the helicoidal computed tomography [2,5-7]. CBCT is also able to provide a larger amount of information than a whole set of radiographs routinely used in orthodontics (periapical, panoramic, and cephalometric), with the advantage of a lower radiation dose [8-10]. Better access to this new technology is redirecting the two-dimensional diagnosis toward a three-dimensional visualization of the craniofacial structures [2,10,11].

Unlike the cephalometric radiographs, small head deviations do not distort the image obtained by the CBCT, as long as it provides a slice thickness of at least three millimeters [12,13]. In the typical cephalometric analysis, the left structures are used as references as they are nearer the radiographic film and, therefore, present less distortion. In the case of three-dimensional images, there is no distortion, allowing the comparison of any of the sides` structures [11,13]. For a long time, orthodontists have been assessing their patients by evaluating only the left anatomical structures. Nevertheless, it must not be forgotten that even people considered clinically symmetric present skeletal asymmetries masked by soft tissue compensation [14]. So, an important question is: To what extent can these compensations be efficient?

The aim of this research is to assess whether individuals considered acceptably symmetrical show significant discrepancies between both the right and the left sides of the skull.

Methods

The present study was submitted to the local ethical research committee (filed under number 124/2010) and performed in accordance to its norms.

The material used consisted of cranial CBCT scans of individuals with facial symmetry characteristics. The scans were acquired through the 3D-i-CAT (Imaging Sciences International Inc., Hatfield, USA) computerized tomograph and processed through the software's own image capture scanner, Xoran 2.0.21 (Xoran Technologies Inc., Ann Arbor, USA) to create a DICOM file. Image acquisition was performed in natural head position with the Frankfort horizontal plane parallel to the ground, and the patient was instructed to keep the mandible in centric occlusion to maximum intercuspation [13,15,16]. The CBCT was obtained in the complete FULL 220-mm mode, where the scanner performs two rotations (20 + 20 seconds; 0.4 voxel), allowing to scan the entire skull [13,17].

The 57 CBCT scans used in this study were acquired in the period between 2008 and 2010. Patients in this database were aged between 8 and 64 years, with 28 males and 29 females. The following exclusion criteria were applied: facial asymmetry, cases treated with orthognathic surgery and images that evidenced the absence of part of the maxilla, mandible, or the upper border of the external acoustic meatus. Individuals were considered simetric when the distance between the vertical reference line to menton point was less than 4 mm [18]. Thirty-five exams remained: 13 male and 22 female, aged between 8 and 64.

The information obtained from DICOM file extension was entered into the invivodental 5.0 software (Anatomage, San Jose, USA). With this program, three windows were opened with coronal, sagittal, and transverse multiplanar images, in the same position acquired by the tomograph. Using the Reorientation tool, the images were positioned analogous to the patient´s head posture to get a lateral cephalometric radiography. To obtain the Frankfort horizontal plane, the left anatomical porion (Pol) and the right (Orr) and the left (Orl) orbital points were used as references. These three points were included in the same plane parallel to the ground (Figure 1).

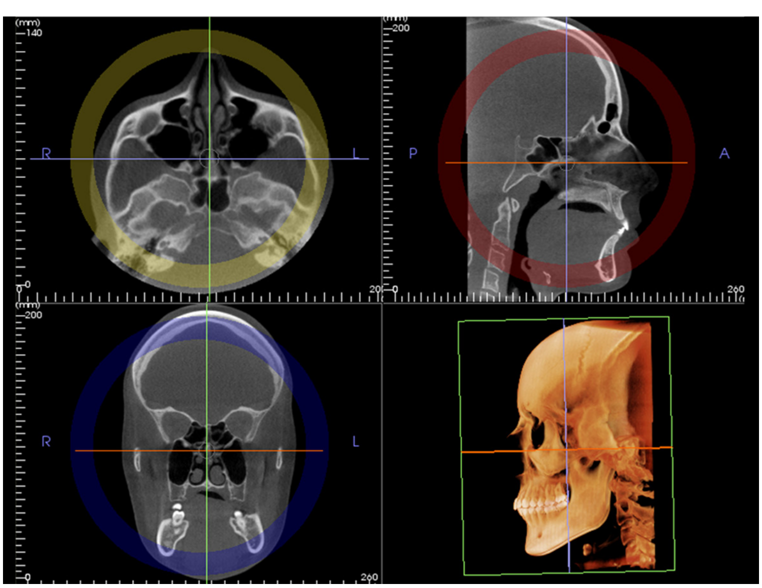

Fig. 1. Positioning the Frankfort horizontal plane parallel to the ground (Or_r, Or_l, and Po_l points).

The visualization was changed into volume rendering to locate the following points: subspinal (A), gnathion (Gn), menton (Me), sella (S), right (Gor) and left (Gol) gonions, right (Cdr) and left (Cdl) condylars, as well as right (Cor) and left (Col) condylions. In some cases, the points were selected aided by a grayscale filter, with the skull positioned in lateral vision until the desired anatomical contour could be completely visualized. Then, the teeth filter was used and the skull was manipulated seeking the marking point improvement (Figure 2). Eight variables were measured from these selected points, represented by the following linear distances and angles:

- Go-Me (mm), corresponding to the length of the lower border of the mandible;
- Go-Cd (mm), corresponding to the mandibular ramus height;

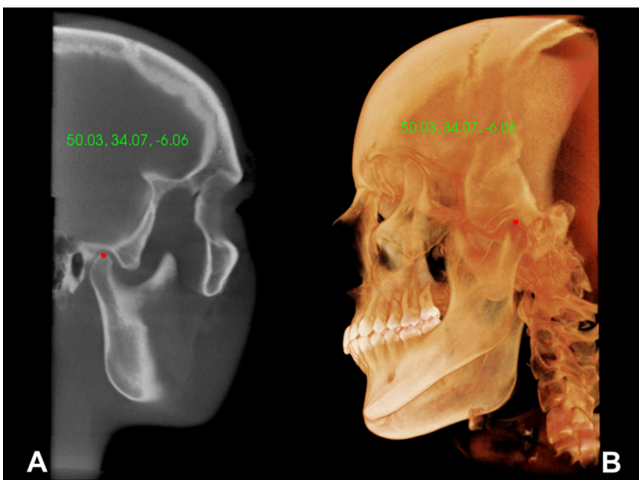

Fig. 2. Lateral view of skull with grayscale filter (A) and teeth filter (B), allowing a better visualization of the condylar point.

- S-Cd (mm), corresponding to the distance comprised from the geometric center of the sella turcica to the highest point of the mandibular condyle;
- Co-Gn (mm), corresponding to the effective mandibular length;
- Co-A (mm), corresponding to the effective maxillary length;
- mego.Cd (degrees), corresponding to the gonial angle;
- FMA (degrees), corresponding to the inclination of the mandibular plane in relation to the Frankfort horizontal plane.
- gogn. SN (degrees), corresponding to the mandibular plane angle.

To assess the right and left condilles position, the following five variables were measured (Figure 3):

- Linear distance between the most posterior point of the condyle (P1) and the point in the glenoid fossa nearest to P1 (P2);
- Linear distance between the uppermost point of the condyle (P3) and the point in the glenoid fossa closest to P3 (P4);
- Linear distance between the most anterior point of the condyle (P5) and the point in the glenoid fossa closest to P5 (P6);
- Linear distance between the most medial point of the condyle (P7) and the point coincident with the glenoid fossa of the shortest distance to P7, perpendicular to the sagittal plane (P8);
- Linear distance between the uppermost point of the medial condyle and the point in the glenoid fossa closest to P9 (P10).

All the variables were measured by the invivodental 5.0 software 3D Cephalometric Analysis (Anatomage, San Jose, USA).

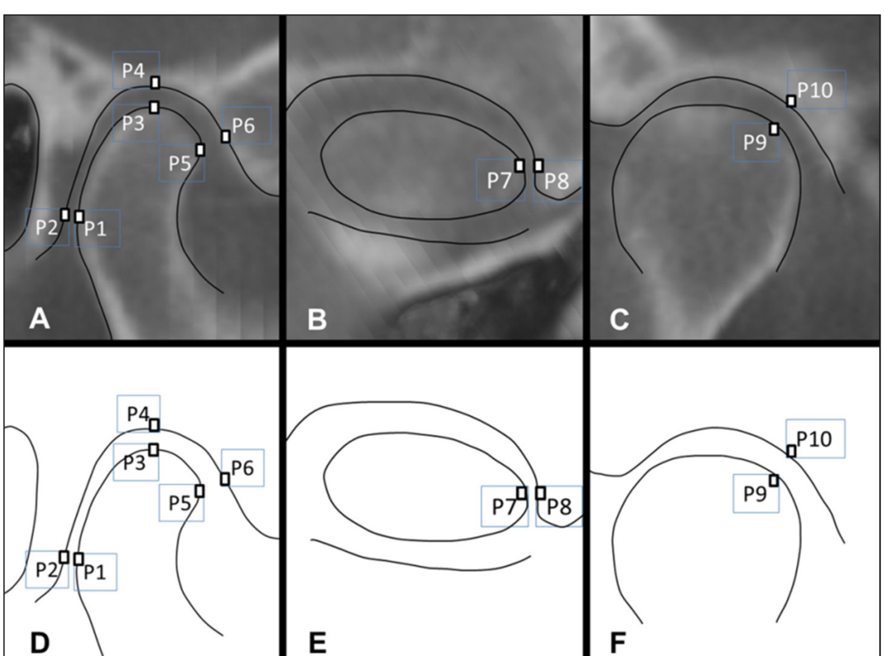

Fig. 3. Computer tomographic images in a sagittal (A), coronal (B) and transverse (C) view, marking the points P1, P2, P3, P4, P5, P6, P7, P8, P9 and P10.

The asymmetry has been evaluated both the absolute difference between the values of the right and left sides as the relative variation using the average of two measures as a reference.

Statistical analysis

Intraclass Correlation Coefficient (CCI) and paired Student´s t test were used to verify the diferences (symmetry) between the variable values on the right and the left sides of the skull. Intraclass correlation coefficient was obtained by the model "two-way mixed ANOVA." The same strategies were used to validate the method. SPSS v.17 software (IBM, Armonk, USA) was used to obtain the results of the statistical tests. A 5% probability ($p<0.05$) significance level was adopted.

Results

With respect to the sides of the skull, in relative terms the differences ranged from 1.1% (cogn) to 8.4% (FMA). The other variables, except S-Cd (CCI=0.485), showed high CCI, having cogn obtained the highest value (ICC=0.984), which meant higher symmetry. In assessing the t test outcome, only Co-A (p=0.859) and FMA (p=0.687) were considered symmetrical. The values of the other variables were statistically different, though clinically insignificant in magnitude. The only exception was S-Cd ($p<0.001$), which presented a low ICC (0.485), and media of 2.16mm right and 5.8% of relative asymmetry. No significant differences ($p<0.05$) were found with respect to the right and the left condyles position. P5-P6 (p=0.087) and P7-P8 (p=0.198) presented the lower vallues, as well as the lower CCI values (0.342 and 0.498) (Table 1).

Table 1. Symmetry analysis of orthodontic variables.

Variables	Indicators of symmetry for left and right sides (L and R)			
	Media of L-R	Media of |L-R|%*	ICC**	p-value of paried t test
Go-Me	1.07	2.7%	0.933	0.015
Go-Cd	-1.66	4.1%	0.892	< 0.001
S-Cd	-2.16	5.8%	0.485	< 0.001
Co-Gn	-0,94	1.1%	0.984	< 0.001
Co-A	0.07	1.8%	0.921	0.859
MeGo.Cd	-1.10	1.9%	0.896	0.026
FMA	0.14	8.4%	0.910	0.687
GoGn.SN	0.88	5.2%	0.938	0.012
P1-P2	-0.06	14.7%	0.665	0.530
P3-P4	0.06	22.5%	0.499	0.592
P5-P6	0.22	22.3%	0.342	0.087
P7-P8	-0.33	25.8%	0.498	0.198
P9-P10	-0.02	21.7%	0.394	0.843

* Difference in magnitude on the average of the two sides.
** Intraclass correlation coefficient obtained by the model "two-way mixed ANOVA".

The paired Student's t test was used to assess the reproducibility of the variables. There was a statistically significant difference ($p<0.05$) only for gogn.SN (Table 2).

Table 2. Reproducibility analysis of orthodontic variables.

Variables	Indicators of reproducibility for the two evaluations (T1 e T2)			
	Media of T1 - T2	Media of |T1-T2|%*	ICC**	p-value of paried t test
Go-Me	-0.42	1.8%	0.961	0.080
Go-Cd	0.16	2.0%	0.972	0.352
S-Cd	0.19	2.7%	0.861	0.360
Co-Gn	-0.15	0.5%	0.997	0.098
Co-A	0.02	1.1%	0.960	0.921
MeGo.Cd	0.18	0.8%	0.983	0.211
FMA	-0.04	4.7%	0.970	0.791
GoGn.SN	-0.28	3.0%	0.979	0.049
P1-P2	-0.03	7.0%	0.904	0.986
P3-P4	-0.03	4,5%	0.973	0.185
P5-P6	-0.02	4.3%	0.985	0.131
P7-P8	0.00	3.7%	0.994	0.914
P9-P10	0.01	5.8%	0.956	0.551

* Difference in magnitude on the average of the two sides.
** Intraclass correlation coefficient obtained by the model "two-way mixed ANOVA".

Discussion

The replacement of conventional radiographs by three-dimensional imaging is a trend in dentistry. For this transition to occur, more studies and protocol use definitions are needed [19]. In studies involving quantitative variable measurement, the adequate assessment of their method errors is an important factor to be considered [20]. It is believed that many cases should be replicated as otherwise only large systematic errors could be identified. Even a relevant systematic error may be overlooked if an insufficient number of cases are used. There were no significant differences between the two measurement moments with respect to systematic error, except to gogn.SN angle. The statistical error, although significant (ICC=0.979), was considered small and clinically insignificant. Regarding the random error, the values found were small when compared to the mean values of the studied variables. Such results validated the methodology used in this research for data collection.

During the tomographic exam acquisition, patients are instructed to remain with their teeth clenched in centric occlusion. Ideally, this position should coincide with the centric relation (CR), but this does not always occur [21]. In the future, efforts should be made to obtain the orthodontic data in accordance to the CR position, as this prerequisite must be considered when performing the occlusal analysis [22], which is an important part of the orthodontic diagnosis. The question is whether the centric relation can be accurately reproduced, since different methods of manipulation of the mandible lead to different positions [23].

Cranial asymmetry is a natural phenomenon of varied etiology: it may be genetic or caused by habits and trauma [24]. In most cases, it is unnoticed at first, being identified only after comparing both sides of the skull [14]. Even people considered clinically symmetric present skeletal asymmetries masked by soft tissue compensation [25]. In this study, FMA and mego.Cd angles showed no statistically significant difference between the sides. The same occurred with the Co-A, Go-Me, Co-Gn, and Go-Cd linear distances, although the values found for each side were different in all the cases.

Therefore, there is no need to obtain bilateral values to assess the skull of individuals with no evident asymmetries through these variables. A statistically significant difference was evidenced only in relation to the S-Cd ($p<0.001$ and ICC=0.485) variable. The first conclusion could be the existence of an effective mandibular deviation in the individuals of the sample, even though they have been considered acceptably symmetrical. Nevertheless, as the Student`s t test and the CCI could not identify any significant difference ($p<0.05$) with respect to the right and the left condyles position (Table 1), the most likely explanation, then, is the difficulty to locate de sella point (S) in a 3-dimensional study, which created inexistent discrepancies concerning the condyles location.

Although it was not the aim of the present paper, another interesting finding is about the sella point (S). The transference of this cephalometric landmark to a 3-dimensional image is not a simple proceeding. Due to its definition, errors may occur in any plane of the space (sagittal, transverse, or coronal) or simultaneously in more than one plane. Therefore, its substitution for a skeletal reference is recommended when using 3D cephalometrics. Meanwhile, new protocols must be elaborated to allow that standardization acceptable indexes could be reached.

Conclusions

No statistical differences between the right and the left sides were observed when Go-Me, Go-Cd, Co-Gn and Co-A linear distances, as well as mego.Cd, FMA, and gogn.SN angles were analyzed, which means that there is no need to obtain bilateral values to assess the skull of individuals with no evident asymmetries through these variables. In relation to S-Cd variable, the difficulty to mark the sella point (S) in a 3-dimensional study created inexistent discrepancies between the right and the left condyles position.

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