Definition of New Three-Dimensional Cephalometric Analysis of Maxillomandibular Sagittal Relationship for Orthodontics and Orthognathic Surgery: Normative Data Based on 700 CBCT Scans

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Abstract: The objective of the study was to define the norm of new 3-dimensional cephalometric analysis of maxillomandibular sagittal relationship with the patient in Natural Head Position. A cross-sectional study was performed using 700 consecutives cone beam computed tomography datasets of pre-orthodontic patients received for three-dimensional craniofacial analysis. To stablish the clinical norm of the new sagittal reference (linear distance A-B), the correlation with the gold standard (ANB angle) was estimated with the Pearson's correlation coefficient. Subsequently, the prognostic values of the linear distance A-B was calculated to define the clinical norm. The sample was composed by 463 women (66.1%) and 237 men (33.9%). The mean age was 30 ± 14,5 years old (range 6–71 y old). According to the skeletal class classification (ANB), 46.1% (323) were class I, 42% (294) class II, and 11.9% (83) class III. The regression model found that each additional grade of the ANB angle imply a mean increase of 1.24 mm of the distance A-B ($P < 0.001$). The normative value of the linear distance A-B was obtained through the prognostic values of the distance for the limits of the ANB norm 0 to 4. These values were on the range of 0.52 to 5.48 mm. Therefore, the clinical norm for cephalometric maxillomandibular sagittal relationship using linear distance from point A-B is: 3 ± 2.48 mm. With this new approach, we can define the skeletal sagittal relationship of the patient in natural head position overcoming the limitations of using intracranial or occlusal plane references improving the diagnosis and orthognathic surgical planning process.

Key Words: Natural head position, orthodontics, sagittal relationship, three-dimensional diagnosis

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The maxillomandibular anteroposterior relationship is one of the key aspects in orthodontic diagnosis. Because of its impact on the treatment plan, different proposals have emerged over the years to offer a measurement reliable enough to obtain an accurate diagnosis.[1–5]

Of all of them, the most widely used continue to be the ANB angle and the Wits Appraisal. In fact, ANB is still considered the gold standard in orthodontic sagittal diagnosis by several authors.[6,7] However, each analysis has its limitations and drawbacks. It has been demonstrated that ANB angle is highly influenced by some factors that can lead to a wrong interpretation of the patient's sagittal relationship. Of those factors, anteroposterior[4] and vertical position[8] of Nasion in relation to point A and B, the vertical growth (distance N to B) and increase in dental height (vertical distance A to B) have shown to have a great impact on ANB.[9]

To overcome these limitations, Jacobson[10] proposed the use of the Wits Appraisal which is performed by tracing perpendicular lines from points A and B to functional occlusal Plane. However, this approach implies to perform a skeletal diagnosis using a dental parameter. Therefore, it is still influenced by other factors as tooth eruption, dental development[9] and even the change on the inclination of the occlusal plane after treatment.[11,12]

Because of the great variability observed in intracranial references, the description of measurements that are not influenced in any way by this variation is essential.[13–15] .To do this, conducting diagnostic analyses with the patient in the Natural Head position is fundamental.[14,16] In such a manner, measurements can be generated related to the true horizontal and vertical planes that, therefore, are not influenced in any way by the variability of the structures of the craniofacial complex, nor by the changes that occur in them with age.[17]

Regarding reproducibility, natural position of the head has shown less variability when compared with other intracranial reference planes in the pitch axis. In this sense, Madsen et al[14] in which they studied 11 reference planes, they found that the variability of the intracranial planes is very high. The planes that showed less variability with respect to the true horizontal were Frankfurt and KW line, with SDs of 4.6 and 4.7 degrees, respectively, which is twice the reproducibility of NHP in the pitch axis (mean square error 2.1 degrees).[14]

Therefore, the analysis in natural position of the head is of great relevance in the orthodontic field, craniofacial anomalies,[18] planning of orthognathic surgery,[19,20] craniocervical angulation, and in the analysis of soft tissues.[21]

Along with all this, the introduction of cone beam computed tomography (CBCT) has brought a new reality to the study of our patients. With this, the limitations that we had in the past with 2-dimensional radiology have been overcome. It completely eliminates overlapping structures and distortion problems.[22] It also allows more accurate marking of landmarks as long as they are made in all three views of the multiplanar reconstruction.[23,24] Thanks to the 3-dimensional image, today we have a clearer analysis of the diagnosis of asymmetries[25,26] and the study of the temporomandibular joint.[27] This being of vital importance since alterations in the condylar position can alter the interpretation of the maxillomandibular sagittal and transverse relationship,[28] as well as undiagnosed condylar degenerative pathologies can lead to both a misdiagnosis and lack of stability of the treatment.[29–31]

In front of this scenario, this study attempts to define a method to analyze 3-dimensionally the real maxillomandibular sagittal relationship and define the normative value for its clinical application.

MATERIALS AND METHODS

A cross-sectional study was performed using 700 consecutives CBCT datasets of pre-orthodontic patients received for 3-dimensional craniofacial analysis on a private center of diagnosis. As this study used pre-existing CBCT, it neither alter the diagnostic imaging protocol applied to patients in any way nor is it necessary to perform another x-ray that involves increased radiation for the patient. Therefore, inclusion in this study does not harm the patient in any aspect. This project follows the ethical guidelines of the Declaration of Helsinki. To anonymize the data, a numerical identification was given to each patient and used during the data processing.

It was excluded for the study data from patients with the following characteristics confirmed in the 3-dimensional craniofacial analysis: patients who had taken any orthodontic treatment or had undergone any maxillofacial surgery, patients with facial asymmetry, congenital diseases, temporomandibular degenerative, or hyperplasic conditions and CBCT of patients who exhibit a marked vertical condylar distraction on the sagittal view.

Image Processing

The CBCT scans were performed using a standardized scanning protocol (i-CAT, Imaging Sciences International, Inc., Hatfield, PA). Patients were instructed to sit upright and position themselves in natural head position looking forward as they were seeing themselves. They were instructed to maintain the maximum intercuspation. They were asked to rest the tongue in a relaxed position, breathe lightly, and avoid any other motor reaction. Vertical scanning was performed in "extended field" modus (field of view 17 cm diameter, 22 cm height; scan time 2×20 s; voxel size 0.4 mm) at 120 kV (according to DICOM field 0018,0060 kVp) and 48 mA (according to DICOM field 0018,1151 x-ray tube current).

DICOM datasets were imported to Dolphin Imaging 3D version 11.8 software (Dolphin Imaging & Management Solutions, Chatsworth, CA) for analysis. All the steps of the three-dimensional craniofacial analysis were performed by the same investigator.

Virtual Head Orientation

Natural head orientation (NHO) was selected for 3-dimensional craniofacial analysis. For that purpose, extraoral photographs in NHO were used. Patients were instructed to stand in their natural position and to stare at their own eyes reflected in a 60×90 cm mirror at a distance of 1 m. Before that, patients were asked to tilt their heads forward and backward with decreasing amplitude until they came to a comfortable position. They were instructed to maintain their habitual occlusion with maximum intercuspation and to relax their lips while their facial photographs were taken.

To reorient the virtual patient on the software (soft tissue layer) the following steps were performed. First of all, orientation on pitch axis was done. To do so, angulation between Tragus point (Trg) and Exocanthion point (Ex) with the true horizontal on the photo was transferred to the virtual patient. Then, a double check of the position was performed transferring the angle between the soft tissue Nasion point (Ns) and Pronasale (Prn) and the true horizontal to the virtual patient. After that, orientation on the roll axis was performed. Angulation between Right and Left Ex point and the true horizontal was transferred to the software. The last step to orientation on yaw axis was done on the craniocaudal view the 3-dimensional reconstruction was rotated until the Midsagittal plane pass through Nasion, Basion, and Crista Galli and the coronal plane passes through the transporionic plane as described by Cevidanes et al[32] Then, planes were verified on multiplanar reconstruction views. After the orientation of the virtual patient, intrinsic true planes of the software were left at this levels: axial plane was set at a height level of right Orbitale, Coronal plane was set as transporionic level and midsagittal plane was set passing through Nasion, Basion, and Crista Galli.[33] (Fig. 1)

Landmarks and Measurements

To study the normative values for the proposed new 3-dimensional sagittal measurement for skeletal class categorization, the following landmarks, and measurements were performed by the same investigator (I.M.M.).(Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/SCS/E861)

All the landmarks were marked in the 3 multiplanar views (axial, coronal, and sagittal) of the CBCT. (Fig. 2)

Measurements:

(1) ANB angle: the angle formed by point A, Nasion and point B (normal range = 0–4 degrees).
(2) Linear distance A-B: Moving the true vertical at level of point A with virtual patient on NHO, the linear distance from point B to A was measured. (Fig. 3)

Statistical Analysis

The data analysis was performed using SPSS for Windows version 15.0.1 software (SPSS Inc., Chicago, IL. First). Descriptive analysis of the variables was performed. After that, descriptive analysis was extended with the 95% CI for the mean, coefficient of

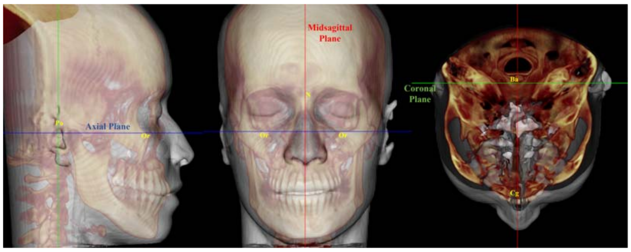

FIGURE 1. Virtual head orientation. Lateral, frontal, and craniocaudal view.

variation and the study of the adjustment to normal distribution of the A-B distance using the Kolmogorov-Smirnov test. As 2the sample is large, all the objectives of the study are addressed using a parametric approach.

The inferential analysis included the following tests:

(1) Independent samples *t* test (2-sample *t* test) to compare the means of parameters according to sex (evaluation of sex dimorphism).
(2) Pearson χ^2 test, to assess the association between skeletal class according to ANB and profile variables (such as sex).
(3) Pearson correlation coefficient to estimate the degree of linear association between cephalometric variables and age.
(4) Estimation of a simple linear regression model with dependent variable the distance A-B and independent the angle ANB. The equation of the model will allow defining the clinical norm for distance. Estimates of beta coefficients, 95% CIs, and coefficient of determination were provided to assess the quality of match. The theoretical hypotheses of the model are tested (normality, homoscedasticity, and no autocorrelation of the residuals). The level of significance used in the analyzes was 5% ($\alpha = 0.05$).

RESULTS

Sample was composed by 700 CBCTs of pre-orthodontic patients that were received with 3-dimensional craniofacial diagnosis purposes. Four hundred sixty-three of them were women (66.1%) and 237 men (33.9%). The mean age was 30 ± 14.5 years old (range 6–71 y old).

According to the skeletal class classification (ANB), 46.1% (323) were class I, 42% (294) class II, and 11.9% (83) class III.

As a means to stablish the clinical norm of the proposed new sagittal reference (linear distance A-B) it is required to demonstrate whether there is a strong correlation with the gold standard (ANB angle). For that purpose, it was estimated the Pearson correlation coefficient obtaining a $r = 0.89$ ($P < 0.001$). So, it was found a robust relation between both parameters. (Supplemental Table 2, Supplemental Digital Content 1, http://links.lww.com/SCS/E861)

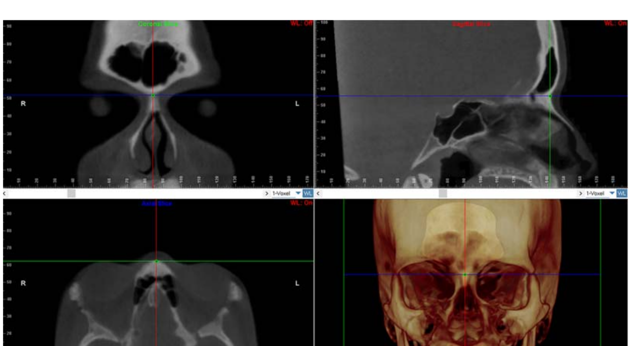

FIGURE 2. Landmark identification. Location of points was made in the coronal, sagittal, and axial MPR views with the 3D skeletal renderization. 3d indicates 3-dimensional; MPR; multiplanar reconstruction.

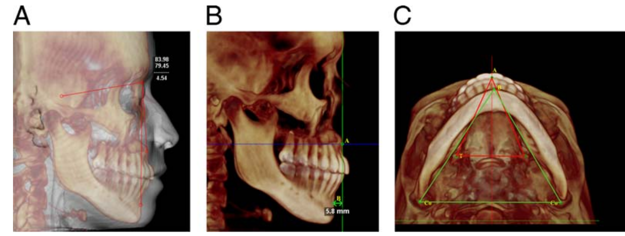

FIGURE 3. (A) SNA, SNB, and ANB. (B) Lateral view of the linear distance A-B. (C) Caudo-cranial view representing distance from point B to A and also evaluate the symmetry between the mandible and the maxilla in the yaw axis.

The regression model allows to obtain the equation of the tangent line:

Linear Distance AB = 0.52+1.24 ANB.

Each additional grade of the ANB angle imply a mean increase of 1.24 mm of the distance A-B. This impact was statistically significant ($P < 0.001$).

The normative value of the linear distance A-B was obtained through the prognostic values of the distance for the limits of the ANB norm 0 to 4. These values were on the range of 0.52 to 5.48 mm. In other words, Class I patients can be classified using the linear distance A-B using the following normal values: 3 ± 2.48 mm, Class III patients have values of the linear distance A-B < 0.52 mm and class II patients > 5.48 mm.

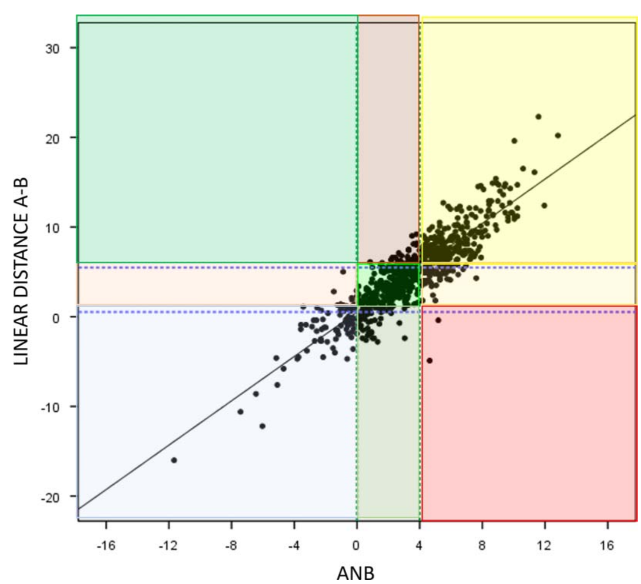

FIGURE 4. Classification according ANB and linear distance AB. (Dist. A-B). Light green area: class I according to ANB and class I according to dist.A-B. Blue zone: class III according to ANB and class III according to dist.A-B. Yellow zone: class II according to ANB and class II according to dist.A-B. Dark green zone: class III according to ANB and class II according to dist.A-B. Brown zone: class I according to ANB and class II according to dist.A-B. Violet zone: class II according to ANB and class I according to dist.A-B. Red zone: class II according to ANB and class III according to dist.A-B. Orange zone: class I according to ANB and class III according to dist.A-B. Pink zone: class III according to ANB and class I according to dist.A-B.

Obviously, not every individual in a certain skeletal class (according to ANB) is going to be in the same class according to linear distance A-B and vice versa. This concept is illustrated on Figure 4. This fact is basically due to the impact that variations on the anteroposterior and vertical position of Nasion point on ANB values as has been previously demonstrated by Hussel et al[9]

Effect of the Variables Studied

There is an evident gender dimorphism on the studied parameters with several statistically significant differences. The ANB is one of the most important, showing that the ANB angle is statistically significant larger on female (mean difference -1.15 < 0). In fact, the percentage of class I is almost identical on both sexes, about 46%. However, class III is much more frequent on males (20.3% versus 7.6%).

Regarding to age, it was found also statistical significance for some of the parameters. However, in this case, due to the huge sample size, correlations as low as r = 0.08 are significative but, probably with no clinical relevance.

Study of Method Error

One month after the first analysis, the same investigator repeated the measurements on a subgroup of 26 patients randomly selected to study the error of the method and the intraobserver reproducibility. For this purpose, the following parameters were calculated: Dalhberg´s formula, Intraclass correlation coefficient and coefficient of variation.

It has been obtained values between 0.10 and 0.30 mm of Dalhberg D for the linear measurements and between 0.23 and 0.25 for the angles. Therefore, reasonably low absolute error has been obtained. The CCI was 0.99 for all the measurements. Therefore, it can be considered a very high reproducibility as is higher than 0.90 for all the parameters.

DISCUSSION

The ANB angle was described to relate the maxillary and mandibular bone bases and therefore be able to diagnose the sagittal skeletal relationship with respect to a cranial reference.[1] However, over time it has been shown that the cranial base passing through the S and N points undergoes variations during growth and that therefore the Nasion and Sella points are not stable references.[5] This fact is of vital importance in the diagnostic interpretation, as the anteroposterior and vertical position of the Nasion will interfere with the ANB value even if points A and B were in exactly the same sagittal relationship between them.[9] For this reason, several authors have insisted on the fact that the ANB angle is not a reliable reference to identify an altered maxillomandibular sagittal relationship[4,34]

That is why other measures such as Wits Appraisal have been introduced to overcome the limitations presented by the ANB. In this sense, it has been statistically demonstrated that ANB varies depending on age and Wits does not.[17] However, the Wits appraisal involves making skeletal diagnosis based on dental parameters[35] and, therefore, is highly influenced by the degree of dental development, vertical movements of incisors, molars, or both during treatment.[11]

To this is added that if we think about the diagnosis of the patient 3-dimensionally, it is common to exist large variations in the occlusal plane between the right side and the left side, especially in the Roll axis (Canting) that would lead to different diagnostic interpretations depending on the side to be evaluated. Therefore, it would suppose a re-evaluation of the clinical norm of the Wits that was described in 2 dimensions in lateral skull radiographs and that therefore would not take into account these bilateral variations.

In like a manner, it would happen with variations of the Wits like the one described by Chang[36] in which he projects the points A and B on the Frankfort plane. When we analyze patients 3-dimensionally, large variations in the position of the right and left Porion and Orbitale points are observed, therefore, would have a large impact on the diagnostic interpretation performed in this way.

In this scenario, we have to consider that currently that it is possible to carry out a comprehensive diagnosis of the patient 3-dimensionally, the anatomic variations of the bilateral cranial or dental landmarks make necessary to define new measures that overcome these limitations. This diagnosis inevitably involves using extracranial reference lines and therefore related to the true vertical and horizontal planes. For this, the diagnosis unavoidably passes through the use of the Natural Head position.

To this is added that the use of orthodontic 3-dimensional diagnosis in NHP allows to use a common diagnosis for the different specialties, especially for ortho-surgical cases, as it is the reference position used by the main virtual planning protocols in orthognathic surgery.[37,38,19]

Accordingly, we defined a new 3-dimensional protocol that would allow obtaining an objective interpretation of the maxillomandibular sagittal relationship without interference of intracranial or occlusal variations. On the basis of the study on a sample of 700 CBCT, it has been possible to establish the clinical norm for the sagittal diagnosis based on the linear difference between point A and B based on the true vertical: 3 ± 2.48 mm. When it was related to the ANB, a robust relationship was found [r = 0.89 ($P < 0.001$)], however, not perfect due to the aforementioned variations in the position of the Nasion.

Another important aspect occurs with the interpretation of dental and skeletal asymmetries and midlines, in which the relationship between alterations in the position of the condyle and the dental and skeletal midline has already been demonstrated by means of a CBCT study.[28] Understanding all these factors will allow us to have a much more precise understanding of the real asymmetries in relation to postural deviations.

On the basis of that knowledge, future investigations should study in depth the influence of craniofacial compensatory alterations and condylar position and its effect on sagittal and transverse measurements.

CONCLUSIONS

It can be concluded that the clinical norm for the cephalometric maxillomandibular sagittal relationship using the linear distance from point A-B is: 3 ± 2.48 mm. So, Class III patients have values of the linear distance A-B < 0.52 mm and class II patients > 5.48 mm. This new reference overcomes the limitations of using intracranial or occlusal plane references improving the diagnosis and orthognathic surgical planning process.

REFERENCES

1. Downs WB. Variations in facial relationships: their significance in treatment and prognosis. *Am J Orthod* 1948;34:812–840
2. Riedel RA. The relation of maxillary structures to cranium in malocclusion and in normal occlusion. *Angle Orthod* 1952;22: 142–145
3. Beatty EJ. A modified technique for evaluating apical base relationships. *Am J Orthod* 1975;68:303–315
4. Jacobson A. Application of the "Wits" appraisal. *Am J Orthod* 1976;70:179–189

5. Nanda RS, Merill RM. Cephalometric assessment of sagittal relationship between maxilla and mandible. *Am J Orthod Dentofac Orthop* 1994;105:328–344
6. Almaqrami BS, Alhammadi MS, Cao B. Three dimensional reliability analyses of currently used methods for assessment of sagittal jaw discrepancy. *J Clin Exp Dent* 2018;10:e352–e360
7. Järvinen S. A comparison of two angular and two linear measurements used to establish sagittal apical base relationship. *Eur J Orthod* 1981;3:131–134
8. Binder RE. The geometry of cephalometrics. *J Clin Orthod* 1979;13: 258–263
9. Hussels W, Nanda RS. Analysis of factors affecting angle ANB. *Am J Orthod* 1984;85:411–423
10. Jacobson A. The 'Wits' appraisal of jaw disharmony. *Am J Orthod* 1975;67:125–138
11. Rotberg S, Fried N, Kane J, et al. Predicting the 'Wits' appraisal from the ANB angle. *Am J Orthod* 1980;77:636–642
12. Viazis AD. A cephalometric analysis based on natural head position. *J Clin Orthod* 1991;25:172–181
13. Lundström A, Lundström F, Lebret LML, et al. Natural head position and natural head orientation: Basic considerations in cephalometric analysis and research. *Eur J Orthod* 1995;17:111–120
14. Madsen DP, Sampson WJ, Townsend GC. Craniofacial reference plane variation and natural head position. *Eur J Orthod* 2008;30: 532–540
15. Li B, Zhang Z, Lin X, et al. Sagittal cephalometric evaluation without point nasion: sagittal G-triangle analysis. *J Craniofac Surg* 2022;33:521–525
16. Verma SK, Maheshwari S, Gautam SN, et al. Natural head position: key position for radiographic and photographic analysis and research of craniofacial complex. *J Oral Biol Craniofacial Res* 2012;2:46–49
17. Bishara SE, Fahl JA, Peterson LC. Longitudinal changes in the ANB angle and Wits appraisal: clinical implications. *Am J Orthod* 1983;84:133–139
18. Cassi D, De Biase C, Tonni I, et al. Natural position of the head: review of two-dimensional and three-dimensional methods of recording. *Br J Oral Maxillofac Surg* 2016;54:233–240.
19. Hernández-Alfaro F, Giralt-Hernando M, Brabyn PJ, et al. Variation between natural head orientation and Frankfort horizontal planes in orthognathic surgery patients: 187 consecutive cases. *Int J Oral Maxillofac Surg* 2021;50:1226–1232
20. Oh J, Han JJ, Ryu S-Y, et al. Clinical and cephalometric analysis of facial soft tissue. *J Craniofac Surg* 2017;28:e431–e438
21. Hoogeveen RC, Sanderink GCH, Berkhout WER. Effect of head position on cephalometric evaluation of the soft-tissue facial profile. *Dentomaxillofacial Radiol* 2013;42:20120423
22. Bayome M, Hyun Park J, Kook YA. New three-dimensional cephalometric analyses among adults with a skeletal class I pattern and normal occlusion. *Korean J Orthod* 2013;43:62–73
23. Ludlow JB, Gubler M, Cevidanes L, et al. Precision of cephalometric landmark identification: Cone-beam computed tomography vs conventional cephalometric views. *Am J Orthod Dentofac Orthop* 2009;136:312.e1–312.e10
24. Hassan B, Van Der Stelt P, Sanderink G. Accuracy of three-dimensional measurements obtained from cone beam computed tomography surface-rendered images for cephalometric analysis: Influence of patient scanning position. *Eur J Orthod* 2009;31: 129–134
25. Dos Santos RMG, De Martino JM, Haiter Neto F, et al. Cone-beam computed tomography-based three-dimensional McNamara cephalometric analysis. *J Craniofac Surg* 2018;29:895–899
26. Porto OCL, De Freitas JC, De Alencar AHG, et al. The use of three-dimensional cephalometric references in dentoskeletal symmetry diagnosis. *Dental Press J Orthod* 2014;19:78–85
27. Cevidanes LHS, Hajati AK, Paniagua B, et al. Quantification of condylar resorption in temporomandibular joint osteoarthritis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontology* 2010;110: 110–117
28. Roque-Torres GD, Peyneau PD, Dantas da Costa E, et al. Correlation between midline deviation and condylar position in patients with Class II malocclusion: a cone-beam computed tomography evaluation. *Am J Orthod Dentofac Orthop* 2018;154: 99–107
29. Arnett GW, Milam SB, Gottesman L. Progressive mandibular retrusion-idiopathic condylar resoption. *Part I Am J Orthod Dentofac Orthop* 1996;110:8–15
30. Bilodeau JE. Retreatment of a patient who presented with condylar resorption. *Am J Orthod Dentofac Orthop* 2007;131:89–97
31. Hatcher DC. Progressive condylar resorption: pathologic processes and imaging considerations. *Semin Orthod* 2013;19:97–105
32. Cevidanes L, Oliveira AEF, Motta A, et al. Head orientation in CBCT-generated cephalograms. *Angle Orthod* 2009;79:971–977
33. Ruellas AC, de O, Tonello C, et al. Common 3-dimensional coordinate system for assessment of directional changes. *Am J Orthod Dentofac Orthop* 2016;149:645–656
34. Taylor CM. Changes in the relationship of nasion, point A, and point B and the effect upon ANB. *Am J Orthod* 1969;56:143–163
35. Nagar S, Nagar R, Raghav P. Why WITS? Why not a way beyond? *Contemp Clin Dent* 2014;5:518
36. Chang HP. Assessment of anteroposterior jaw relationship. *Am J Orthod Dentofac Orthop* 1987;92:117–122
37. Swennen GRJ, Mollemans W, De Clercq C, et al. A cone-beam computed tomography triple scan procedure to obtain a three-dimensional augmented virtual skull model appropriate for orthognathic surgery planning. *J Craniofac Surg* 2009;20:297–307
38. Hernández-Alfaro F, Guijarro-Martínez R. New protocol for three-dimensional surgical planning and CAD/CAM splint generation in orthognathic surgery: an in vitro and in vivo study. *Int J Oral Maxillofac Surg* 2013;42:1547–1556

