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ORIGINAL RESEARCH

Sensitivity and specificity of a radiographic, tomographic and digital model analysis for determining transverse discrepancies**

Sensibilidad y especificidad de un análisis radiográfico, tomográfico y de modelos digitales en la determinación de discrepancias transversales

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ABSTRACT

Introduction: Diagnosis in orthodontics must be performed in the three planes of the space to achieve coordination and harmony of the dental arches at the end of treatment. **Objective:** To determine the sensitivity and specificity of the Ricketts' PA radiographic analysis, the Penn cephalometric analysis and the Hayes model analysis with the CAC. **Material and methods:** A descriptive, cross-sectional and comparative study was performed on 100 Cone-Beam CT scans, 100 posteroanterior radiographs and 100 digital models belonging to 50 patients with normal occlusion and 50 patients with skeletal transverse discrepancy. We performed the Ricketts' PA radiographic analysis, the Penn cephalometric analyses and the Hayes model analyses with the CAC. **Results:** In all transversal analyses comparisons, the sensitivity, specificity and predictive value of the positive and negative test exceeded 85%. **Conclusions:** The Ricketts' PA radiographic analysis has more diagnostic specificity; while the Penn cephalometric analysis and the Hayes model analysis with the CAC have more diagnostic sensitivity.

RESUMEN

Introducción: El diagnóstico en ortodoncia debe ser realizado en los tres planos del espacio para lograr una coordinación y armonía de arcadas al final del tratamiento. **Objetivo:** Determinar la validez y sensibilidad del análisis radiográfico de Ricketts, el análisis cefalométrico de Penn y el análisis de modelos de Hayes con el CAC utilizados para diagnosticar discrepancias transversales. **Material y métodos:** Se realizó un estudio descriptivo, transversal y comparativo en 100 tomografías Cone-Beam, 100 radiografías posteroanteriores y 100 modelos digitales pertenecientes a 50 pacientes con normoclusión y 50 pacientes con discrepancia transversal esquelética; donde se hicieron el análisis tomográfico de Penn, el análisis radiográfico de la PA de Ricketts y el análisis de modelos de Hayes con el CAC. **Resultados:** En todas las comparaciones de los análisis transversales, la sensibilidad, la especificidad, el valor predictivo del test positivo y del test negativo, superaron el 85%. **Conclusiones:** El análisis de la PA de Ricketts posee más especificidad diagnóstica; mientras que, el análisis tomográfico de Penn y el análisis de modelos de CAC poseen más sensibilidad diagnóstica.

Key words: Transverse discrepancy, Penn cephalometric analysis, CAC analysis, postero-anterior radiograph.
Palabras clave: Discrepancia transversal, análisis tomográfico de Penn, análisis de CAC, radiografía posteroanterior.

INTRODUCTION

Diagnosis in Orthodontics must be performed in a comprehensive manner; thatis to say, that it should be an analysis in the three planes of space, both in toothand bony structures; and not only be an evaluation of the dental crowding that the patient has.

The primary objective of orthodontic treatment is to establish a good relationship between the upper and lower arch to achieve a correct static and functional

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occlusion. Additionally, in order to achieve occlusal stability, accompanied by Andrews' Six Keys of Occlusion, the maxilla and mandible should be in proportion sagittally, vertically and in the transverse dimension.

However, over the years, there have been routinely analyzes for the sagittal and vertical plane, but the transverse dimension has been left aside, as a forgotten plan. Transverse arch coordination should be one of the first objectives to achieve during orthopedic and orthodontic treatment; since undiagnosed, misdiagnosed or too camouflaged crossbites lead to a variety of aesthetic, periodontal, joint and occlusal problems.

Diagnosis of the transverse plane can be done through a postero-anterior (PA) X-ray, a CT Cone-Beam or study models.

The PAradiograph involves a more difficult interpretation than the lateral headfilm, due to the large overlap of structures and provides a two-dimensional diagnosis only. However, this type of x-rays are used for the quantification and diagnosis of facial asymmetries, upper and lower midline deviation, posterior cross bites, anomalies of the occlusal plane and directs the procedures that will be performed if there is a need for orthognathic surgery.[1] In this type of radiograph, the skeletal transverse analysis of Ricketts, introduced in 1969, may be performed.The analysis is based on the location of two skeletal points to determine the width of the maxilla and two skeletal points to determine the width of the mandible.[2] For the maxilla, the Jugal point (JL and JR, left and right), is located at the sides of the base bone of the maxilla, in the deepest point of the zygomatic-alveolarcrest, which s in the depth of the concavity of the lateral contours of the maxilla.[3]

On the other hand, Cone-Beam Computed Tomography (CBCT) allows a three-dimensional analysis and the collection of precise and accurate measurements, without the distortion caused by radiographic projections or ambiguities in landmark identification.[4] In this type of diagnostic record the Pennanalysis is performed. Simontacchi-Gbologah, VanarsdallTamburrino, Boucher, and Secchi created this analysis at the University of Pennsylvania in 2010. For the width of the maxilla the same Jugalpoint from Ricketts analysis is used, since it is assumed that the maxilla begins in the projection of the center of resistance of the upper teeth on the buccal surface of the bone cortex. On the other hand, for mandibular width the representation of the Wala ridge is used. This is close to the cortical bone edge opposite to the furcation of the first molars.[5]

Cast or digital study models are three-dimensional diagnostic records, which allow for a static and dynamic analysis of the arches.[2] In study models the Center of the Alveolar Crest (CAC) analysis can be performed to make a diagnosis. John L. Hayes, who performed a bone, not dental, diagnosisin the study models, created this analysis. Transverse diagnosis is measured by the bucco-lingual or bucco-palatalwidth in both arches at the level of the Cementoenamel Junction where the area of the alveolar crestis; and where half of this measurementis marked on the left side and on the right side. In the maxilla the distance is measured from center to center of the alveolar crest at the level of the mesial cusps; and in the mandible, at the level of the central pit.[6,7]

In the PA analysis of Ricketts the standard norm for the transverse assessmentof the maxilla is 10 mm/-1.5 mm per side.[3] On the other hand, for the Penn and CAC analyses, the norm states that the maxilla should be 5 mm wider than the mandible.[5-7] Therefore, the aim of this study was to determine the validity and sensitivity of the radiographic analysis of Ricketts, the cephalometric analysis of Penn and the modelanalysis of Hayes with CAC used to diagnose transverse discrepancies.

MATERIAL AND METHODS

The study was descriptive, cross-sectional and comparative; the study population consisted of digitised material corresponding to patients with normal cclusion and patients with skeletal transverse discrepancy. A convenience sampling method was used to collect 100 CBCTs, 100 PA X-rays and 100 digital models belonging to 50 patients with normal occlusion and 50 patients with skeletal transverse discrepancy. The patients' ages ranged between 11 and 40 years and their records were obtained from the database of the Orthodontic Postgraduate Program of the Division of Postgraduate Studies and Research (DEPeI) at UNAM.

The selection criteria were: records belonging to patients with upper and lower first molars, without bisphosphonates intake, without active periodontal disease, dental abnormalities or craniofacial syndromes; without prior orthognathic surgery, or condylar hyperplasia.

In each selected patient, the radiographic analysis of Ricketts, the tomographic analysis of Penn and the CAC model analysis of Hayes were performed. We began with the PA analysis of Ricketts, where we measured the maxillo-mandibular width on the left and right side *(Figure 1)*.

Next, we opened the CBCT to perform the Penn analysis and began with the cross-sectional measurement of the maxilla. The measurements were performed with the calibrated ruler of the CBCT viewer. We started in the sagittal section, at the start of the furcation of the first molar.

Then we moved to the coronal section, by placing the cursor at the right Jugalpoint. Finally, the measurement was made in the axial section from the right jugalpoint to the leftjugal point. In contrast, in the mandible, we started in the sagittal section likewise at the level of the first molar furcation; then in the coronal section at the level of the right WALA and the measurement was made in the axial section from left to right WALA. Finally, the difference between maxillary and mandibular widthwas determined *(Figures 2 and 3)*.

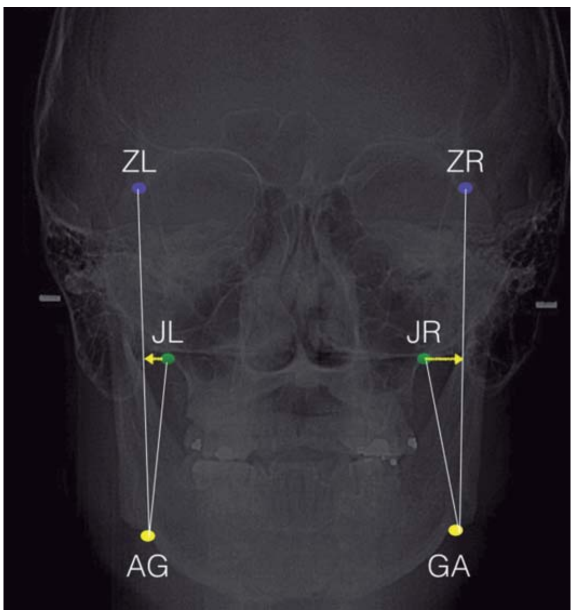

Figure 1. Anatomical points in the PA radiograph.

From the same patients, the 3 Shapede viewer was opened to view the digital models. The limits of the alveolar crest were traced in the maxilla and the mandible on the left and right side; the center of each onewas determined, in the maxilla at the level of the mesial cusps *(Figure 4)* and in the mandible, at the level of the central pit *(Figure 5)*. Then we measured from center to center and the difference between maxilla and mandiblewas determined. These measurements were performed with the same software since it also comes with a calibrated ruler at a 1:1 proportion.

The information was captured and analyzed by means of a statistical package. To determine the diagnostic concordance between the researcher and the observer, the Kappa test was applied, in which a concordance index of 90% was obtained.

The sensitivity of a diagnostic test determines the proportion of transverse discrepancies that are correctly identified by the diagnostic analysis in patients with transverse discrepancy. The sensitivity varies from 0 to 1 (0-100%), so that the higher the numerical value, the better the ability to detect patients with transverse discrepancy.

In contrast, the specificity measures the proportion of patients without transverse discrepancy that are correctly identified by the diagnostic analysis in patients without transverse problems. Specificity varies from 0 to 1 (0-100%); hence, the higher the numeric value, the better ability to detect patients with normal occlusion and no transverse discrepancy.

Sagittal Coronal Axial

Figure 2. Tomographic sections for the Penn analysis in the maxilla.

Sagittal Coronal Axial

Figure 3. Tomographic sections for the Penn analysis in the mandible.

To calculate the sensitivity and specificity between the three analyses, we applied the Screening Test, which is a test of filtration that determined the values in the following way:

- Sensitivity = TP/(TP + FN) × 100
- Specificity = TN/(TN + FP) × 100

Once the sensitivity and specificity of the three transverse analysis was determined, we obtained four diagnostic types:

1. True positive (TP): the diagnostic analysis predicted correctly the transverse discrepancy where one did exist.
2. False positive (FP): the diagnostic analysis predicted a transverse discrepancy where one did not exist.
3. False negative (FN): the diagnosticanalysis determined that there was notransverse discrepancy where it did exist.
4. True negative (TN): the diagnostic analysis predicted that there was no transverse discrepancy where one did not exist.

For the three diagnostic tests, the predictive values of the positive and negative tests were also calculated as follows:

- Predictive value of the positive test = TP/(TP + FN) × 100
- Predictive value of the negative test = TN(TN + FP) × 100

The predictive value of the positive test indicated the percentage of patients who were diagnosed by the analysis as patients with transverse discrepancy and that actually had this condition. In contrast, the predictive value of the negative test, determined the percentage of patients who were diagnosed with a negative test for the condition, i.e. patients with normal occlusionand who really did not have a transverse discrepancy.

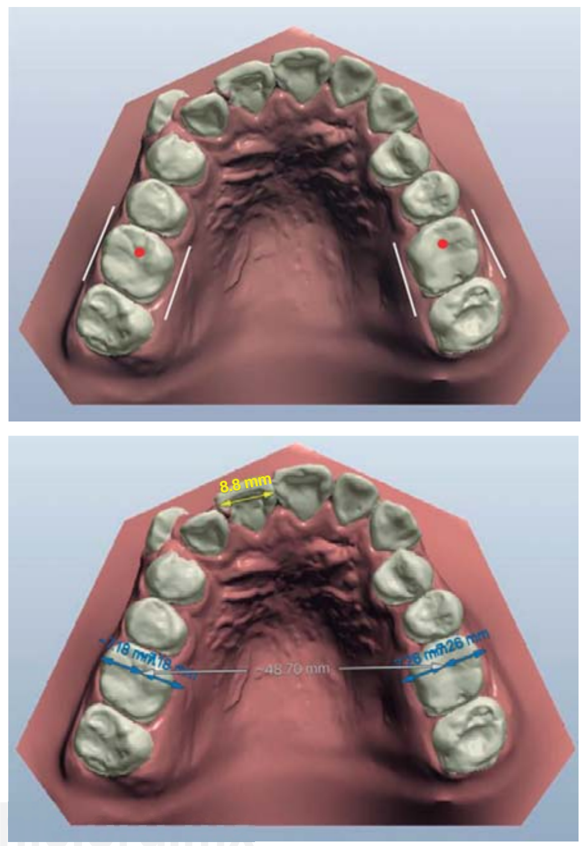

Figure 4. Measurements in the maxilla for the CAC analysis.

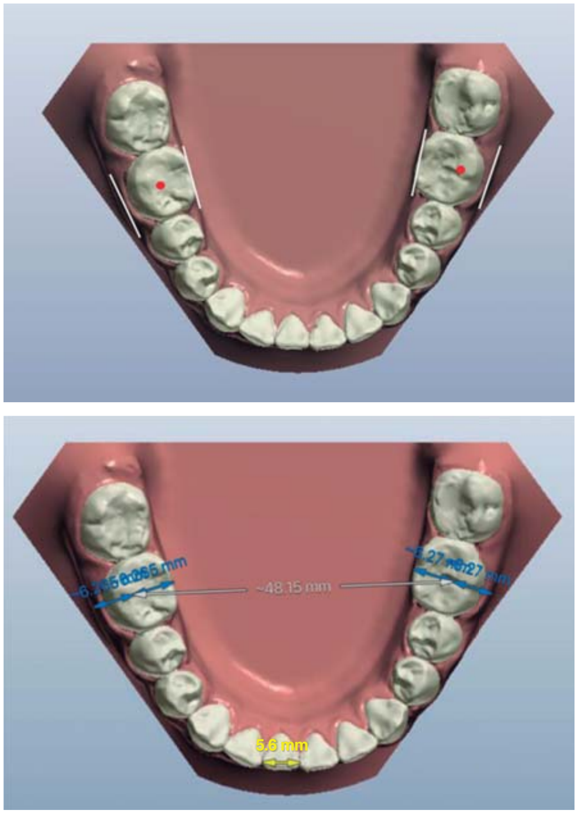

Figure 5. Measurements in the mandible for the CAC analysis.

Table I. Sensitivity, specificity, predictive values for the positive and negative tests.

Comparison	Results %
PA versus Penn analysis	Sensitivity = 97.8
	Specificity = 88.8
	PPVT = 88.2
	NPVT = 97.9
PA versus CAC analysis	Sensitivity = 97.9
	Specificity = 86.5
	PPVT = 87
	NPVT = 97.8
Penn analysis versus PA	Sensitivity = 88.2
	Specificity = 97.9
	PPVT = 97.8
	NPVT = 88.8
Penn analysis versus CAC analysis	Sensitivity = 94
	Specificity = 96
	PPVT = 95.9
	NPVT = 94
CAC analysis versus PA analysis	Sensitivity = 87
	Specificity = 97.8
	PPVT = 97.9
	NPVT = 86.5
CAC analysis versus Penn	Sensitivity = 95.9
	Specificity = 94
	PPVT = 94
	NPVT = 96

RESULTS

With the obtained diagnosis in the three transverse analyses, 2 × 2 tables were used to make paired comparisons. The determination of the sensitivity, specificity, and predictive value of the positive test and the predictive value of the negative test are summarized in *table I*.

It should be noted that, when comparing PA Ricketts analysis with the Penn analysis the sensitivity of the analysis of Penn was of 97.8%. In the comparison between Ricketts PA analysis and the Hayes analysis with CAC in digital models the sensitivity of the CAC analysis was 97.9%. When the Penn analysis was compared with the CAC model analysis; and the CAC analysis versus tomographic analysis of Penn, the sensitivity was 94% and 95.9% respectively. In contrast, the comparison of the CAC model analysis versus the PA radiographic analysis, the sensitivity decreased to 87%, which is also reflected in the comparison of the Penn tomographic analysis versus Ricketts PA radiographic analysis, where the sensitivity was 88.2%.

On the other hand, in the determination of specificity, it was observed that, the ability to identify normal occlusionswas expressed as follows: CAC analysis of digital models versus Penn analysis, the specificity was 94%; when comparing the Penn analysis with Hayes models analysis the specificity was 96%; analysis of Penn versus Ricketts PA Analysis, the specificity of the PA was 97.9%. Upon comparison of the CAC models analysis with the PA analysis, the specificity of the PA analysis was 97.8%. Finally it was shown that the Penn analysis and Hayes models analysis with CAC are less specific, since, when compared with the Ricketts PA analysis, they obtained a specificity of 88.8% and 86.5%, respectively.

In all comparisons of the transverse analysis, the predictive value of the positive and negative tests exceeded 85%.

DISCUSSION

One of the fundamental objectives of orthodontic treatment is the certainty of a diagnosis to perform a proper treatment. Tamburrinoy et al[5] established in their article the parameters, benefits, disadvantages and limitations of three scientifically validated transverse analysis: Ricketts PA analysis, Wala

Ridge analysis in models and Penn analysis on CBCT. However, they did not make a comparison between them; but rather with the collection of information, it can be seen that the Penn tomographic analysis shows the greater benefits and fewer limitations.

Miner and colleagues[8] also performed a study to determine the sensitivity and specificity of the tomographic analysis for the transverse widths of the maxilla. They determined that, in addition of being a diagnostic method with a high percentage of sensitivity and specificity, it aids in determiningby means of the coronal section if there is a skeletal and/or dental transverse discrepancy. This is achieved through additional anatomical points in the palatal, lingual and in the longitudinal axis of the molars.[9]

On the other hand, in a systematic review of diagnostic methods to determine skeletal and/or dental transverse deficiencies in the maxilla,[10] the authors concluded that the transverse analysis performed in tomography are those with greatest superiority and diagnostic certainty.

With regard to the transverse diagnosis made in posteroanterior radiographs, it is a method that has some disadvantages, since it performs a two-dimensional diagnosis of a three-dimensional structure. In addition, there are «projection» problems due to image magnification and «identification» problems of the anatomical points due to structure superimposition.[11,12] In addition, Legrell, Nyquist and Isberg[13] claim that the Goniac and Antegoniac points are invalid for measuring mandibular width, as they are very far from the center of resistance of the lower molars and of the mandibular alveolar/skeletal base. It is therefore considered an invalid point to be compared in a millimeter measurement with the left and right Jugale points in the maxilla that are close to the center of resistance of the upper molars and maxillary bone base.[14]

Regarding the transverse analysis in study models, over the years, usually diagnoses were made at a dental level and not at the level of bone. John Hayes explains in his articles that orthodontists have been accustomed to replace bone points with dental points of reference; since they only consider the position of the mesio-labial pits of the upper molars and the central pits of the lower molars. However, orthodontists often forget to analyze whether these molars are compensated or not by a transverse skeletal problem.[6,7] For this reason, he suggested to use the measurement at the Center of the Alveolar Crest (CAC) on both sides to perform a skeletal diagnosis of the transverse dimension.

To perform an accurate transverse diagnosis is essential to achieve good results in orthodontic treatment. If the wrong transverse diagnosis is made, fenestrations may be caused while preforming dental compensationsor produce occlusal instability due to interferences and premature contact points as well as periodontal problems, joint problems, among others.[5,15]

In the present study, three diagnostic techniques were compared, using the Screening Test to determine the sensitivity, specificity, positive and negative predictive value of the test. The study made it possible to obtain valid conclusions because we identified through the Screening Test the genuine cases of transverse discrepancy; discarding false positive diagnoses.

CONCLUSIONS

1. The PA analysis of Ricketts, the tomographic analysis of Penn and the CAC analysis of models have a sensitivity and specificity of more than 85%.
2. The analysis of Penn and the CAC analysis of models have 10% more diagnostic sensitivity than the PA analysis of Ricketts; therefore, they avoid false negative diagnoses.
3. The PA analysis of Ricketts has 10% more diagnostic specificity than the analysis of Penn and the CAC analysis of models; therefore, it avoids false positive diagnoses.
4. Due to the diagnostic validity of the Penn analysis and the CAC analysis, they can be considered as the new gold standards for the precise diagnosis of transverse skeletal discrepancies.

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