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Role of cephalometric analysis of hard tissues in the diagnosis of malocclusions

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Abstract

Objective: Conduct a literature review to understand how cephalometric hard tissue analysis contributes to the diagnosis and classification of malocclusions.

Materials and Methods: A literature search was carried out in English and Spanish on the Pubmed, Scopus, Sciencedirect and Scielo platforms, as well as in graduate studies. Conclusions: Cephalometric hard tissue analysis is a fundamental tool in the field of modern orthodontics, as it not only contributes accurately to the diagnosis and treatment of malocclusions, but also strengthens an evidence-based approach, which allows orthodontists to obtain and offer more effective treatment plans, personalized and adapted to the needs of each patient.

Keywords: Cephalometry; Bone tissues; Diagnosis; Malocclusion

1. Introduction

The understanding of malocclusion is fundamental since it is one of the most common dentofacial alterations in orthodontics, in which its correct evaluation is essential for the success of the treatment. Cephalometric analysis of hard tissues facilitates diagnosis and treatment planning by evaluating craniofacial bone structures through reference points. Hard tissues have evolved thanks to advances in three-dimensional (3D) imaging and the use of artificial intelligence (AI), providing greater accuracy in the interpretation of malocclusions, particularly in the analysis of the position and relationship between the maxilla and mandible.

The purpose of this article is to examine how cephalometric hard tissue analysis aids in the diagnosis of malocclusions, highlighting points of agreement with current practice and examining the benefits of sophisticated three-dimensional imaging methods in diagnostic accuracy.

2. State of the art

2.1. History of cephalometric analysis in orthodontics

Historically, cephalometry has played a fundamental role in orthodontic diagnosis since its beginnings, when Hofrath and Broadbent implemented their craniofacial radiographic analysis techniques in 1930. In the beginning, the analysis was based on two-dimensional (2D) radiographs, which had limitations in accuracy and could cause bias in the analysis. With current three-dimensional imaging techniques and the use of computed tomography (CT), cephalometry has advanced in reliability and accuracy, particularly in the diagnosis of complex maxillofacial disorders (1,2).

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Current research, such as that of Yao K, et al.(2023) (1), demonstrates that three-dimensional cephalometric analysis systems provide superior reliability when analyzing hard tissue landmarks. This analysis highlights the use of 126 landmarks divided into cranial, mandibular and dental regions, which provide an accurate description of facial symmetry and the relationship between bony structures.

The implementation of artificial intelligence in the development and analysis of cephalometric points represents another important progress (3). They compare 2D and 3D measurements, noting that 3D images allow better identification of malocclusions, as they provide a spatial context that enhances the understanding of structural relationships. Automation through artificial intelligence decreases the possibility of human error, promoting greater accuracy and consistency in diagnoses(4)(5).

2.1.1. Evolution of Cephalometry

Cephalometric study began with research where angles and distances were measured on lateral cephalic radiographs to analyze facial bone structures, focusing on the hard tissues (skull and jaw bones). This methodology provided orthodontic experts with an objective method of evaluating skeletal structure and understanding the relationship between teeth and facial structures. Downs, Riedel and Tweed created additional techniques to standardize these measurements and increase diagnostic accuracy (6).

2.2. Fundamental Cephalometric Parameters in Malocclusion Diagnosis

In the orthodontic field, cephalometric parameters are fundamental to diagnose malocclusions and program treatments accurately. These parameters allow orthodontists to classify malocclusions according to the patient's skeletal and dental relationship, facilitating the development of personalized treatment strategies. The interpretation of these parameters should always be integrated with the clinical evaluation and other diagnostic records to achieve a comprehensive approach to orthodontic treatment.

2.2.1. Main Cephalometric Parameters

- ANB angle: This angle is generated between the lines joining points A (the most anterior point of the maxilla), N (nasion, the point at the base of the nose) and B (the most concave point of the anterior border of the mandible). An ANB angle of 2° to 4° is considered normal. An ANB greater than 4° indicates a Class II relationship (maxillary protrusion), while a value less than 2° suggests a Class III relationship (mandibular prognathism) (7).
- Angle Class Ratio: although not a direct cephalometric parameter, Angle's classification is based on the relationship of the first permanent molars. Cephalometry facilitates the location of these molars with respect to the reference planes, providing accurate data on the malocclusion.
- SNA and SNB angle: The SNA angle measures the position of the maxilla in relation to the reference plane (nasion line-point A), and the SNB angle measures the position of the mandible in relation to the same plane (nasion-point B). The difference between these two angles (ANB) indicates precise information about the relationship between the maxillary and mandibular structures.
- Maxillary and Mandibular Length: The length of the maxilla (A) and mandible (B) is performed to assess growth and the relationship between both structures, which is fundamental in the diagnosis of skeletal malocclusions.
- Frankfort plane: This horizontal plane is used as a reference point for measuring other angles and relationships. The inclination of the Frankfort plane has an impact on the position of teeth and the relationship between facial structures.
- Relationship of the Incisors: The inclination and position of the maxillary and mandibular incisors in relation to Frankfort's plane and the mandibular plane is essential in establishing tooth alignment in malocclusions.
- Goniac angle: this angle is formed between the mandibular ramus and the mandibular plane, and indicates the vertical or horizontal orientation of the mandible. An increased goniac angle indicates a more vertical mandible, while a decreased one indicates a horizontal mandible, this angle contributes in the classification of malocclusion.
- Facial height: The anterior and posterior facial height indicate the vertical growth of the face, which help us to understand the facial proportions and their relationship with occlusion (7,8)(9).

2.3. Cephalometric Characteristics in Normal Occlusion and Malocclusions

- Normal occlusion: In a normal type of occlusion (Class I), the lower first molar is correctly aligned with respect to the upper first molar. The incisors are positioned vertically on the alveolar bone, and cephalometric angles, such as the ANB, are in the range of 2 to 4 degrees, indicating a balanced relationship between the maxilla and

mandible. Facial height is also well proportioned, contributing to a harmonious and proportional facial appearance.
- Mild malocclusions: In mild cases, there may be minor variations in the molar relationship, such as mild retrognathia or prognathia in the incisors. These deviations usually have little or no impact on function or esthetics, and the ANB angle is usually in the range of 1 to 3 degrees, indicating a near-normal relationship between the jaws.
- Class II: Characterized by an elevated ANB angle (greater than 4 degrees), indicating a disproportion between the maxilla and mandible. This malocclusion is related to a convex facial profile and a possible retrusion of the mandible, which is assessed by a decreased SNB angle. The upper incisors are more protruded, while the lower incisors tend to be inclined lingually.
- Class III: In this malocclusion, the ANB angle is negative or very low, indicating that the mandible is in a more forward position compared to the maxilla. This is reflected in an elevated SNB angle and a concave facial profile. Mandibular protrusion is common, with mandibular incisors more advanced than the maxillary incisors.

These parameters, among others, provide detailed and thorough information on dental alignment and facial proportions, which allows orthodontists to decide correctly on extractions, the use of appliances and other interventions (8).

2.4. Modern Methods of Cephalometric Analysis of Hard Tissues

Due to the current technology on the market, cephalometric analysis has evolved significantly, moving away from manual tracing and towards digital analysis. This transition has provided orthodontists with greater precision in measurements and has optimized both diagnosis and treatment planning. Therefore, the following highlights the main advantages of using digital cephalometric methods over traditional methods, highlighting how modern software has transformed orthodontic practice.

2.4.1. Advantages of Digital Cephalometry over Manual Tracing

- Accuracy and Uniformity: Digital systems, such as Dolphin software, offer superior accuracy in cephalometric measurements, minimizing errors by the dental professional compared to manual tracing. This is crucial for reliable identification of malocclusion patterns and ensures more accurate diagnoses for orthodontic professionals.
- Time Savings: Unlike manual tracing, which can be a time-consuming process, digital analysis allows for quick diagnoses. This leaves more time for treatment planning and follow-up, improving patient care.
- Optimized Visualization: Programs such as Dolphin include three-dimensional (3D) visualization tools that allow practitioners to examine images from different angles. This helps identify spatial relationships and malocclusion patterns that might go unnoticed in a two-dimensional analysis.
- Detailed Analysis: Digital cephalometry facilitates statistical analysis and comparisons between measurements, allowing orthodontists to evaluate the effectiveness of treatments and adjust their approaches according to the results obtained.
- Ease of Storage and Access: Digital systems allow secure and accessible storage of large volumes of patient data. This facilitates tracking progress over time and provides a detailed and complete history of each case.
- Error Reduction: The elimination of manual steps in the measurement process reduces the possibility of errors, ensuring more accurate and reliable diagnoses, especially in orthodontic treatments that require high precision.
- Accessible Interface: Most modern programs offer intuitive interfaces, making them easy to use even for those unfamiliar with the technology. This makes cephalometric software accessible to a wide range of orthodontists, facilitating its integration into clinical practice (9,10).

2.5. Impact of Cephalometric Analysis of Hard Tissue in Skeletal Malocclusions.

Cephalometric analysis of hard tissues is essential in orthodontics to distinguish between malocclusions of skeletal and dental origin. This differentiation guides treatment, since skeletal malocclusions may require orthognathic surgery in addition to orthodontics, while those of dental origin are usually resolved with orthodontics alone (11).

2.5.1. Classification of Malocclusions

- Skeletal Malocclusions: These are due to discrepancies in the growth of the maxilla or mandible, detectable by angular relationships, such as the ANB angle. An elevated ANB indicates that the mandible is more retruded, which may require surgery.

- Dental malocclusions are related to the alignment of teeth in normal bone structures. Cephalometry helps to evaluate if dental malpositions are the cause of the malocclusion.

2.5.2. Key Applications

- Evaluation and Treatment Planning: Cephalometric angles and measurements allow to decide between orthodontics and surgery, especially in cases with severe discrepancies.
- Identification of Asymmetries and Discrepancies: Allows to see facial asymmetries and vertical and transversal discrepancies that are not identified in two-dimensional analysis (12).

2.6. Growth Prediction and its Relation to the Diagnosis of Malocclusions

Cephalometry is effective in evaluating and predicting facial growth, especially in pediatric and adolescent patients, allowing anticipation of skeletal changes that may affect occlusion and facial esthetics (13).

2.6.1. Key Issues in Growth Prediction

- Morphological Data: Allows to obtain detailed images of the craniofacial structures, measuring anatomical points that help to evaluate the shape and dimensions of the skull and face, favoring the prediction of growth in each patient.
- Classification of Facial Types: Patients can be classified into facial types (hypodivergent, normodivergent and hyperdivergent) based on cephalometric angles. This classification allows for anticipating distinct growth patterns that impact treatment planning.
- Identification of Growth Trajectories: Longitudinal studies show that each facial type follows a specific growth trajectory, which is critical in predicting how the facial structure will develop over time.

2.6.2. Treatment Planning Applications

- Early Planning and Treatment: Growth prediction allows for early interventions in cases where mandibular or maxillary development is expected that could correct Class II or III malocclusions without the need for surgery.
- Minimizing complications: Anticipating growth helps avoid treatments that could worsen malocclusion. For example, in Class II cases, an intervention that does not consider the potential for mandibular growth can lead to major discrepancies.
- Evaluation of Condylar Growth: By evaluating the growth of the mandibular condyle, abnormalities such as hypoplasia or hyperplasia can be identified, which affect the function of the TMJ and can result in occlusion problems. This is of vital importance in classifying and treating complex skeletal malocclusions(14)(13).

2.6.3. Technological Advances in Cephalometry

Digital cephalometry and the implementation of AI have revolutionized cephalometric analysis. Systems such as Dolphin software offer accuracy and speed in the identification of cephalometric points, minimizing human error. (1) demonstrate that 3D systems, by integrating AI, provide an improved spatial context that facilitates the understanding of the relationships between bony structures, allowing a more accurate classification of malocclusions.

In addition, studies by Albarakati, et al (2021). highlight that 3D imaging allows detailed visualization of facial structures, key to complex diagnoses, improving the understanding of discrepancies between the maxillae and mandible.

3. Discussion

Cephalometric hard tissue analysis has proven to be an essential tool in orthodontic diagnosis and treatment planning, especially in addressing malocclusions. Over time, this technique has evolved considerably, from the use of two-dimensional radiographs to the incorporation of three-dimensional methods and the use of artificial intelligence, providing a more accurate assessment of craniofacial bony structures (8).

The incorporation of three-dimensional (3D) imaging and artificial intelligence has greatly improved the accuracy of cephalometric analysis. Recent studies, such as that of Wei et al (2023), have shown that the use of three-dimensional landmarks improves accuracy in the evaluation of facial symmetry and the relationships between the maxilla and mandible, which are decisive elements for classifying and planning the treatment of malocclusions (1).

These advanced techniques also facilitate the identification of skeletal discrepancies in patients with severe malocclusions, providing a more detailed and accurate view of structural relationships, which is difficult to achieve with traditional two-dimensional methods.

One of the major contributions of cephalometric hard tissue analysis is its ability to differentiate between malocclusions of skeletal and dental origin. This distinction is crucial, as it allows treatment to be tailored to the specific needs of the patient. Skeletal malocclusions may require surgical interventions to reposition these structures. On the contrary, malocclusions of dental origin can be corrected with orthodontic treatment without surgery(4)(8).

Cephalometric analysis is also crucial for predicting facial growth and development, mainly in growing patients. According to Knigge et al. (2021), this analysis allows to classify patients according to their facial types (hypodivergent, normodivergent or hyperdivergent), which is key to anticipate growth patterns and adjust treatment according to expected projections(4).

In addition, this prediction allows early interventions in cases where mandibular or maxillary growth could improve or correct a malocclusion without surgery, optimizing long-term treatment and avoiding unnecessary interventions(15).

Digital systems and artificial intelligence have transformed orthodontic practice, providing tools such as Dolphin software that allow for more detailed and faster analysis, minimizing human error. These technologies not only facilitate storage and access to patient records, but also allow continuous assessment of changes over time, which is especially useful for patients in prolonged treatment.

In short, cephalometric hard tissue analysis continues to be an invaluable resource in the diagnosis and management of malocclusions, adapting to technological innovations to improve accuracy and customization of treatment. Modern methodologies have facilitated more specific classification of malocclusions and better treatment planning, improving outcomes and raising standards in orthodontic practice(15,16).

4. Conclusion

Cephalometric hard tissue analysis has become an essential and advanced tool for the diagnosis, classification and planning of orthodontic treatments, especially in the approach to malocclusions. From its beginnings in two-dimensional analysis to the incorporation of three- dimensional images and artificial intelligence systems, it has increased accuracy and reliability in orthodontic practice, allowing a better evaluation of skeletal and dental structures.

Thanks to technological advances, digital cephalometric analysis has facilitated a precise differentiation between malocclusions of skeletal and dental origin, facilitating the design of highly personalized treatments. In the case of skeletal malocclusions, cephalometry helps to identify those conditions that may benefit from surgical intervention, while, in malocclusions of dental origin, it optimizes orthodontic treatment without the need for surgery. On the other hand, its ability to predict facial growth is of great value in pediatric and adolescent patients, allowing early interventions and guiding facial development effectively towards a functional and esthetic occlusion.

In conclusion, cephalometric hard tissue analysis is an essential tool in modern orthodontics. Not only does it increase accuracy in the diagnosis and treatment of malocclusions, but it also makes it possible to offer more effective, personalized solutions adapted to the needs of each patient. With the constant development of new technologies, cephalometry will continue to raise the standards in orthodontic practice and improve long-term clinical outcomes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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