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3D Cephalometry: Is it really worth?

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ABSTRACT
Ever since the science of cephalometry has been invented, it has been a very important tool in the field of orthodontics for diagnosis and treatment planning. Conventional cephalometry is two dimensional representation of three dimensional structures. But now with the use of Cone Beam Computed Tomography (CBCT) it is possible to visualize the craniofacial structures in all the three dimensions. 3D cephalometry has many advantages over conventional cephalometry. It is more informative in diagnosis in treatment planning of certain conditions in which conventional cephalograms are not useful like orofacial cleft, orthognathic issues and severe craniofacial deformities. However, high cost and high radiation exposure are the major disadvantages of this technique. This article signifies the role of 3D cephalometry in present day orthodontic practice. Today 3D cephalometry is not being used for all patients but with further development and research in this field it will help orthodontist to carry out diagnosis and treatment planning more efficiently and accurately.

Key words: cephalometry, CBCT, MSCT

I. INTRODUCTION

Cephalometric radiography was first introduced in 1931 by Hofrath in Germany and Broadbent in the United States. [1] The method uses frontal and lateral cephalometric radiographs to evaluate the craniofacial complex, dentofacial proportions, malocclusion and changes related to growth, all of which are important for orthodontic treatment planning and evaluation. A conventional cephalometric radiograph is a two-dimensional representation of three-dimensional structures. Although widely accepted as a standard tool for treatment planning, it still has several downsides, such as geometric distortion and superimposition of structures. [2,3]

Recently, three-dimensional images have started to play an important role in orthodontic diagnosis and treatment planning. Several years ago computed tomography (CT) was introduced into the dental field. In 1996, Cone-Beam Computed Tomography (CBCT) was invented, and the technology has been evolving ever since. With relatively lower radiation doses than Multi-Slice CT (MSCT), CBCT has become very popular in dentistry. 3D cephalometric application allow orthodontists to visualize craniofacial structures in three dimensions and overcome the drawback of 2D conventional cephalometric analysis Three-dimensional cephalometric analysis requires input from 3D images of the patient, either on CBCTs or on MSCTs, and software that offers 3D cephalometric measurement tools.[4]

Review regarding landmark identification, accuracy and reproducibility of 3D CBCT generated cephalograms

Many studies have been conducted in past for judging accuracy of landmark identification and its reproducibility in 3D cephalograms.

Adams et al (2004) in their study found that certain midsagittal measurement (Na-B, Na-s, Na-A and A-B) were significantly more accurate than 2D cephalograms.[5]

According to Lascala CA et al (2004), 3D CBCT measurements are not only more accurate than 2D measurements but also are close to reality.[6]

Mohammed Bayone et al from their study conclude that CBCT images are an essential element in diagnosis and treatment planning for patients in need of orthodontic and/or orthognathic surgeries.[7]

According to So-jim Kim et al (2012), 3D computed tomography enables accurate measurements without distortion regardless of head orientation using real anatomic surface landmarks, not projected and 3D representation of complex morphology including volumetric measurements.[8]

According to John Ludlow et al (2009), CBCT images generally provided a more precise identification of all landmarks as compared to conventional cephalograms.[9]

PC Chien et al (2009) [10] and Manuel Lagravere et al (2010)[11] from their studies concluded that CBCT allowed for better and more reliable inter-observer and intra-observer reliability in most of the landmarks when compared to 2D digital imaging.

According to CPC Zolo (2010), the measurements taken from 3D images showed less dispersion and greater reliability in identifying cephalometric landmarks as compared to conventional cephalograms.[12]

According to Damstra et al (2011), manual landmark plotting on a three dimensional images is a challenging task which influences cephalometric analysis in terms of accuracy and reliability. It requires considerable efforts and time, notwithstanding a significant level of experience which may be needed in marketing these 3D images.[13]

According to Chang Seo-Park et al (2012), the linear measurements between the two imaging modalities were not statistically different except for the U1 to facial plane distance. Angular measurements between the two imaging modalities were statistically different with the exception of the Gonial angle, ANB difference and facial convexity.[14]

Advantages of 3D Cephalogram

Three-dimensional cephalometric method allows the analysis of anomalies in three spatial planes (sagittal, frontal, and axial), directly and visually, without the need to interpolate different measurements obtained in each of the three spatial planes. Real-size (1:1 scale) and real-time 3D cephalometric analysis [15] is possible with the help of CBCT. No superimposition of anatomic structures occurs.[16]

Three-dimensional cephalometric method seems to be more accurate and reliable than conventional.[17] The additional information provided by a direct 3D cephalometry helps to solve postural and growth problems more easily and faster than with 2D cephalometry

Conventional cephalometric radiographs are no longer made for patients with orofacial clefts, orthognathic issues, or severe maxillofacial deformities. Because these patients undergo long, intensive treatment until late adolescence, their growth and development must be well-documented and for that 3D cephalometric radiographs should be use.

Disadvantages of 3D Cephalogram

CBCT has high cost and high radiation dose compared to conventional radiography. In CBCT it is difficult to compensate for the differences in enlargement (termed "projective displacement") of structures which lie at different distances from the frontal and lateral film surfaces.[18]

3D tracings are not suitable for longitudinal research in cases where there are only 2D records from the past. Some inherent flaws and errors of this scheme include tracing and digitizing errors, failure of the porions to superimpose in the lateral film. There is also lack of a detailed occlusion due to artifacts.[15]

Comparison with 2D and conventional cephalograms

In a cephalostat, the distance between the midsagittal plane of the head and the radiation source is fixed, as is the distance from the midsagittal plane to the film. In the CBCT device, the radiation source moves around the patient, very much as in an orthopantomogram. These differences may lead to variations in magnifications and distortion. For angular measurements, this is not a problem, e.g. for angle ANB. However, absolute distances between landmarks, e.g. AR-A, can show differences between both methods, especially if they are located in different tomographic planes.[17,18] Chidiac et al found a close relationship between angular measurements, but a difference in the accuracy of linear measurements.[19]

In conventional cephalometry, the position of the patient in the cephalostat is fixed by the ear rods for movements along the long axis of the skull. In the CBCT device, there are no ear rods to fix the position of the patient. Extra care must be taken when placing the patient in the CBCT machine.[15]

Conventional cephalometrics involves a 2D representation of a 3D structure. This has certain disadvantages. Now there is possibility of making a 3D image of the skull, it is also possible to perform a 3D cephalometric analysis. In such an analysis, the actual anatomic structures can be identified, instead of a 2D projection. On the other hand, some other landmarks used in conventional cephalometric analysis cannot be used, e.g., articulare, because this is a constructed landmark. Therefore, there is a need to develop and test new 3D-cephalometric analyses, foremost because there are newly defined 3D landmarks.[2]

Lateral cephalometric radiograph

2D image obtained with Cone-Beam Computed Tomography, in lateral

3D image obtained with the Cone-Beam Computed Tomography, in lateral view.

Carolina Perez Couceiro,Oswaldo de Vasconcellos Vilella 2D / 3D Cone-Beam CT images or conventional radiography: Which is more reliable?11

Three-dimensional images are more reliable for the identification of some cephalometric landmarks which are difficult to detect in 2D images, such as porion (Po), orbitale (Or), subspinale (A), supramentale (B) and nasion (N). [10] The lower mandibular border seemed easier to identify 3D images do not seem to be as reliable for identifying the long axes of the upper and lower incisors. [10]

II. CONCLUSION

Over the past few decades, conventional cephalometry is being used for diagnosis and treatment planning in orthodontics and dentofacial orthopedics. But CBCT has expanded the diagnostic possibilities and changed the way of diagnosis. Computed tomography provides 3D image, high spatial resolution smaller size lower acquisition cost and maintenance making it a natural fit for craniofacial imaging. With the recent advances in the field of radiographic techniques and orthodontic diagnostic tools, 3D cephalometry provide more accurate, reproducible and reliable option for orthodontist compare to conventional cephalometry.

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