Comparison between 3D and 2D Cephalometric Analysis of 200 Thai Patients
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Cephalometric radiography is an important diagnostic tool in orthodontics and craniomaxillofacial surgery. Conventionally, cephalometric variables are measured using two-dimensional cephalometric analysis on either lateral or frontal analysis, which could lead to erroneous results in skull measurements due to inherent shortcomings of 2D cephalometric analysis which could not take the combined result of lateral and frontal measurement into account. This paper presented the three-dimensional cephalometric analysis on DICOM data from I-CAT CT cone-beam machine. The averaged values and standard deviations of 44 cephalometric angular- and 30 cephalometric linear-measurements were determined from CT radiographs of 200 Thai non-severe patients, which 100 men and 100 women. DICOM data from the CT had been transformed into 3D data using Simplant Master and performed 3D cephalometric Analysis using Simplant CMF from Materialise. The result of cephalometric analysis in 3D has been compared with the 2D cephalometric analysis which showed that 3D analysis results yielded 2 sections which were either significantly different or not significantly different results comparing to the 2D analysis on using the same skull. Cephalometric analysis results in 3D will be used as a set of average Thai patients in the Clinical Ceph3D services as requested by dentists and researches with interests on cephalometric analysis and anthropology with focus on Thai subjects.

1. INTRODUCTION

Cephalometric analysis is one of essential tools for the orthodontic diagnoses as well as craniomaxillofacial surgery. Two-dimensional cephalometric measurements from lateral and/or frontal cephalograms were widely studied in several ethnic groups including Thai people [1, 2, 3]. However, 2D-cephalometry which is a projection image of 3D-structures has several weak points, such as; non-homogenous enlargement and distortion especially of lateral structures, overlapping structures leading to inaccurate landmark locations, landmarks that appear on the lateral may not appear on the frontal image or vice versa, improper head position may lead to fault diagnosis. Furthermore, using average measurements of left and right structures in 2Dcephalometry as though both sides of the face are symmetrical is not realistic since human face is rarely symmetrical [4]. Olzewsksie et al. has demonstrated that 3D analysis gives the same results and adequate diagnoses as 2D analysis using the same skull [5] while Adam et al. has shown that using a 3D method is more precise with 4-5 times more accurate than the 2D approach [6]. However, few 3D cephalometric analysis researches were focusing on a large number of samples [7, 8, 9].

2. METHODS

I-CAT cone beam CT scan was used with 512 x 512 matrices, radiation at 120 kV and 87.75 mAs taken at 0.4 mm slice thickness. Simplant Master™ (Materialise N.V.), medical image processing software, was used for 3D reconstruction from CT DICOM data with 0.4 mm interpolated slice
thickness. All anatomical landmarks were first identified on the 3D model, and their positions were verified in multi-planar reformat mode in axial and sagittal views [7].

Figure 1: 2D and 3D Cephalometric Measurements

Forty-four angular measurements and thirty linear measurements [10, 11, 12, 13] based upon thirty-three landmarks were analyzed from CT radiographs of 100 men and 100 women, non-severe Thai patients. Figure 1 (A) and (B) depicted 3D images where 3D cephalometric analysis was derived from. Simplant CMF™ was applied to calculate default 2D cephalometric analysis in form of lateral x-ray in Figure 1(C). Readjustment of the sagittal plane to display an x-ray image of frontal skull was applied to get 2D frontal analysis in Figure 1(D). Subsequently, 3D cephalometric analysis was compared with corresponding 2D lateral and frontal analysis.

The ages of 100 males were ranged from 19 to 70 years while the ages of 100 female patients were ranged from 16 to 69 years. The mean age from 100 males was $36.72 \pm 13.55$ years while the mean age from 100 females was $36.26 \pm 13.64$ years.

3. RESULTS

Randomly selected 10 males and 10 females were digitized twice by the same operator for the test of accuracy and reliability. Paired T-Test through command TTEST of Microsoft Excel® was used to analyze the differences at $p<0.05$. The results showed that most had the probability levels over the 0.05 threshold, indicating high reliability on digitizing of landmarks. The paired T-Test was also applied to compare 2D measurements and corresponding 3D measurements as well as the cephalometric measurements from male patients and the corresponding measurements from female patients in both linear and angular measurements. The data along with comparison of 3D and 2D for linear measurements and angular measurements can be shown in Table 1 and Table 2 respectively to analyze whether the mean values differed significantly at $p \geq 0.05$ as “NS”, $p<0.05$ as “*,” $p<0.01$ as “***”, and $p<0.001$ as “****”. The differences were shown in percentage using the formula with the results rounded to integers.

$$\text{Percentage} = \frac{|B_D - 2D|}{2D} \times 100$$ (1)

Results indicated that some 2D measurements could be substituted for 3D measurements while many could not since neither lateral nor frontal measurements in 2D were closed to 3D measurements. However, many angular measurements from males can be substituted into the corresponding angular measurements from females while few linear measurements from males could be substituted for the corresponding linear measurements from females.
4. RESULTS

The comparison of 3D and 2D measurements derived from midline structures to midline structure (e.g. A-B, ANS-Me and so on) and measurements derived from lateral structure to lateral structure (e.g. CcL-GoL, CcR-GoR and so on) showed similar results. Angular measurements derived from all the landmarks in mid-sagittal plane (e.g. SNA, SNB and so on) showed similar results between 3D and 2D. Angular measurements derived from 3 points with 1 point midline to 2 points lateral (e.g. A to FHL, A to FHR and so on) in 3D showed minor differences from 2D measurements. However, measurements derived from 4 points in different planes, 3D and 2D data had significant differences since measurements in 3D were not measured from the same projected planes as in 2D so angular measurements in 3D should not be interpreted in the same way as conventional 2D. However, all 3D measurements derived from midline structures to lateral structures were larger than 2D since 2D measurements were projected image rather than true measurement as shown in Figure 2(A) that showed Me-GoR represents the distance in 3D while Me-GoR’ represents distance in 2D. Diagrams in Figure 2(B) and (C) are showing different results between 3D and 2D angular measurement, Me-GoL to FHL. Figure 2 (B) shows projected measurement from 2D onto mid-sagittal plane and Figure 2(C) shows that GoL and FHL are not on the same plane in space.
Figure 2 Diagrams showing Different Results between 3D and 2D Measurements

Landmarks such as Porion (Po) and Condylion (Cond) were difficult to locate due to the narrow field of view of the CT scan that was too small to cover these landmarks in patients with big skulls. In general, the standard deviations of most measurements in this study were higher than previous studies [9, 12] due to the data collected from patients group which have larger variation than the data collected from normal population.

REFERENCES