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Clinical Note

Accuracy of Three Dimensional CT Craniofacial Measurements Using Mimics and InVesalius Software Programs

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Abstract: The purpose of this study was to determine the dimensional accuracy of the linear and angular craniofacial measurements obtained from three dimensional computed tomography (3D CT) images using Mimics V17.0 and InVesalius 3.0 software programs. CT images were taken from archive of Hospital University Sains Malaysia (HUSM) for ten Malaysian patients. The resultant two dimensional (2D) images were stored in Digital Imaging and Communications in Medicine (DICOM) format. The segmentation of the images was prepared in Mimics V17.0 and InVesalius 3.0 softwares. Linear and angular measurements were based on craniometric anatomical landmarks pre-defined by the authors and were identified by radiologist. Ten linear and three angular measurements were repeatedly made between identified landmarks on each of the selected ten patients. Each of the linear and angular measurements was repeated 3 times and the average was taken to determine the absolute difference and percent difference between Mimics V17.0 and InVesalius 3.0 softwares. The results demonstrated no statistically significant difference in all linear and angular measurements (P>0.05) performed by two different imaging software programs and obtained from 3D CT images. Mimics and InVesalius craniofacial measurements have the same values.

Key words: Computed tomography, 3D imaging, Mimics V17.0 software, InVesalius 3.0 software

Introduction

In the mid-1970s the first CT scanner was developed, after that several advancements in 3D analytic imaging innovations have happened, prompting a wide range of use in craniofacial clinical practice and research. Analysis of 3D images provides more and superior descriptive information compared with conventional plain 2D images, with the extra advantage of 3D printing for preoperative treatment planning and regenerative treatment[1].

The application of CT imaging, particularly cone beam computed tomography (CBCT) imaging, is increasing in conventional dental practice. Moreover, the dentist may be the first person who is in contact with patients with traumatic facial injuries and other pathologies, requiring him to be informed about the full range of diagnostic imaging modalities[2].

So far, 3D reconstructed image derived from CT information was the best choice available for assessment and treatment of surgical complications in dental and craniofacial surgery and numerous other specialities. The main disadvantage of this modality is that the reconstructed images could not be analyzed comprehensively in different planes and sections as it is only characterised by pictures on a screen[3].

Progresses in craniofacial imaging and image gaining techniques, like the CT introduction, have enhanced the understanding of anatomical structures and possible anatomical differences[4]. Currently available 3D software programs have been developed specially to support diagnosis and treatment planning and to expect results related to orthognathic surgery[5]. However, there are many commercial and open-source software programs available on the market with different methods for linear measurement.

The Mimics V17.0 (Materialise N.V., Heverlee, Belgium) software program has advanced features that perform 3D reconstruction of CT data as well as most types of anthropometric analysis. There are several studies on patients with severe

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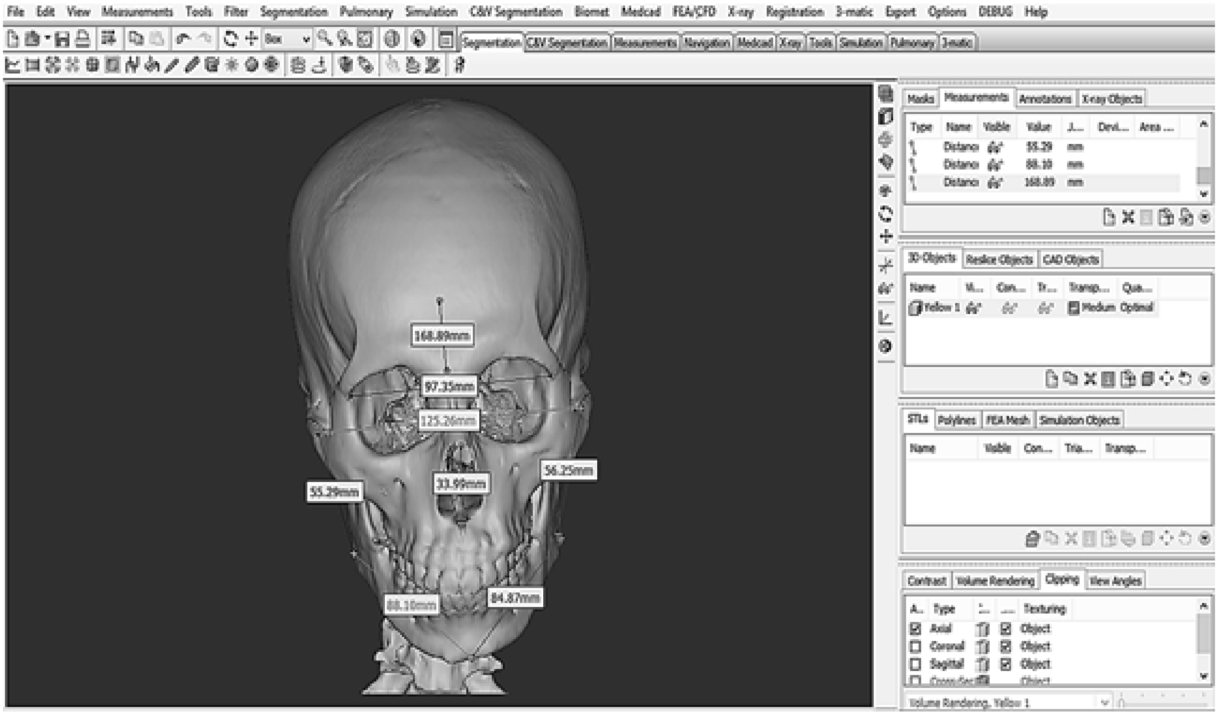

Figure 1. 3DCT craniofacial measurements in Mimics software.

craniofacial defects using software allowing 3D reconstruction of CT scan data and anthropometric analysis, reporting conflicting outcomes on the advantages and disadvantages of the usage of software versus cephalometric analysis performed on conventional two dimensional lateral cephalography[6].

The free open source InVesalius 3.0 software (CTI, Campinas, São Paulo, Brazil[1] had been used in many research studies. The purpose of the software is to process the CT images, reconstruct them into 3D models and to measure the cranial, facial and dental parameters[7]. This software was also used by El- Katatny et al.[8], to reconstruct 3D craniofacial images from the CT slices prior to fabrication of craniofacial replica.

Materials and Methods

Subjects

The subjects of this study were ten (6 men and 4 women) Malaysian patients who had their CT scan at the Radiology Department, HUSM for reasons other than due to craniofacial surgeries. The inclusion criteria were as follows: (1) Malay descent with at least two generations of both parents of Malay origin. (2) Age range between 2 to 20 years. (3) No craniofacial abnormalities either congenital or acquired through road traffic accidents or other forms of trauma and developmental discrepancies. (4) No severe anterior protrusion and facial asymmetry. (5) Subjects had no history of plastic, maxillofacial, orthognathic and reconstructive surgeries. (6) No genetic malformation. (7) High quality CT volumetric data.

CT imaging

CT images were collected from CT database of HUSM. These scans were of high resolution, helical scans obtained with General Electric (GE) Light Speed Plus CT Scanner System (GE company, Medical system group, Wisconsin, USA). The CT resolution was at 1.25 mm thickness and 1.25 mm spacing. These scans were saved in a CT database at the Radiology Department of HUSM and could be accessed online.

3D Reconstruction

CT scans were saved in DICOM3 format, transferred to a personal computer, and reconstructed with a 3D image-segmentation program Mimics V17.0 software and the free open source InVesalius 3.0 software. These softwares use the existing axial view to create cross-sections in the sagittal and frontal views. The Hounsfield Unit (HU), which expresses the gray scale, was adjusted for each tissue in the CT system: 226-3,071 HU for the hard tissue.

Measurements

Fifteen points were carefully selected and thirteen linear and angular measurements were repeatedly made between identified point landmarks on each of the 3D image-segmentation using Mimics Fig. 1 and InVesalius Fig. 2 software programs for comparison. Table 1 lists the landmarks used in this study and Table 2 lists the linear and angular measurements defined using the above mentioned point landmarks. The ten linear measurements done on each 3D image include a vertical, medio-lateral and antero-

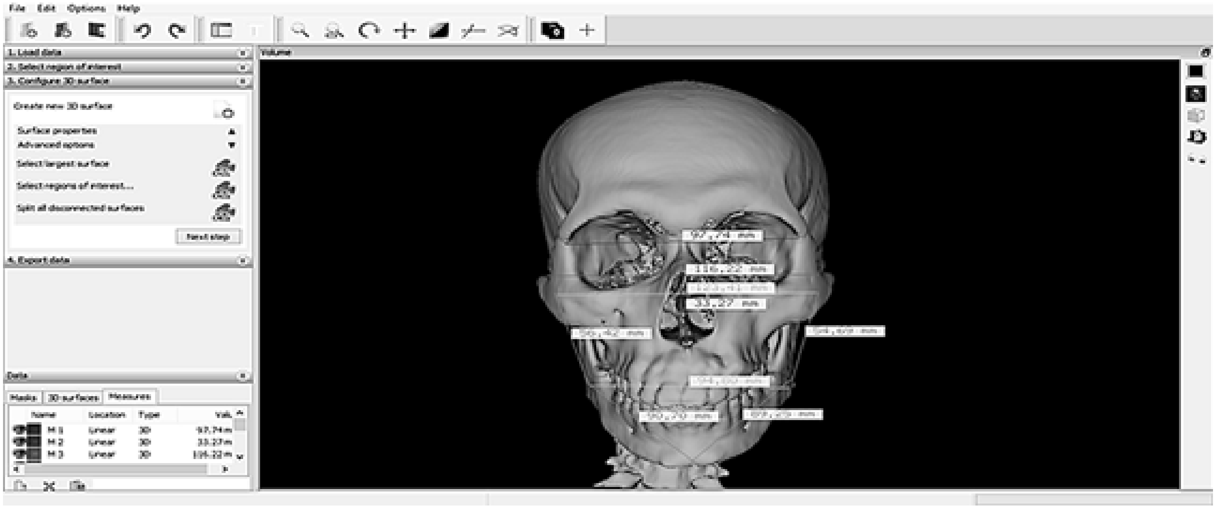

Figure 2. 3DCT craniofacial measurements in InVesalius software.

Table 1. Definition of Landmarks

Landmark	Name	Definition
na	nasale	The tip of the nasal bone to anterior nasal spine
ans	anterior nasal spine	The most anterior point on the floor of nose
gn	gnathion	The most inferior point on the mandibular symphysis in the mid-sagittal plane
zt.l/zt.r	zygo-temporal left/right	The mid-point of the bony concavity formed between frontal and temporal processes of the zygomatic bone
cd.l/cd.r	condylion left/right	The most lateral point on the condylar head
go.l/go.r	gonion left/right	A point on the angle of the mandible located by the bisection of the angle formed by the mandibular line and the ramus line
me.l/me.r	menton left/right	The lowermost point on the symphysis menti on the midsagittal plane
cindexa/cindxap	cranial index left/right	The maximum length of the cranial vault
lor.l/lor.r	lateral orbital left/right	The most lateral point on the orbital rim

Table 2. Definition of Linear Measurements

Measurements	Definition
na-ans	Nasal aperture height
zt.l-zt.r	Superior zygomatic width
cd.l-cd.r	Intercondylar width
go.l-go.r	Intergonial width
cd.l-go.l	Ramus Height (Left)
cd.r-go.r	Ramus Height (Right)
go.l-me.l	Body length (Left)
go.r-me.r	Body length (Right)
cindxa-cindxp	Maximum cranial length
lor.l-lor.r	Maximum orbital width
cd.l-go.l-gn	Left gonial angle
cd.r-go.r-gn	Right gonial angle
go.l-gn-go.r	Anterior mandibular angle

posterior measurements. A total of three vertical heights, four medio-lateral widths and three antero-posterior depth linear measurements were made. A single radiologist did all the measurements. Each linear and angular measurement was repeated 3 times. After the first measurements were completed, the results were blinded to the observer before trying the second measurements. The same blinding was done when the observer measured for the third time. The blinding was done to minimize the examiner's bias. The average of three readings of each linear and angular measurement was considered for the final statistical analysis in order to minimize the intra-examiner variation.

Statistical analysis

SPSS software 22.0 (IBM, Armonk, NY, USA) was used. Descriptive statistics such as (mean values, standard deviations, 95 % CI and minimum and maximum values) were calculated. The Mann-Whitney U-test was used for comparison between the

Table 3. Median of Craniofacial Measurements Between Mimics and InVesalius Softwares Made of 13 Variables.

	Median(IQR)			
Variables	**Mimics**	**InVesalius**	**Z statistics**	**p value**
na-ans	25.16(6.54)	24.92(5.80)	-0.227	0.821
zt.l-zt.r	107.62(18.7)	107.05(17.9)	-0.076	0.940
cd.l-cd.r	105.05(162)	105.27(12.3)	-0.038	0.970
go.l-go.r	82.36(16.16)	80.12(19.05)	-0.454	0.650
cd.l-go.l	47.44(14.91)	46.88(14.40)	-0.076	0.940
cd.r-go.r	47.69(15.04)	48.14(15.67)	-0.302	0.762
go.l-me.l	71.36(21.97)	72.60(24.71)	-0.302	0.762
go.r-me.r	71.94(22.74)	72.49(22.46)	-0.076	0.940
cindxa-cindxp	162.99(8.16)	162.71(5.91)	-0.038	0.970
lor.l-lor.r	90.51(11.81)	90.41(12.50)	-0.302	0.762
cd.l-go.l-gn	127.88(6.08)	127.75(4.08)	-0.113	0.910
cd.r-go.r-gn	128.11(2.44)	128.26(1.60)	-0.302	0.762
go.l-gn-go.r	82.13(9.53)	82.05(8.33)	0.00	1.00

same measurements derived from the InVesalius and Mimics softwares.

Results

The results of the linear and angular measurements are shown in Table 3. The results show the mean value in millimetres using CT for both software programs (Mimics and InVesalius). According to our finding, the comparison showed no statistical difference in any of the measurements performed.

Discussion

Since 3D analysis is accurate, it is nowadays an essential tool for precise assessment of craniofacial morphology[9,10]. A number of 3D techniques have been brought forward in order to make up for the shortcomings of 2D measurements[11]. The criteria for 3D analysis are playing an important role to ensure the accuracy of treatment planning.

A single software platform has been used to improve pre-, intra- and postoperative anatomical analysis by the development of new software programs[10,4]. That commercial software which are on today's market have similar tools, such as endocranial navigation, image rotation and translation, image adjustment, multiplanar and 3D reconstructions as well as linear and angular measurements. Different reconstruction algorithms and/or methods of measurement are however being used by the programs, whose purpose is to help the specialists in making more accurate maxillofacial diagnosis and plans of treatment. Volumetric rendering or surface rendering have shown since before to determine the reconstruction pattern[12,13] even though the evaluation of patterns of linear and angular measurements is still unclear.

Along with the improvement of qualitative assessment by using 3D imaging, a large number of quantitative measurements on patients have been performed with the help of CT. Linear and angular measurements have been carried out in the followings, for example, the cranial vault, brain, orbits and spinal canal[14]. The accuracy of parameters gained from CT scans has also been investigated in the field of dentistry. Exact measurement is the important factor in orthodontics and maxillofacial surgery, especially in cases of complex craniofacial disorders. Few studies only have been dedicated to maxillomandibular region, although the accuracy of parameters has been studied through CT scans[15].

The dimensions of the 3D models appreciated done in this study are the vertical, medio-lateral and antero-posterior craniofacial linear measurements. Thereby a thorough understanding of the possible dimensional alterations has been achieved and that leaves no room for weakness of the validation study[3].

The result of craniofacial measurements obtained from InVesalius software, which is free of charge is as valuable as Mimics software, which is very expensive. So every researcher can perform successful and reliable measurements by using software which is available for free instead of using the expensive one.

This study was undertaken to determine the dimensional accuracy of the craniofacial measurements produced using the Mimics V17.0 and InVesalius 3.0 softwares with the aim of validating the system for clinical applications at HUSM. The data for this validation study was derived from 3D CT images of five Malaysian patients. The results of the study showed no significant difference (P>0.05) in the accuracy of both softwares (Mimics and InVesalius).

Conflict of Interest

The authors have declared that no COI exists.

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