Comparison between the Anatomical Models of Skull Reconstructed from DICOM Data and Anatomical Models Reconstructed after Modification of this Data, by Increase Thickness of the Slice

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Abstract: ***Background**: When medical model is requested, in the most times the suggested scanning protocol of the CT scan involve the thinnest possible slice to be taken. This will result in increased dosage of radiation that the patient will receive as the thinnest the slice in the CT scan the more radiation it requires. Five DICOM data sets were selected randomly from our hospital radiology unit. These data (skull images) were taken using CT scan protocol specific for PNS (paranasal sinuses). The protocol involves (0.625mm) slice thickness. Five Skull models sets were reconstructed first according to these original data thickness (0.625mm). These skull models sets were reconstructed again after modifying the slice thickness of the original DICOM data to be (1 mm) by a software used in the CT scan unit (mention the software used for this purpose). An advanced software (ATOS PROFESSIONAL/GOM GMBH), used in aerospace and automotive industries, compare precisely these two skull models derived from both original data sets and modified data sets by inspection of any dimensional and anatomical changes of skulls that were reconstructed from the modified data. **Aim of study**: to see if the increase slice thickness in the CT scanning obtained for reconstruction of medical models has a strong effect on overall accuracy of those models, this is in favor of decreasing the high radiation dosage that may be applied when obtain a thinner slice. **Results**: The inspection showed that both models (original data model and modified data model) for each patient were almost the same from the anatomical point of view and both are nearly superimposed on each other except minute deviations which were not statistically significant. **Conclusion**: by overall inspection of the two models sets we support that scanning protocols of 1mm slice thickness yields a very similar results to those resulted with usage of 0.625mm slice thickness protocols, and can be applied in craniofacial modelling with the benefit from concomitant radiation dosage reduction.*

Keywords: Medical modelling, CT scan protocols, slice thickness

1. Introduction

With advancement of modern diagnostic facilities such as high definition CT scanner with multidetector that are capable of capturing large area of the body with single breath hold, smallest captured details had been downed to less than 0.6 mm. We can now develop correct idea about human anatomy and retrieve precise medical models from DICOM data acquiesced using CT scan (1). Medical modeling is the retrieving of the specific anatomical region from patient investigational3d DICOM datato be utilized inreconstructing adigital model applied in computer guided or navigational surgery and radiotherapy or manufacturing a physical or hand-grasped model to be used in orthopedics, forensic medicine, prosthodontics, ...etc. It is a multidisplinary specialty that involve radiology and computer science (2). Medical models reconstructed first as digital version from the patient data taken by CT scan (DICOM) for example, then can provided as physical copy from the digital one if required,both have the same anatomical dimensions (3).In most situationsof orthopedics, osteotomies are done depending on the surgeon skills and experience,but recent development of medical modelling allows for precise cutting to achieve more accurate results through surgical jigsand those Surgical jigs design and manufacturing also depend upon correct anatomical modelling from the patient being treated (4). Furthermore, Bespoken implants are enormous growing industry that serve the medical staff to provide more accurate and helpful services for the patient suffering from different tissues loses due to different pathologicalconditions by using the medical modelling(5).Robotic surgery and computer navigational surgery is another aspect of medical modelling which had given sophisticated solutions for complex surgeries with intricate prerequisites.The corner stone in all of the previous advancedapplications accuracy is precise medical modelling(6). However, Human body is very forgiving and dimensional error in bespoken implants may be accepted even if it is up to 6 mm (6000 micron) as the woundrepair will do the filling job (7). Also, for the medical model which is originally intended for illustration, training or diagnosis, the small error is permissible (8).However, in many critical applications such as computer guided surgery, especially in neurosurgery, as in case where the surgery is held around nerves or their canals, only slight error can result in in devastating injury for the patient (9). Because in the craniofacial region, the anatomy is very delicate and the bony structures are highly complex which impose stricter protocols in comparison to the other areas like knee or pelvis, therefore when Medical modelling of bones in this regionis required and toacquire higher details when scan the patient, many suggest protocols with higher CT tube currency, thinner slices, pitch modification, longer time.... etc. All will result in higher radiation dosage that the patient will receive[10].Many try to achieve this through different ways, in order to decrease the higher radiation emitted by a specific scanning protocol[11]. The objective ofthis study istoshowing that modifyingscanning protocols of the CT scanningby modifying one of its parameters, which is the thickness,may give almost the same results, with more saving in the radiation that the patient will receive in the current protocol.

2. Materials and Methods

Five DICOM data sets of the mid face and part of the cranium, were chosen from the database of Ashty hospital, radiological unit. Patients` consentswere acquired to submit the data of the CTscans to our research.These patients had been referred from the ENT department to the radiology unit, and CT scan requested for investigational purposes.They were taken by CT machine(PHILIPS Brilliance 64). The data for all patients were taken using the protocol of paranasal sinuses (PNS) for the area of the midface. The scanning protocol used for all of the patients involves slice thickness of (0.625mm). The data set for every patient had been reformatted inside of the CT machine workstation software to a (1mm) data set, by adding supplemental scanning protocol.The reconstructed virtual versions of theanatomical modelsrepresent the bones in the midface and part of the cranium. Bone model of every patient was reconstructedfrom both of the original data sets and modified ones, using Mimics Innovation Suite 19 (Materialise, Belgium). Workstation SLADE PRO from Digital Storm was used in our work (Intel Core i7-7700). In all processes, the relative location of the original and modified model for every patientwere fixed to the coordinate system to establish correct geometrical evaluation, so that the realignment is not needed which may introduce error in the reading. We evaluate the different results using highly sophisticated industrial 3D metrology inspection equipment used in aerospace and automotive industries (ATOS PROFESSIONAL/GOM GmbH). We compared the 2 sets for each patient separately.For statistical calculation (Z test)for the mean difference of the dimensional deviations between the two anatomical models was calculated.

3. Results

The skull is the skeleton of the head consists of cranial bones and facial bones, the cranial bones consists of 8 bones: 2 parietals, 2 temporals, 1 frontal, 1 occipital, 1 sphenoid, and 1 ethmoid.The facial bones consist of 14 bones: 2 nasals, 2 lacrimals, 2 zygomatics, 2 maxillaries, 2 palatines, 2 inferior turbinates, 1 mandible, and 1 vomer.

Results shown by figures below showing the superimposition of the two models of each set, so figure(1, 2, 3, 4, 5) represents models of (first, second, third, fourth, and fifth patient), respectively. (A) represents the midface and (B) represents part of the cranium. Each image shows the original data model and the modified data model of each patient, superimposed on each other, to elicit the dimensional deviationsand anatomical variations measured by millimeterand indicated by different colors.Aided by (ATOS PROFESSIONAL), we can inspect and calculate the exact and precise values by which these points will differ, given in millimeter.

In all figures, there is a scale represents a range of deviations between the two models for each patient graded by colors.The points represent depressionin comparison to the standard model are in the –ve values in the scale (blue scale), the pointsrepresent elevation in comparison to the standard model are in the +vevalues in the scale (red scale).The green color represents the exact superimposition between the two models represents zero deviation and it is represented by the green color in the scale. Most of the models are in the scale of green, which means the majority of the surface areas of both of the models are superimposed with each other.

Note: the colored numbered-boxes in the following figures points to the areas of deviations between the two models whether increase in thickness (yellow, orange and red) or decrease (light blue to the dark blue), this is clarified more by the colored scale, the scale provides a clue for the colored points each color provided graded value from –ve towards +ve one (this is true for all images as all represented by the same colors).

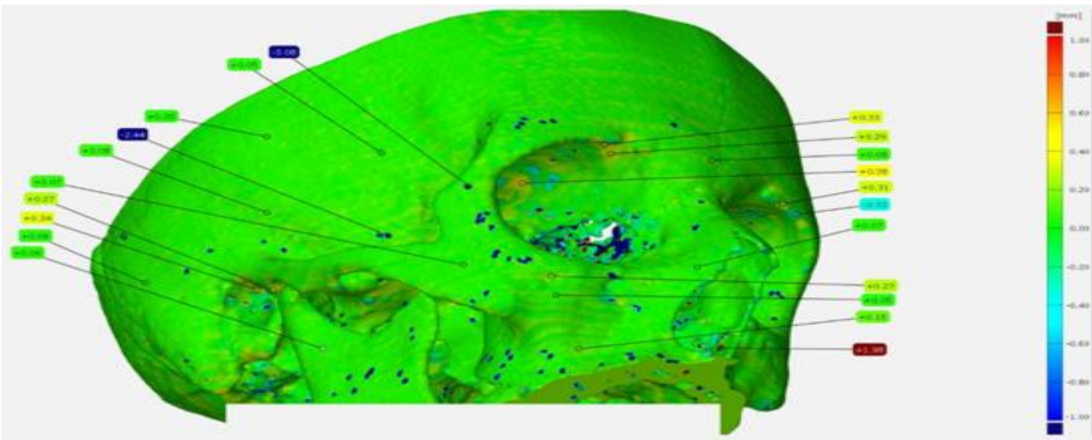

Figure 1 (A) Patient 1 midface model. Here the maximum decrease in thickness was 3.08 mm in a point lateral to the orbital border in the frontal process of the zygomatic bone below the fronto-zygomatic suture while the maximum increase in thickness was 1.98mm which is at the inferior turbinate of the nose

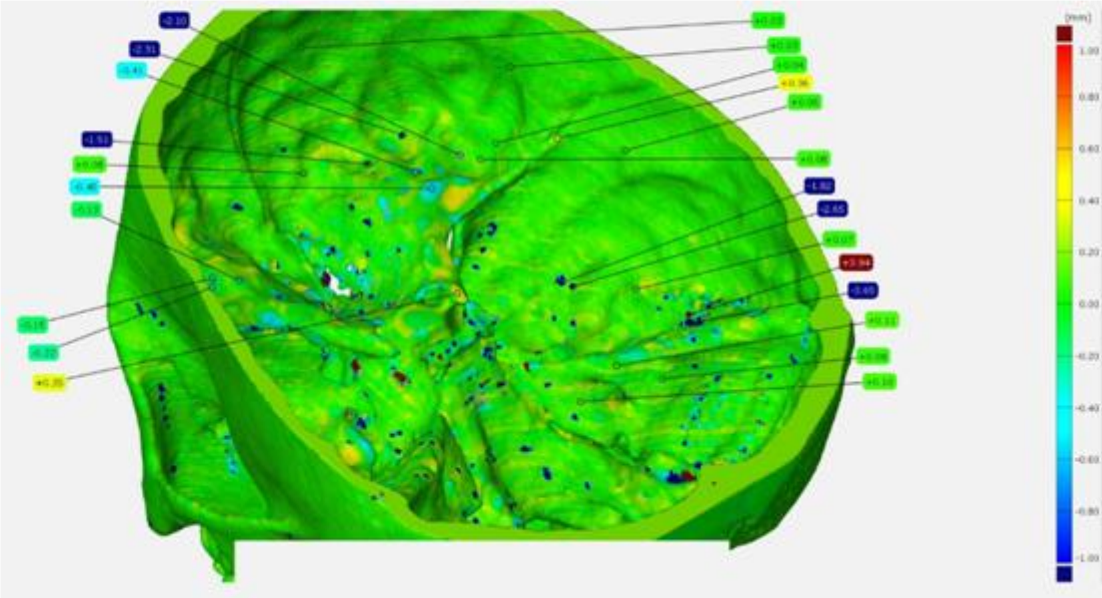

Figure 1 (B): Patient 1 cranium modelThe maximum decrease is 3.65 mm in the arcuate eminence of the petrous bone of temporal bone. The maximum increase is 3.94 mm in the area just anterior to the arcuate eminence

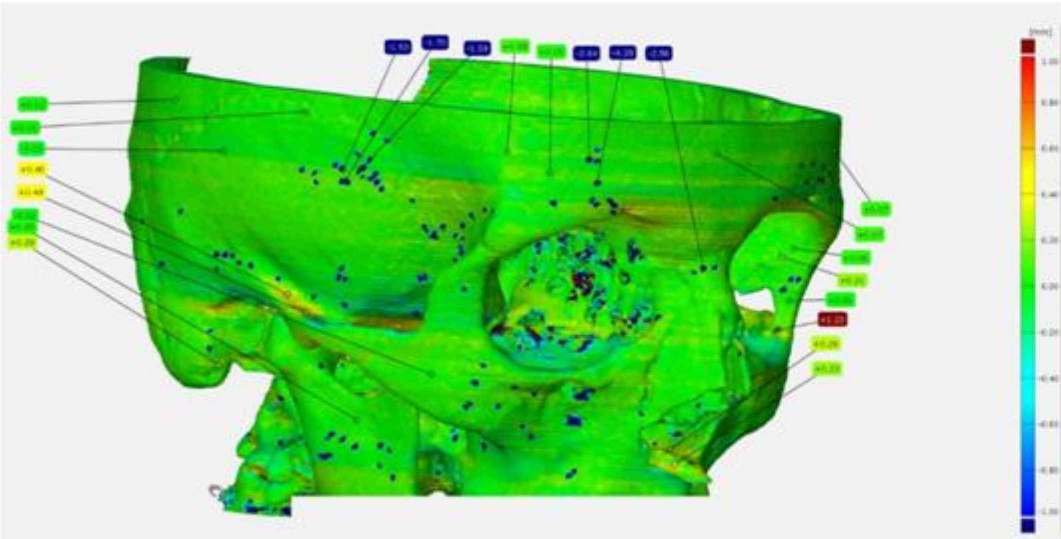

Figure 2 (A) Patient 2 mid face modelthe maximum decrease is 4.30 in the in the superciliary arch of the frontal bone the maximum increase is 1.20 in the innerside of the frontal process of the zygomatic bone

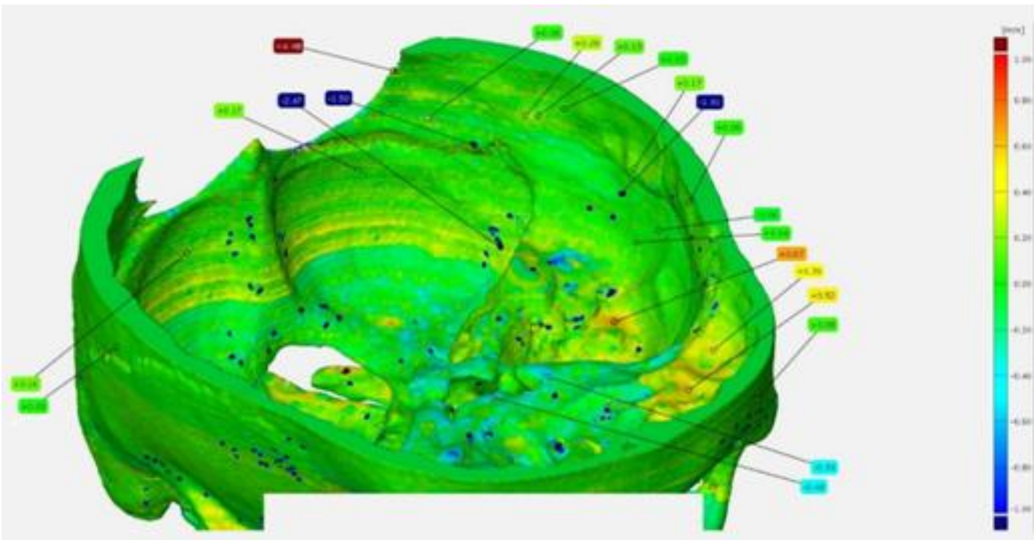

Figure 2 (B): Patient2 cranium model The maximum decrease is 2.47 in the squamous part of the occipital bone in the groove of the sigmoid sinus the maximum increase is 4.48 in alateral point in the superior occipital fossa of the occipital bone

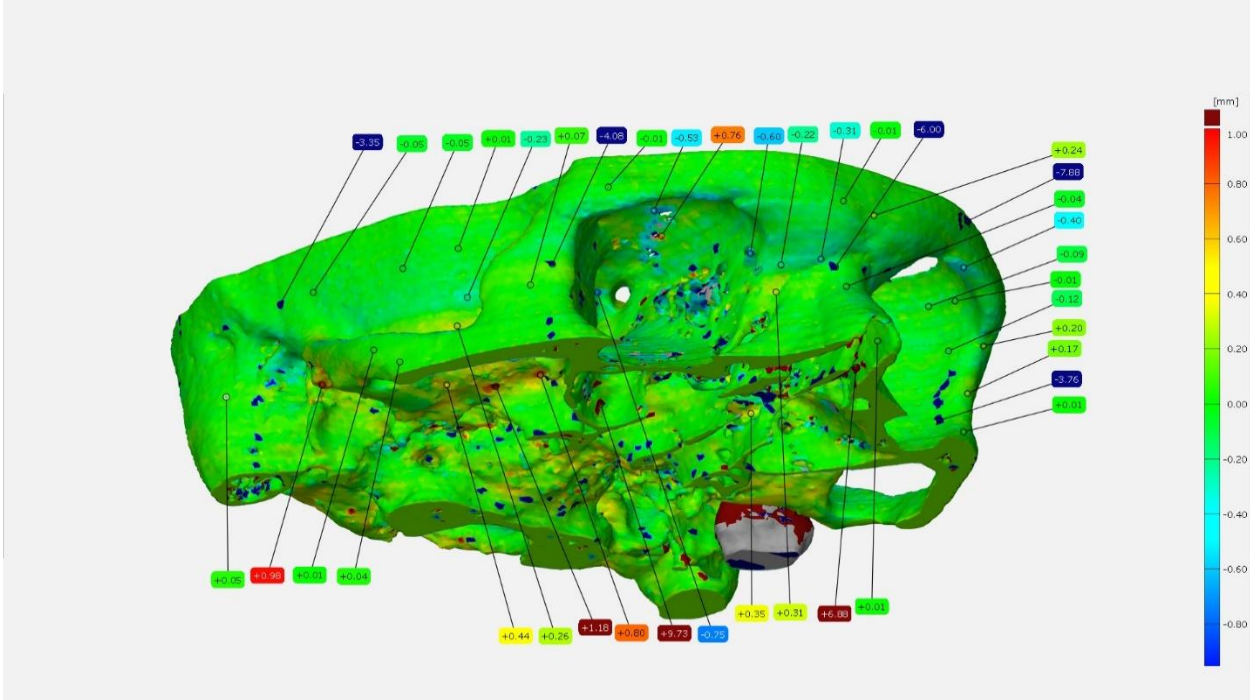

Figure 3 (A): Patient 3 midface model The maximum decrease is 7.88 in the superciliary arch the maximum increase is 9.73 in the posterior wall of maxillary sinus

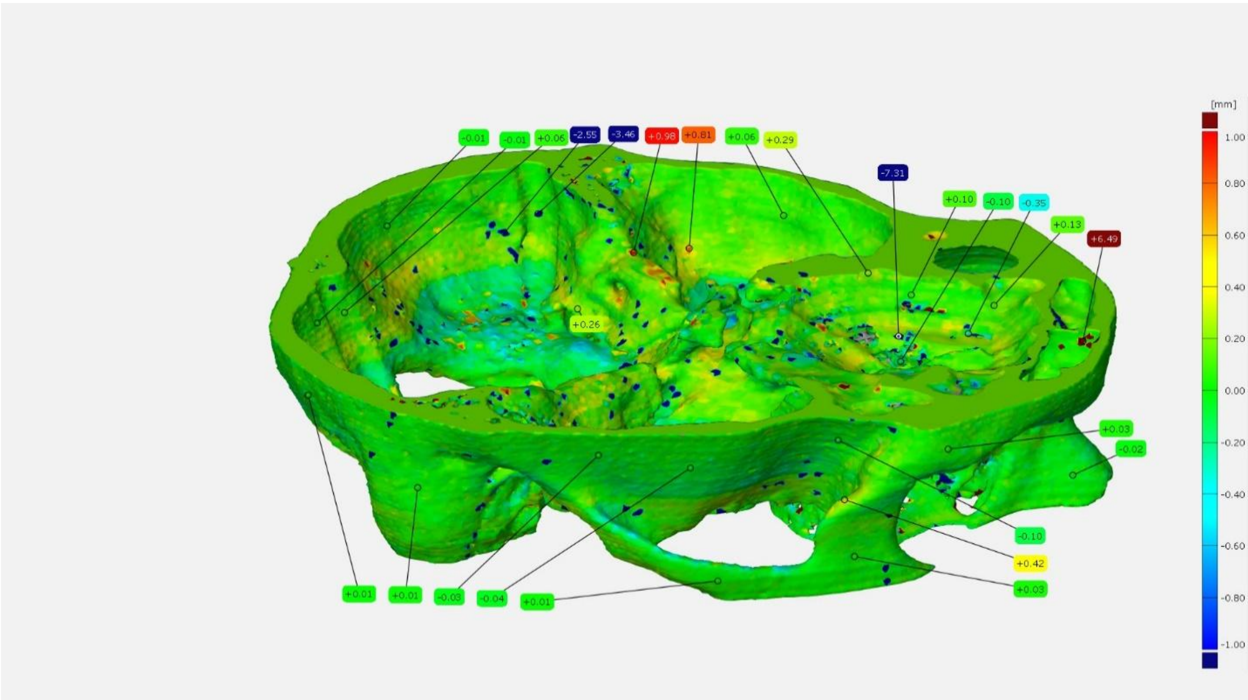

Figure 3 (B): Patient 3 cranium model The maximum decrease is 7.31 in the orbital part of the frontal bone the maximum increase is 6.49 in the antero-inferior wall of the frontal sinus

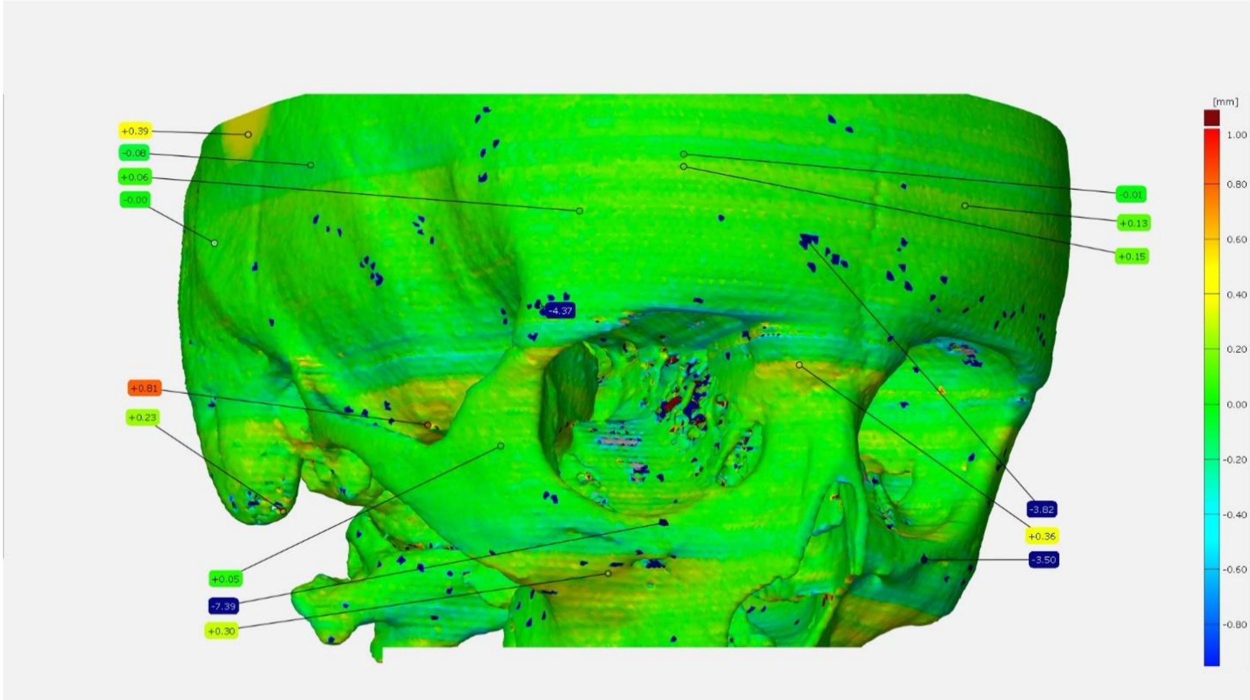

Figure 4 (A): Patient 4 midface model The maximum decrease is 7.39 in the infraorbital margin the maxillary part,the maximum increase is 0.81 inferior part of the temporal fossa

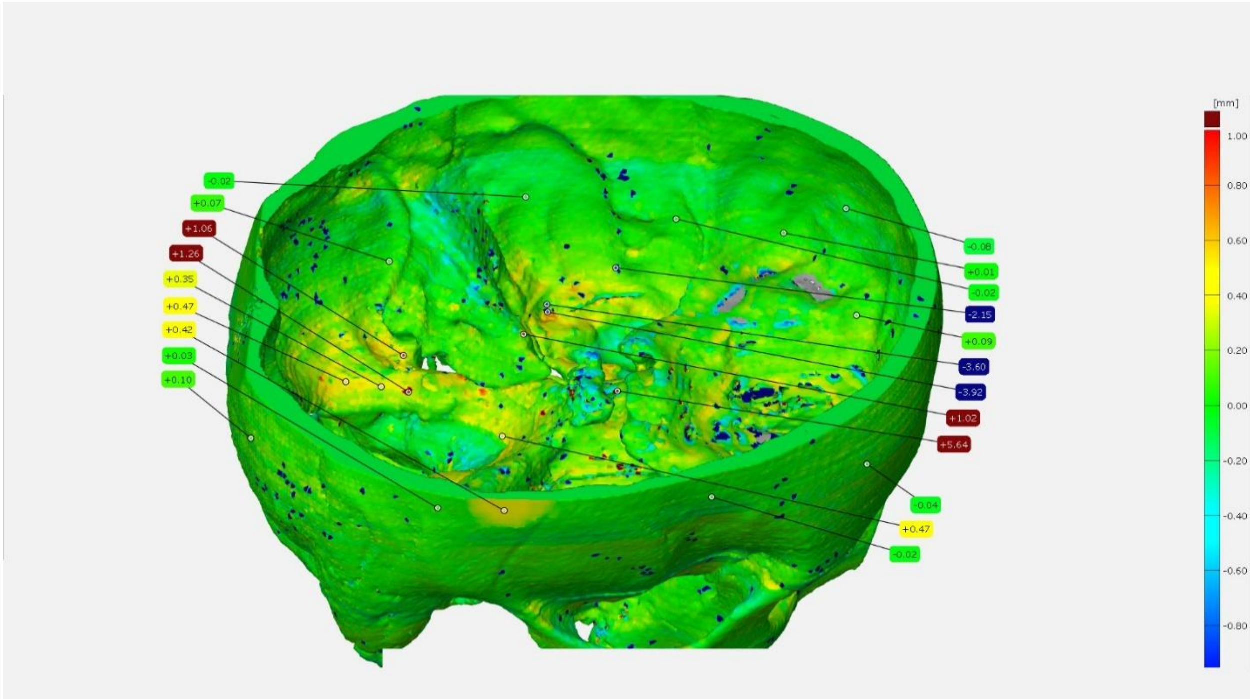

Figure 4 (B) Patient 4 cranium model The maximum decrease is 3.92 in the apex of petrous bone, the maximum increase is 5.64 in the body of sphenoid in the hypophyseal fossa

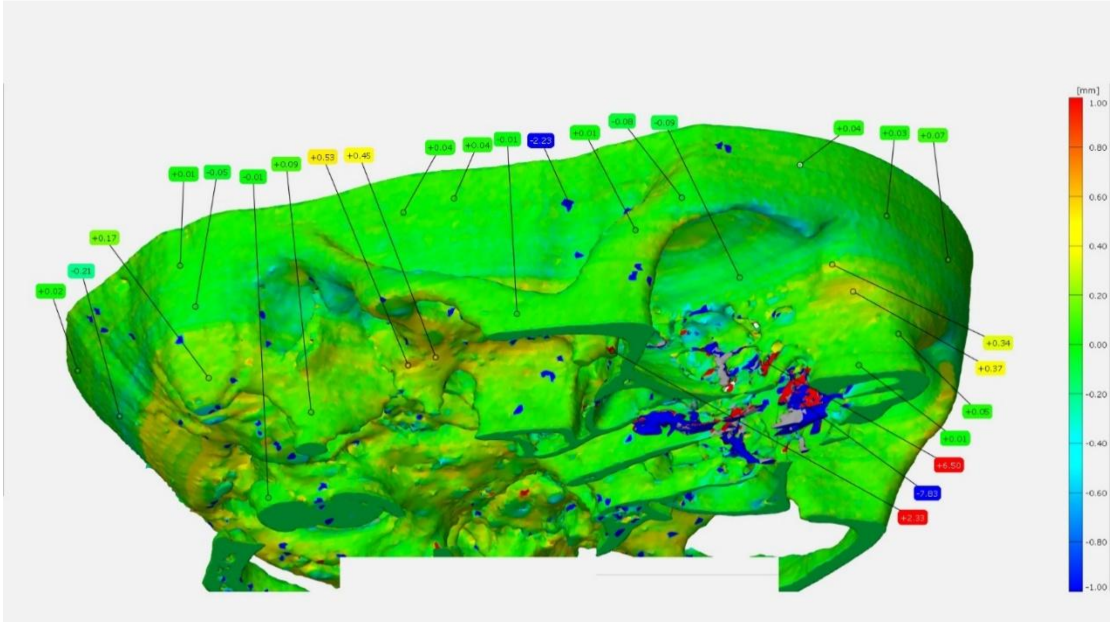

Figure 5 (A): Patient 5 midface model the maximum decrease is 7.83 in the ethmoidal complex, the maximum increase is 6.50 in the ethmoidal complex

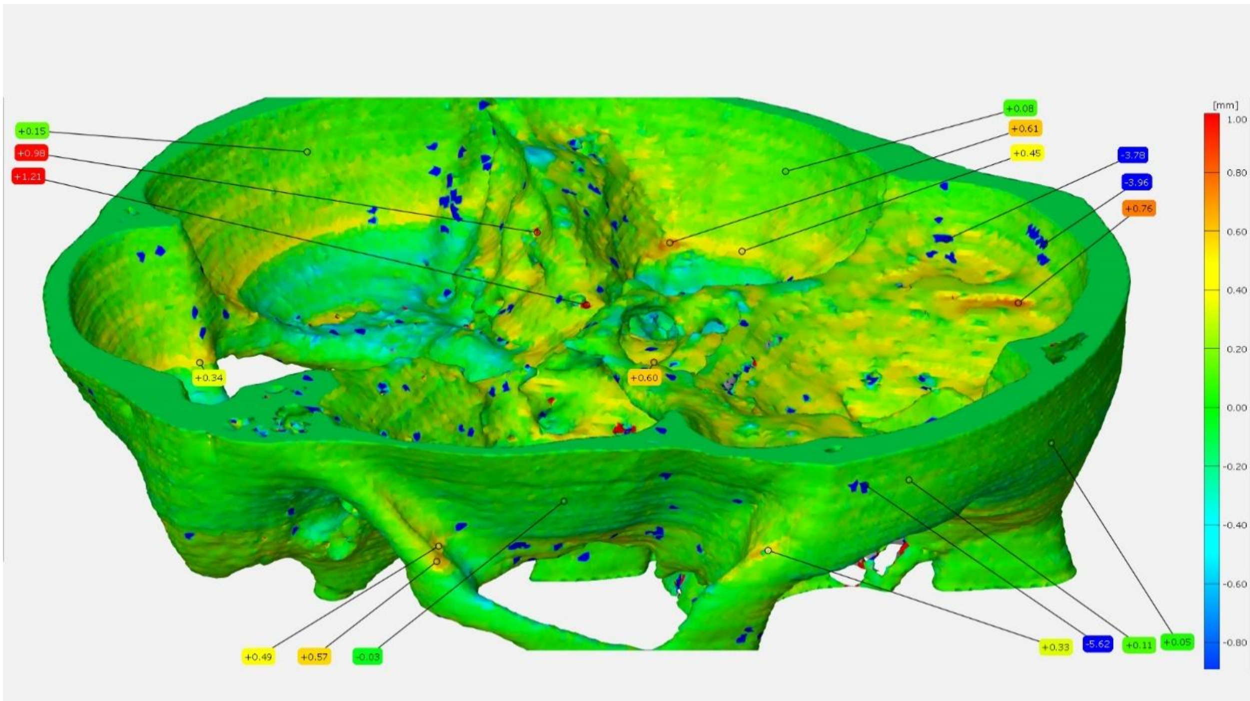

Figure 5 (B): Patient 5 cranium model The maximum decrease is 5.62 in thefrontal eminence of the frontal bone,the maximum increase is 1.21 in the medial part of the petrous bone

Table 1: Volumes of the resulted models used in our study

Patient no.	Model volume from the original reconstructed data	Model volume from the modified reconstructed data
Patient 1	346.79 m^3	255.08 m^3
Patient 2	310.30 m^3	311.85 m^3
Patient 3	160.74 m^3	161.40 m^3
Patient 4	261.60 m^3	262.70 m^3
Patient 5	135.21 m^3	136.83 m^3
Mean	242.928 m^3	225.572 m^3

df-t: 7.1; p for the difference of means= 0.62753
Difference not significant at 5%

Table 2: Comparison between the Two Models in Regard to the Midface Modelling

	Maximum increase points between the two models	Maximum decrease points between the two models
Patient 1 A	1.98	3.08
Patient 2 A	1.20	4.30
Patient 3 A	9.73	7.88
Patient 4 A	0.81	7.39
Patient 5 A	6.50	7.83
MEAN	4.044	6.096

df-t: 5.9; p= 0.18097
Difference not significant at 5%

Table 3: Comparison between the Two Models in Regards to the Cranial Modelling

	Maximum increase between the two models	Maximum decrease between the two models
Patient 1B	3.94	3.65
Patient 2B	4.48	2.47
Patient 3 B	6.49	7.31
Patient 4 B	5.64	3.92
Patient 5 B	1.21	5.62
Mean	4.352	4.594

df-t: 7.5; p= 0.42469
Difference not significant at 5%

4. Discussion

Anatomically accurate models can be computer-generated from medical image data. CT is widely used to image biological features from whole body image to particular area of interest such as craniofacial region[1]. Certain parameters rule the protocol of imaging for medical modelling, one of these parameters are slice thickness. Although, Thinner slices result in higher quality models preserving critical anatomical details[12],it has two disadvantages; the thinner the slices the more the radiation applied with the CT scan [13], alsothe thinner the slicesthe unnecessary wear on the scanner's tubereducing the life of the scanners tube[12]

This work is based upon changing a variable, which is the slice thickness, then applying this when reconstructing anatomical models. We reformatted the DICOM data without the need to repeat the CT scan for the same patient, since our research, for a medico legal concern, don't justified repetition of the CT for the same patient after changing a new parameter. we try to inspect the end result data after the model reconstructed from the new data to be sure that they have no substantial difference with the original ones.This new reconstruction of the data couldgive us a clear idea of simple measurement that save the risk of radiation a lot. This change in thickness will preserve the radiation applied by the CT scanning in future medical modelling[14].

The software of reformatting the DICOM:
Philips Brilliance 64 work station software version 3.5.5 were used to do the reformatting of the DICOM data by adding new scanning protocol of (1mm) to the original scanning protocol for each patient, so both of the data sets will generated simultaneously.

Applying new software for inspection of the 3D models?
ATOS Professional is a process-reliable software solution that controls ATOS 3D scanners, produces precise 3D surface data, and offers complete inspection and reporting functionalities. It used in many engineering desplines and proven to be reliable in the demanding application that require high precision [15].Availability of this modern inspection equipment enable us to compare the two results of each patient with the same coordination system, it eliminates the need for realignment which may introduce errors when done [16].

Deviations between the two models:
As we see from the results after changing the slice thickness,there is no statistically significant difference between the overall dimensions of the models derived from modified and original DICOM data of the craniofacial region (the p value for the difference is not significant) (table 1-3). We can apply this in CT protocol in the future.This is similar to what was found in [12],although, in the latter study, this was conducted by different procedures. We found that The flat areas are almost the same, but the dimensional deviation was increased with the curved and complexedprojections and grooves.We explained thesefew areas of high deviations as normal, because of the partial volumeeffect could occur when reformat the DICOM data,this goes with what was explained in[17].It may happen routinely when do inspection in the engineering analysis as the missing areas effects.The difference in the volume between the models is different from other studies and in contrast to our expectation[14]and it may bedue to the algorithmused in segmentation, which is differentacross multiple platforms. However, the overall increase in the volume was not significant statistically as we show the p value was not significant (table 1). The difference in volume between original and reconstructed models was around 0.98% which is much lower than the found value when changed the tube currency as done in other studies [14]. The total data size (in bytes) of the modified models on the hard disc of computer was less than the size of the original models. This will affect the processing time, data transfer, data storage… etc.

5. Limitation

Due to limited studied cases no. and single area studied (craniofacial area), further work for other regions is needed to extend the results.We suggest doing this study with physical phantom and conduct CT scan with 0.6 mm slice thickness, and another scan with 1 mm slice thickness then inspectthe results, as it will be an alternative and applicable method [18].

6. Conclusion

We conclude that the application of modern engineering Inspection in medical fields give a suggestion about capability of reducing the morbidity of the patient due to exposure to extra radiation by changing a single variable which is the slice thickness. Study showed that craniofacial region can be scanned with aslice thickness of 1mm instead of 0.625mm, so that critical detail for 3D modeling is preserved and no significant variation is observed.This work can be applied in other medical specialties some of these are: comparison between preoperative and postoperative, evaluation of different treatment modalities, and sequential changes of growth.

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