A Novel Computerized System To Simulate Orthodontic Treatment Plan

Kadry Ali Ezzat

Assistant Lecturer, Biomedical Engineering Department,
Higher Technological Institute, 10th of Ramadan City, Egypt,
Corresponding author Email: kadry_ezat@hotmail.com, Telephone: 002-01064664762

Dr. Ahmed H. Kandil

Associate Professor, Biomedical Engineering and Systems Department,
Faculty of Engineering, Cairo University, Giza, Egypt,
Email: ahkandil_1@yahoo.com, Telephone: 002-01001234060

Dr. Sahar Ali Fawzi

Associate Professor, Biomedical Engineering and Systems Department,
Faculty of Engineering, Cairo University, Giza, Egypt,
Email: sahar_fw@yahoo.com, Telephone: 002-01001234061

Abstract
Detection and treatment of malocclusions and other dental deformities are a considerable field of work in the plan of orthodontic treatment. Severe malformations of the mid face such as maxillary or mandibular deformity can be treated by the distraction and reformation of skull bones. During an operation, the appropriate bony part of the mid-face is separated from the rest of the skull (osteotomy), slowly moved into the ideal position by way of a distraction device. In the current clinical practice, planning for orthodontic treatment and orthognathic surgery was based on Computed Tomography (CT)data sets. CT images are inefficient for helping the orthodontists and surgeons in treatment and surgical planning. A tool is needed to help the physicians and surgeons in the treatment planning in order to anticipate the results and give the accurate decision, in this paper there are preliminary descriptive studies on DICOM images of the skull to help the orthodontists by providing the following algorithms: Segmentation of the lower jaw (mandible), Segmentation of the upper jaw (maxilla) from CT data, Segmentation of upper teeth, each tooth and computation of mandible volume.

Keywords: CT-scans, threshold, K-mean, Region growing, DICOM.

Introduction
The need for clear images of cranial morphology has an important role in the progress of treatment and planning for craniofacial surgery [1]. Improvements in three-dimensional (3D) imaging [2] allowed shaping analysis and measurement of distance and volume of the shapes. By using 3D medical modeling, it is got to be conceivable to acquire a precise of the patient's skull and facial structures. Recent developments in software algorithms to segment the lower, upper jaw and each tooth enabled simulation of orthodontic treatment [3] but the stability and accuracy of segmentation were deficient considering the speed of segmentation. Several methodologies have been proposed for the segmentation of mandible, maxilla, teeth and separating each tooth. H. Lameckera et al

[4] programmed separation of the mandible from the weak-dosageCT scans. The fundamental idea of model-based segmentation is to capture the anatomical variability of ordinarily created mandible shapes in a factual atlas (preparing phase) and to match this atlas to a given CT data set through a deformable model methodology (segmentation phase). This method shows automatic separation for the mandible. Also, the teeth region was not considered in the measurable investigation for the atlas that builds because, as a rule, teeth vary in their number and the topology of the reconstructed geometry (contact vs. Non-contact) from patient to patient and this may cause the model not precise to be employed in the segmentation. Patrick Neumann [5] describes a method for segmenting mandible where the user starts the definition of a bone segment by placing a seed point in a chosen view of the object after choosing an initial voxel, segmentation is carried out by connected-component analysis based on a 26-voxels neighborhood. To control the volume-growing process, the bone segment borders can be interactively defined by placing cuts. A cut was characterized by drawing a seam in a freehand mode with the visual pointer of the input device. This method is shown also a complete segmentation for the mandible, but an input device was applied to delineate the line that isolates the mandible from the maxilla and that device is expensive and not usable for many patients to use it, this method was too perplexed in the determination of the area of interest, as they determine required cuts by using input device, and this method took some pixels from the upper jaw and considered them as mandible pixels. H. Akhoondali [6] described a strategy to discrete the mandible and maxilla by utilizing a technique based on greatest intensity projection in Y-bearing and a stage like region growing algorithm but this technique does not segment the mandible totally from the skull. The development of simulating software for the craniofacial surgery required development in segmentation techniques for mandible segmentation compute the volume of the mandible, maxilla segmentation followed by segmentation of each tooth in the upper jaw and creation of simulated cutting tools. Schutyser [7] utilize a 3D "virtual blade" and underline the ongoing parts of simulation, this method was not accurate in

segmentation as there are some pixels from maxilla considered as skull pixels. Koch [8] identifies a scheme depend on linear versatility, are determined on 2D images, this method was used for 2D images where is too old. Jens G. Schmidt [9] describes a tool chain for simulation of maxillofacial surgery, depending on a cephalometric analysis that creates points in maxilla that used after that to gain a clipping tool to cut through maxilla, this method is likewise complicated and not accurate where some pixels of the mandible were taken as maxilla pixels.

There are some techniques depend on 2D radiology images, in what followed, a description of some of these techniques will be given. Jain et al [10] utilized a self-loader strategy on 2D radiology teeth picture to discover the outline of the teeth. Chen et al [11] introduced a method depend on a view of a dynamic form which utilizes an iterative technique until the contours converge, so this strategy is moderately slow and difficult for outlining the functions enforcing region's geometric data. Li [12] utilized a different level set strategy in normal panoramic X-ray slices. Samir Shah [13] Describe automatic segmentation method of tooth utilizing form edges on dental panoramic images. All the past techniques depend on 2D segmentation, which is not precisely in the segmentation of teeth. Gao [14] presented different teeth partition technique by finding an isolating plane between two contiguous teeth in 3D space over the jaw curve. This strategy seeks for an ideal position and guidance of the teeth partition plane, which has the minimal mean intensity rate. However, as it does not appropriately handle the delicate pulp within the tooth, that has lower-intensity values, a plane intersects the delicate pulp can be improperly distinguished. There have additionally been two self-loader strategies to distinguish the tooth. Chae and Gao [15] proposed a self-loader teeth separation strategy utilizing an upgraded level set strategy[16]. This strategy utilizes the state and intensity of the earlier data of a tooth, that decides the contracting or growing power of the level set function. Depend on the intensity and state of the earlier data on the tooth crown and root, distinctive segmentation systems are applied to the crown and the root. In spite of the fact that this strategy fragments a tooth with a little error, obliges clients to physically draw an underlying form around every tooth, that takes about 5 minutes as well the initialization time. Galanis et al [17] introduced a technique to implant axis identification. This strategy decides the minimum square regression line appropriate to the center of the prosthesis and bone in every piece, the density ranking and uniform geometrical of the bone and prosthesis encompassing the implant axis is taken. This methodology obliges clients to characterize a rectangular district around every tooth to fragment the tooth district. Besides, the separated tooth district incorporates the cortical bone of the jaw as well the tooth, where the axis of the tooth will not be precisely observed. Furthermore, there are different endeavors to determine these issues utilizing Support Vector Machine (SVM) [18] and Principal Component Analysis (PCA) [19], that are disciplined and call attention to the countenance for the image segmentation These strategies need extra information, as well as depend on the level set procedure, so that their processing progress resort to be boring

contrasted with the seed region growing (SRG) strategy and the edge technique [20].

In this paper, vigorous algorithms are proposed that can precisely:

- Segment and visualize the upper and lower jaw in 3D depend on CT scan
- Segment and visualize the upper teeth.
- Segment and visualize each tooth in upper teeth. And establish a computerized system that establishes a virtual reality environment for treatment planning.

Material and Methods

Computer tomography (CT) slices were obtained for the whole skull as DICOM images of the axial perspective of eight patients' skulls, then marching cubes algorithm[21]was implemented to reconstruct the skull from CT slices by usingVTK functions.

A core i7PC with 8 GB RAM and AMD Radeon graphics card was used. Visualization ToolKit (VTK)and C-sharp program were utilized to apply all functions of graphics (VTK Ver. 7 functions). The errands of the orthodontic treatment plan simulation were achieved by applying the following steps: the first one was a complete segmentation for the mandible, Second step was computing the volume of the mandible and the third step was complete segmentation of the maxilla and each tooth as shown in Figure. 1.
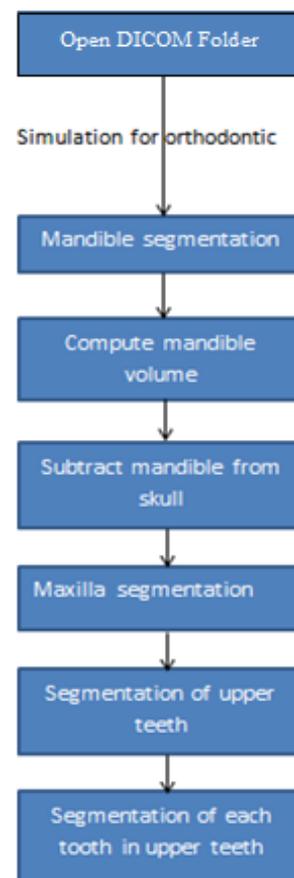

Figure1: flow chart for simulation of orthodontic treatment

Mandible Segmentation.

The mandible segmentation algorithm was performed in three steps respectively, the first step was defining a region of interest (ROI) for the mandible, the second step was a threshold adjustment to see the accuracy threshold for bone. The third step was applied region growing algorithm [22].

Specify a Region of Interest of the Mandible

To determine the region of interest of the mandible a rectangle in YZ plane and another in XZ plan was drawn to form a cuboid in three dimensions which will be the region of interest, as the search on mandible pixels will be in the region of interest as shown in Figure. 2.

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Figure 2: Specifying region of interest in patient skull data

Determination of Accurate threshold for the bone value

In previous research, the bone value was estimated as the mean value between the minimum and maximum values of intensities in CT scans which was not accurate in mandible segmentation.

Determination of the accuracy threshold for the bone value was achieved by obtaining the intensity of both cartilages which has the minimum intensity value of the bone in CT scans and skin.

The intensity distribution in CT scans will be as follows:

1- Skin intensity with the lowest intensity value.
2- Bone intensity which is higher than skin intensity and divided into cartilage, bone, and teeth, as shown in Figure 3.
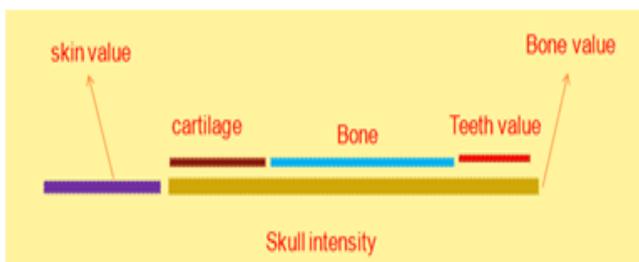

Figure 3: The distribution of the bone intensity in the CT scans.

Threshold computed by assigning three checkpoints in two different slices. Two checkpoints were assigned to the cartilage of spinal cord and one checkpoint assigned to the skin for each slice as shown inFigure4. Each checkpoint will be the center of them ask with the size of 5*10 pixels to compute the accurate value of cartilage and skin intensities by computing the average value of the pixels inside the mask.

Figure 4: Check points were assigned on the cartilage and skin to obtain accurate bone values.

As a result, the minimum bone (spinal cord cartilage) intensity was higher than the maximum skin intensity (Minimum bone value > Maximum Skin value) which will consider as the accuracy threshold for bone value.

Applying Region Growing Algorithm
Homogeneity Condition

$$R = \bigcup_{i=1}^{s} R_i ....1$$

$$R_i \bigcap R_j = \phi ....2$$

Where R is anall inclusive set representing the entire image, i≠ j and (s) is the total numbers of parts in an image whose character

$$H \quad R_i \quad = TRUE ....3$$

$$H \quad RI \quad U \quad RJ \quad = FALSE ....4$$

Is owing to the adjacency of Ri and Rj, hence, they are not homogeneous [23][24].

Algorithm procedures

Two seeds were specified on the mandible bone, which appeared clearly in the region of interest (mandibular region), then a line will be connected between these two seeds and started to move upwards and downwards where the continuity conditions depend on the assumption that each pixel has thirteen neighbors. If any of these neighbors had a gray level

equal or greater than the bone value, then it will be a seed and connected to other segmented pixels, as shown in Figure5, this process will continue till the mandible segmented completely as shown in Figure 6.
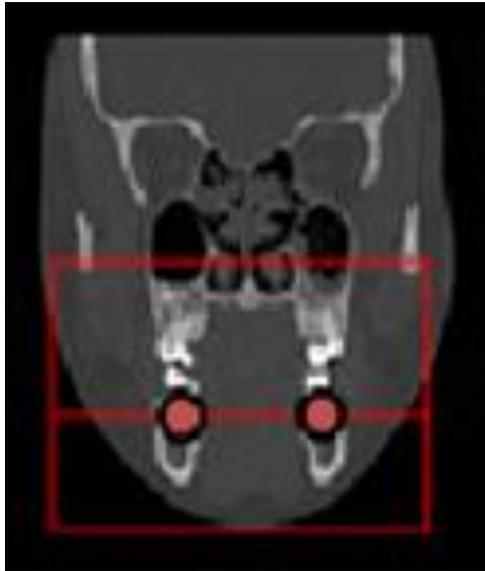

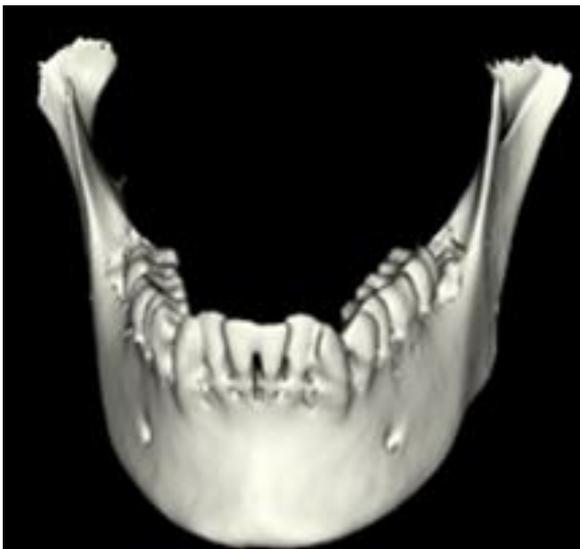**Figure5 (a):** Line passing through two mandible seeds

Figure 6: segmented mandible

The specification of accurate bone intensity value(as discussed before)has a great effect on the complete mandible segmentation process without leaving any remainder pixels, after that a validation process done to show the effect of computing accurate bone value on mandible segmentation by subtracting completely mandible from skull to acquire the skull without lower jawwhich will be starting base for maxilla segmentation later.

If the bone intensity value specified manually (assumption value), the mandible would not be segmented completely and there were many pixels still undefined as shown in Figure7.
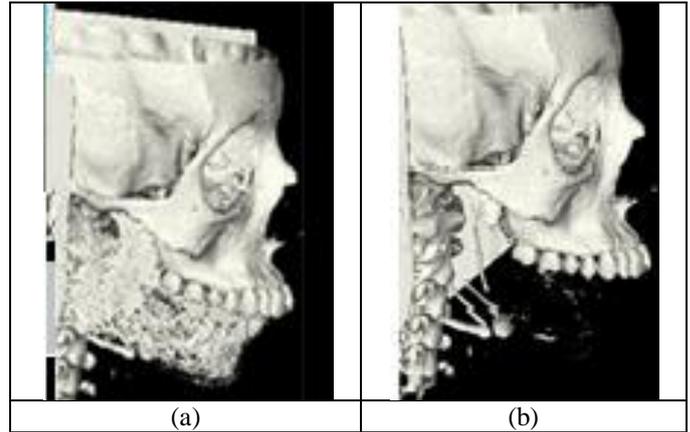

Figure7: (a) skull after incomplete segmentation of mandible. (b) The skull after complete segmentation of the mandible

Computing volume of the mandible
After mandible segmentation, computing mandible volume was important in aiding the surgeon to diagnose mandible case, to decide whether if there was osteolys is of bone (Gorham's disease) [25], rapid bone resorption and deposition (Paget's disease) [26] or not. So that a new method created to compute mandible volume and this method was evaluated experimentally in the laboratory.

Calculating volume of mandible
To compute the volume of the segmented mandible, the following steps were applied using the VTK toolkit as shown in Figure8. The first step was representing a geometric structure comprising of lines, vertices, polygons, and triangle strips by using vtkPoly Data, the second step was generating triangles from input triangle strips and polygonsvtkTriangleFilter, Third step was normalizing shape index of a triangle mesh using vtkMass Properties and the last step was to compute the volume using Get Volume instruction.
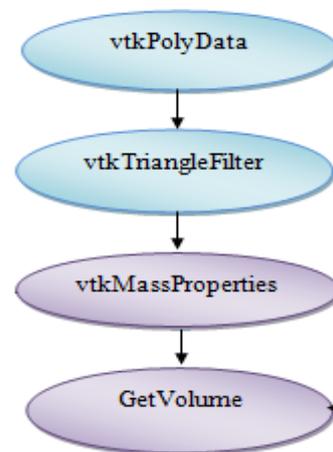

Figure 8: Flowchart of VTK commands for computing mandible volume

After applying the algorithm, the volume of the mandible was computed which approximately equal to 174 cm^{3}as shown in Figure9. A validation experiment applied to evaluate the values that computed by the algorithm.
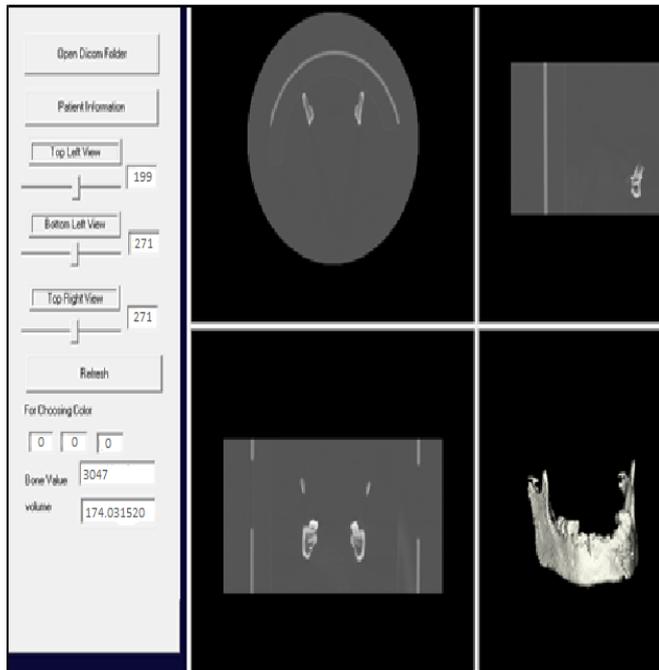

Figure 9: Volume computation of mandible

Segmentation of the maxilla
Maxilla segmentation started by reconstructing and visualizing the skull without mandible, then the points checked manually on one side of skull surface while corresponding points on the other side at the same level will be checked automatically. Each checked point will represent by a sphere to be visualized clearly and then a straight line utilizing the equations 1and 2 was drawn to connect between every two adjacent spheres to form a closed polygon (cutting tools) as appeared in Figure10.

$$x = x_o + t \ (x_1 - x_o)$$

$$y = y_o + t \ (y_1 - y_o) \ ....1$$

$$z = z_o + t \ (z_1 - z_o)$$

$$x = \ (1 - t) \ x_o + tx_1$$

$$y = \ (1 - t) \ y_o + ty_1...............................2$$

$$z = \ (1 - t) \ z_o + tz_1$$

Each point on these lines will act as starting points to another straight line, which moves horizontally across the skull to the other corresponding point on the other side of the skull.
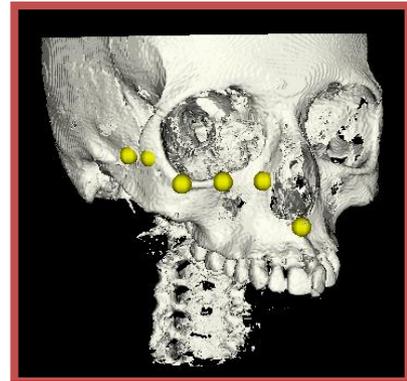The closed polygon forms a cutting tool that is used to separate the maxilla from the skull as shown in Figure11.

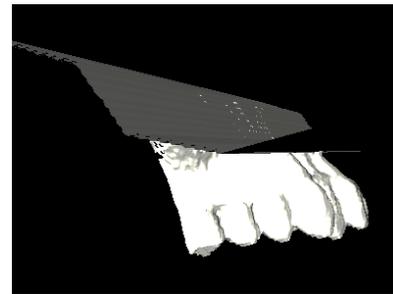**Figure 10:** The drawn polygon on skull without mandible

Figure 11: Segmentation of maxilla

Segmentation of teeth in lower and Upper Jaw
The teeth main parts are crowns and roots, each part has its own gray level (intensity), with studying X-beam imaging, it was found that teeth enamel (the hardest area covered the crown of the teeth) demonstrated the most astounding intensity in the image of the skull volume [27], In addition, the roots showed intensity equivalent to or higher than the bone intensity as it connected with the bone of the jaw as shown in Figure12So that the segmentation process that used to isolate the teeth from the lower jaw, data involves two steps. The first step is segmentation of theteeth crowns. The second step is to segment the roots.
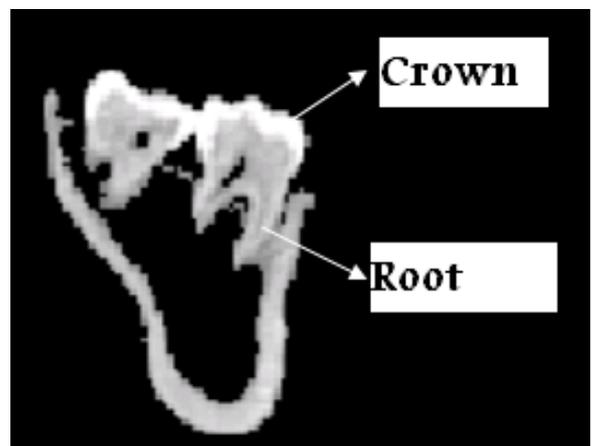

Figure 12: CT scans of the lower teeth show that teeth crowns have a higher intensity than the teeth roots that have an intensity equal to the intensity of the bone.

Teeth Crowns Segmentation:

The following algorithm steps used in the segmentation of the crowns:

Step 1: Segmentation of the crown pixels by using the connected component algorithm.

Step 2: After segmentation, setting crown pixels in the mandible matrix by a certain high intensity.

Step 3: A vertical line of higher intensity is created in the middle of the mandible, then scan from the top right of the mandible matrix to the middle of the matrix and from the left right of the mandible matrix to the middle of the matrix. If horizontal scanning finds a pixel of maximum intensity at one side and from the other side at the same level find a pixel of maximum intensity. Then crown pixels were found and the pixels bellow that line would take as crown pixels and transfer to the teeth matrix.

This algorithm overcomes the error in segmentation the crown and makes the mandible appears without the crown. Then, the algorithm of root segmentation is applied with the boundary detection algorithm as shown in Figure 13.
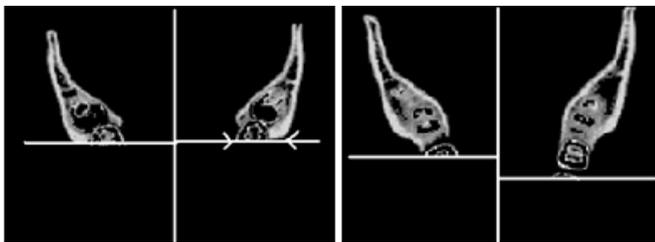

Figure 13: The line threshold algorithm

Teeth Roots Segmentation:

In root segmentation, the following steps were applied:

Step 1: the connectivity algorithm is applied to the crown pixels which considered as a base for the root pixels to acquire the complete teeth.

Step 2: For every pixel in the mandible matrix, check the 49 neighbors of this pixel around and above it in the teeth matrix as shown in Figure14 if there are some crown pixels in the neighbors of about 25% of the total number of the neighbors then these pixels connected with the crown and transferred to the teeth matrix in its corresponding position.
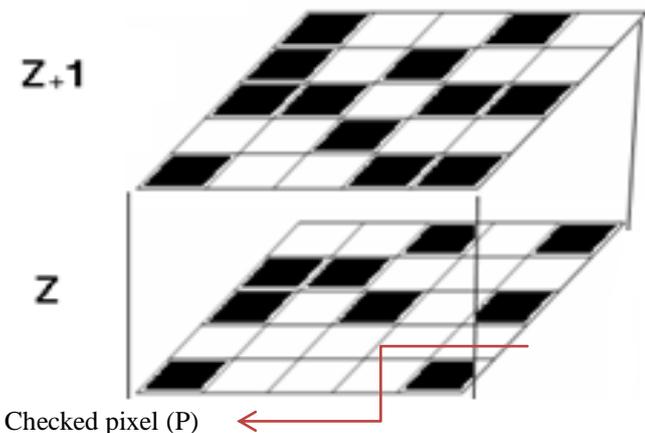

Checked pixel (P)

Figure 14: The 49 neighbors above and around pixel (P)

Upper teeth segmentation was acquired by modification of the lower teeth segmentation algorithm, this technique based on segmentation of crowns from teeth and considers them as seeds to apply the connectivity algorithm to segment upper teeth completely.

Segmentation for every tooth in the upper teeth:

The Segmentation algorithm of every tooth in the upper teeth involved the following steps. First, the K-means [28] algorithm was used to classify each pixel in the starting slice in the upper teeth data set. Second, the pixels in the slices upward and downward the starting one were classified by using a connectivity algorithm as follows:

Step 1: Every pixel P in the slice Z (selected slice) in the upper teeth matrix has 25 neighbor pixels in the slice (Z-1).

Step 2: Counting the number of pixels that had a specific gray level. At that point, the pixel P will be assigned with the same intensity (a graylevel label that was obtained by the majority of pixels. After checking all pixels in the slice (Z-1), in the upper teeth dataset, the algorithm would move downwards (Z-2, Z-3, Z-4,............, Z-m) where m was the total number of the slices.

Step 3: Every pixel P in the slice (Z+1) had 25 neighbors in slice Z (selected slice) in the upper teeth data set, pixel P will be assigned a gray level obtained by the majority of pixels

Step 4: After checking all the pixels in slice Z-1, the algorithm would move upwards (Z+2, Z+3, Z+4,............, Z+m) in the upper teeth data set as shown in Figure15.

After completing the filtering of all pixels in all cuts, every tooth with its own particular gray level or intensity value was obtained as shown in Figure16.
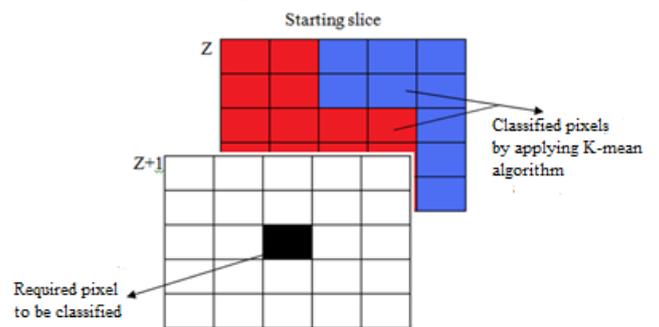

Figure 15: Each pixel P in Slice Z has 25 Neighbors in the above slice when moving upward from the starting slice
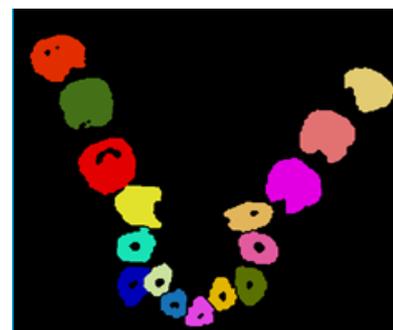

Figure 16: The classification for each tooth

Results and Discussion:

The results for all algorithms that discussed before was examined on 8DICOM datasets of patients with various resolutions and acquired by several CT devices. High-quality structured(mandible, maxilla, and teeth) segmentation was acquired by all datasets, with a precise meaning of the hard shapes and removing of undesired objects. An average computational time of 20 for each dataset is accomplished on a standard Laptop (core i7 Laptop with 8 GB RAM and AMD Radeon 7670M HD graphics card). The resampling filter allows enhancing the computation time while maintaining a sensible, decent quality of the image. Associated with Surface Smoothing the vtk Smooth Poly Data Filter is definitely quicker than all the other filters. Moreover, it offers a safe estimate of the surface if the parameters are well put. Simulation for orthodontic treatment done by complete mandible, maxilla lower and upper teeth segmentation.

Mandible Segmentation:

A segmentation technique used to segment the mandible applied on a various DICOM data for many patients as shown in Figure 17 a fully segmented mandible part.
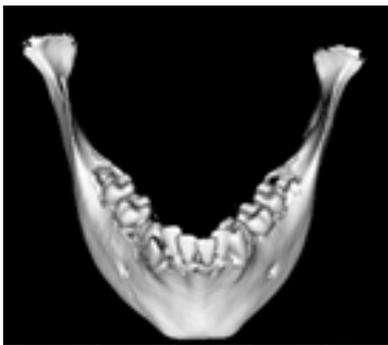

Figure 17: Mandible segmentation

Experimental validation for computing volume for mandible:

The water displacement experiment was the most commonly used technique to compute the volume of the irregular shaped objects (Archimedes principle). This method was applied to measure the volume of the mandible.

Experimental procedures:

1- At first a suitably graduated beaker was filled with a suitable amount of water to fit the mandible as shown in Figure 18, and then records the volume of the water before placing mandible in the beaker which equals 800 ml.

2- After the water's volume has been recorded; carefully place the mandible in the graduated beaker and record new volume, which equals to 976 ml as shown in Figure19.

3- In order to calculate the volume of the mandible, arithmetically subtract the volume of the water without mandible (800 ml) from the volume of the water with mandible (976 ml). The resultant volume will equal to 176 ml.
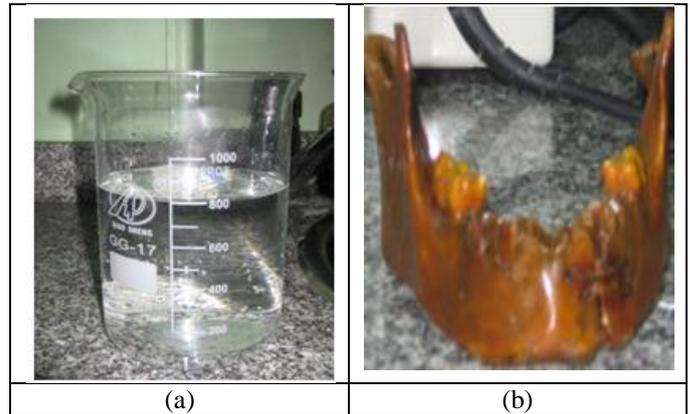

| (a) | (b) |

Figure 18: a The suitably graduated beaker filled with water, 18. b Mandible

Figure 19: Placing mandible carefully into graduate beaker

Maxilla Segmentation:

The result of segmentation technique used to segment the maxilla applied on various DICOM data sets was a fully segmented maxilla part as shown in Figure 20.
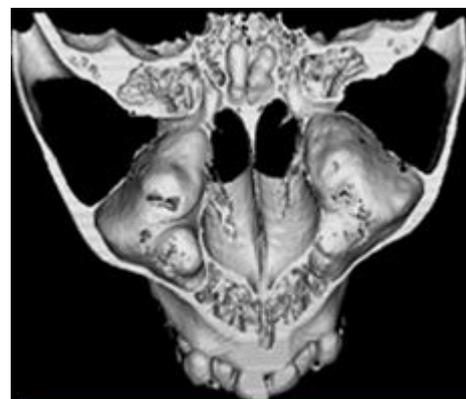

Figure 20: segmented maxilla

The system succeeded in the segmentation of maxilla of 8 patients by > 93%, according to the dentist referred professional experts.

Upper Teeth:
The result of segmentation technique used to segment the upper teeth applied on various DICOM data sets was a fully segmented upper teeth as shown in Figure 21.
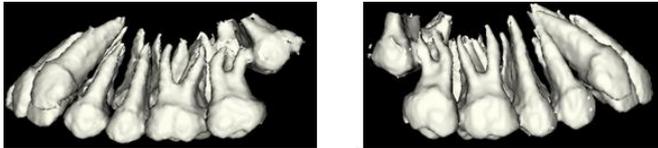

Figure 21: Segmented teeth

The system succeeded in the segmentation of maxilla of 8 patients by > 96%, according to the dentist referred professional experts.

Segmentation for each tooth in the upper teeth:
The result of segmentation technique used to segment the each tooth in upper teeth applied on various DICOM data sets was a fully segmented tooth in each dataset as shown in Figure22
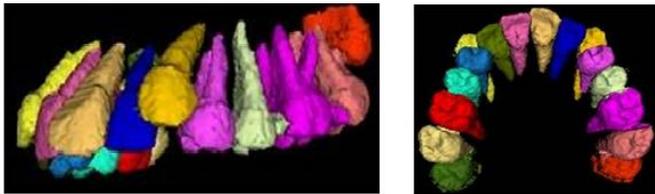

Figure 22: Segmentation for each tooth in upper teeth

The system succeeded in the segmentation of maxilla of 8 patients by > 94%, according to the dentist referred professional experts.

Adding each identified tooth of the maxilla
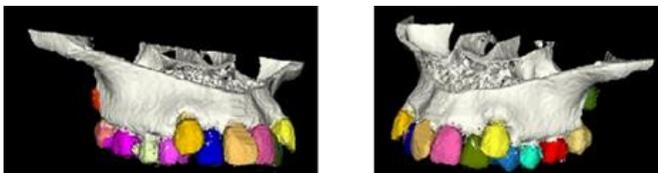Adding each identified tooth to maxilla as shown inFigure23.

Figure 23: Addition of each identified tooth to the maxilla

Simulation for orthodontic treatment achieved by labeling each segmented part of the skull (maxilla, mandible, and each upper tooth) to be easy for the physicians or users to obtain any part of the skull or to translate or rotate any of these parts. The final visualization of the skull and each part showninFigure24.
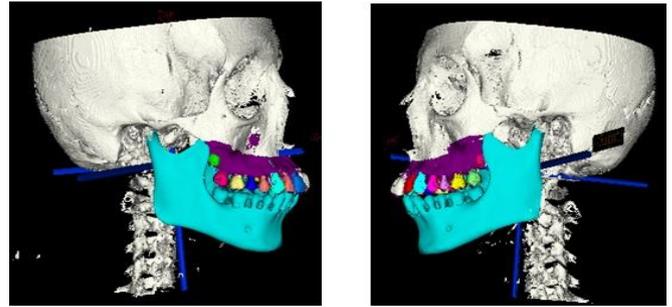

Figure 24: Addition of mandible, maxilla, and each identified tooth with the skull

Conclusions
This work introduces new methods for segmentation of maxilla, mandible and upper teeth in three dimensions based on the CT scans of patients' skulls. Utilizing a new mandible segmentation technique depending on detection of the accurate bone threshold to hold accurate mandible segmentation. A novel method was created for measuring mandible volume and for each segmented part in the skull. Utilizing a new maxilla segmentation technique depending on creating polygon to cut through maxilla
Using a new technique in upper teeth segmentation depending on the K-mean with a connected component algorithm to separate each tooth. Each identified tooth could be saved as a separate STL (stereolithographic) file and then visualized clearly in three-dimension. The system succeeded in segment teeth in all cases (normal and abnormal). Also, the data of the edentulous maxilla could be obtained by subtracting the teeth from the maxilla raw data, the final form of the maxilla with a well-recognized teeth obtained by adding each tooth that recognized and saved before to the edentulous maxilla. After the final form of the maxilla completed the extraction (removal) of any tooth or molar, translation and rotation could be done.

REFERENCES

[1] Bruce Lee and Andrew Newberg, 2005, "Neuro imaging in Traumatic Brain Imaging. ", NeuroRx, 2(2): 372-383, PMCID: PMC1064998.

[2] Long, F., Zhou, J. &Peng, H, 2012, "Visualization and analysis of 3D microscopic images, "PLoS Comput. Biol. 8, e1002519.

[3] Z. Li; Y. Gan; J. Tan; Q. Zhao; Z. Xia, 2014, " A computer-aided visualization system for orthodontic treatment, " Information Science and Technology (ICIST), 4th IEEE International Conference on Pages: 837-840: 10. 1109/ICIST. 2014. 6920607

[4] H. Lameckera, S. Zachowa, A. Wittmersa, B. Webera, 2006, "A New Cone-beam Computed Tomography System for Dental Applications with Innovative 3D Software, "International Journal of Computer Assisted Radiology and Surgery, Volume 1, Supplement 1, 389-402:10. 1007/s11548-006-0026-8.

[5]   Patrick Neumann, 2007, " An Interaction Model for 3D Cutting in Maxillofacial Surgery Planning ", Department of Medical Informatics, University Hospital Benjamin Franklin, Free University Berlin, Hindenburgdamm 30, 12200 Berlin, Germany.

[6]   Akhoondali, H., R. A. Zoroofi and G. Shirani, 2009. "Rapid automatic segmentation and visualization of teeth in CT-scan data". J. Applied Sci., 9: 2031-2044.

[7]   Filip Schutyser, Johan Van Cleynenbreugel, Joseph Schoenaers, Guy Marchal, and Paul Suetens, 1999, "A simulation environment for maxillofacial surgery, including soft tissue implications", In Proceedings of MICCAI, pages 1210-1217.

[8]   R. M. Koch, 2001, "Methods for Physics-Based Facial Surgery Prediction". Ph. D. Thesis, Institute of Scientia Computing, ETH Z Zurich Diss. No. 13912.

[9]   JENS G. SCHMIDT, GUNTRAM BERTI, JOCHEN FINGBERG, JUNWEI CAO AND GERTWOLLNYY, 2004, "A finite element based tool chain for the planning and simulation of maxillofacial surgery, " European Congress on Computational Methods in Applied Sciences and Engineering ECCOMAS, Jyvaskyla, Finland.

[10]   Jain, A. K., H. Chen and S. Minuit, 2003, "Dental biometrics: Human identification using dental radiographs, " Proceedings of the International Conference on Audio and Video Based Biometric Person Authentication (AVBPA), Guildford, UK., Pp: 429-437.

[11]   Chen, H. And A. K. Jain, 2004. "Tooth contouring extraction for matching dental radiographs, " Proceedings of the 17th International Conference on Pattern Recognition, Aug. 23-26, IEEE, pp: 522-525.

[12]   Li, S., T. Fevens and A. Krzyzak, 2006, "An automatic variational level set segmentation framework for computer-aided dental X-ray analysis in clinical environments., " Comput. Med. Imaging Graph, 30: 65-74.

[13]   Samir Shah, Ayman Abaza, Arun Ross and Hany Ammar, 2006, "Automatic Tooth Segmentation Using Active Contours without Edges", West Virginia University, Morgantown, WV 26506 USA, Biometrics Symposium.

[14]   H. Gao and O. Chae, 2008, "Automatic tooth region separation for dental CT images, "inProceedingsofthe3rdInternationalConference on Convergence and Hybrid Information Technology (ICCIT'08), vol. 1, pp. 897-901.

[15]   H. Gao and O. Chae, 2010, "Individual tooth segmentation from CT images using the level set method with shape and intensity prior, " Pattern Recognition, vol. 43, no. 7, pp. 2406-2417.

[16]   J. A. Sethian, 1999, "Level Set Methods and Fast Marching Methods, " Evolving Interfaces in Computational Geometry, Fluid Mechanics, Computer Vision, and Materials Science, Cambridge University Press, Cambridge, UK.

[17]   C. Galanis, M. M. S fantsikopoulos, T. Koidis, M. Kafantaris, and P. G. Mpikos, 2007, "Computer methods for automating pre operative dental implant planning: implant positioning and size assignment, " Computer Methods and Programs in Biomedicine, vol. 86, no. 1, pp. 30-38.

[18]   k. Fernandez and C. Chang, 2012, "Teeth/Palateandinterdentalsegmentationusingartifici alneuralnetworks, "in artificial Neural Networks in Pattern Recognition, vol. 7477 of Lecture Notes in Computer Science, pp. 175-185, Springer, Berlin, Germany.

[19].   G. Kim, J. Lee, J. Seo, W. Lee, Y.-. Shin, and B. Kim, 2012, "Automatic teeth axes calculation for well-aligned teeth using cost profile analysis along teeth center arch, " IEEE Transactions on Biomedical Engineering, vol. 59, no. 4, pp. 1145-1154.

[20]   R. Adams and L. Bisch of, 1994, "Seeded region growing, " IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 16, no. 6, pp. 641-647.

[21]   Sundaresan Raman and Rephael Wenger, 2008, "Quality Is o surface Mesh Generation Using an Extended Marching Cubes Lookup Table, " The Eurographics Association and Blackwell Publishing Ltd. Volume 27, Number 3.

[22]   W. K. Pratt, 2007, Digital Image Processing, 4th Edition, John Wiley & Sons, Inc., Los Altos, California.

[23]   G. Kim, J. Lee, H. Lee, J. Seo, Y.-M. Koo, Y.-G. Shin, B. Kim, 2011, "Automatic extraction of inferior alveolar nerve canal using feature-enhancing panoramic volume rendering, " IEEE Transactions on Biomedical Engineering, 58 (2) 253-264.

[24]   Fan, J., Yau, Elmagarmid, and Aref, 2001, "Automatic image segmentation by integrating color-edge extraction and seeded region growing, " IEEE Transactions on Image Processing, vol. 10, no. 10, pp. 1454-1466.

[25]   Victoria Ohla, Ahmed B Bayoumi, Markus Hefty, Matthew Anderson, and Ekkehard M, Kasper, 2015, "Complex single step skull reconstruction in Gorham's disease, " BioMed Central Surgery, Published online.: 10. 1186/s12893-015-0014-4.

[26]   P. Srinivas Chakravarthi, Ranjit Kumar Peravali, and Vivekanand Kattimani, 2015, "Paget's Disease in Mandible, " A Rare Occurrence in an Indian Sub-ContinentJournal of Clinical and Diagnostic Research, 10. 7860, JCDR, 11468, 5708PMCID, PMC4413172.

[27]   LAMIA N OMRAN, AHMED M EL-BIALY, AHMED H KANDIL, SAHAR ALI FAWZI, 2015, "A SYSTEM FOR SIMULATING THE ORTHODONTIC TREATMENT PLAN, " INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY APPROACH &STUDIES. VOL. 2 ISSUE 2, P90-99. 10P.

[28]   ALON VINNIKOV AND SHAI SHALEV-SHWARTZ, 2014, "K-MEANS RECOVERS ICA FILTERS WHEN INDEPENDENT COMPONENTS ARE SPARSE, " PROC. OF INT'L CONF, MACHINE LEARNING, BURGOS, SPAIN, SECTION: INTELLIGENT COMPUTATIONAL TECHNIQUES IN MEDICAL IMAGE PROCESSING PAGES: 649-655 ISSN: 0302-9743, 978-3-642-04393-2.