

Acquiring Anatomical Representation of Human Maxilla for Rapid Maxillary Expansion

F.A. Zabir¹, A.S. Abdullah¹, N.A. Abu Osman¹, Z. Radzi², N.A. Yahya², N.H. Abu Kasim²

¹ Department of Biomedical Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia

² Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia

Abstract — The purpose of the study is to model and provide a better understanding of maxilla bone involved in the treatment for rapid maxillary expander (RME) for dento-facial applications. The treatment is recommended for patients presented with an arch width deficiency named cross bites. Cross bites often cause abnormal physical forces that disrupt the balance of the occlusal relationship. More commonly, the maxilla or the upper jaw appears to be narrow and contributes to significant degree of crowding in the mouth. Early investigators [1-4] discovered that rapid maxillary expansion resulted in a splitting of the median palatal suture. The expansion is possible with the process of bone resorption and new bone deposition thus maintaining the expansion achieved [10]. This preliminary study shows that the FE model has the potential to be a valuable tool for further analysis of dental simulation and the understanding of orthodontic treatment.

Keywords — Dento-facial , maxillary expansion, automated, orthodontics, continuous force

I. INTRODUCTION

The study suggests an approach to develop a reliable model of maxillary bone in achieving orthodontic expansion. Previous models to assess the biomechanical aspects of rapid maxillary expansion process dealt with the cranial structure [5-8]. For example Jafari, who imposed a 5 mm displacement on each side of the circumaxilla and viewed the result of the various stress accumulated across the skull. For our understanding, we will be focusing on the region of the maxilla to get a detailed model of the particular area.



Fig. 1: Human Palate. (Adopted from [14])

Rapid Maxillary Expander is an approach for young patients, especially children undergoing inter-maxillary expansion as a routine in an orthodontic treatment. The goal is to maximize the orthopedic displacement as the physiological alteration takes place [9]. These appliances have been shown to produce force ranging from 3 to more than 20 pounds.[10,11]

The correction or expansion of the maxilla is recommended during childhood or adolescent years because the bone has not yet sufficiently mineralized or hardened, which can be called as the growing period [12]. Therefore, restructuring is highly possible at this stage. In histological analysis, Murray discusses the early changes caused by splitting the suture [13]. After 7 days of activation, the mid-palatal suture will open in response to the external force being exerted. A key factor responsible for mid-palatal suture (The squiggly line in Fig. 1) expansion is bone resorption which allows the separation to happen in the first place. New bones will be deposited at the site in attempt to maintain the new morphology. [13]

Our goal is to correlate the areas of dissipation of forces to the amount of mineralization of the bone in the region of interest, which is the hard palate. For this, first, we need to get the most accurate anatomical model of the maxilla bone structure.

II. MATERIALS & METHODS

A. Data Acquisition (DICOM Images)

In this section, we acquired the CT image of a 15-year-old patient. The criterion for patient selection is patient with constricted arch who required maxillary expansion as part of the comprehensive orthodontic treatment.

In order to fully understand the biomechanics of the treatment, we looked into the bone and connective tissue morphology of the site of interest, specifically the maxillo-facial region. CBCT images were taken set at 46.72 mAs, 120 kVp at 0.12 mm slice thickness. The 3D image of a 15 year old maxillofacial area was automatically transferred to the i-Cat system for further analysis of the image acquired. The inherent high resolution of the i-CAT™ ensures anat-

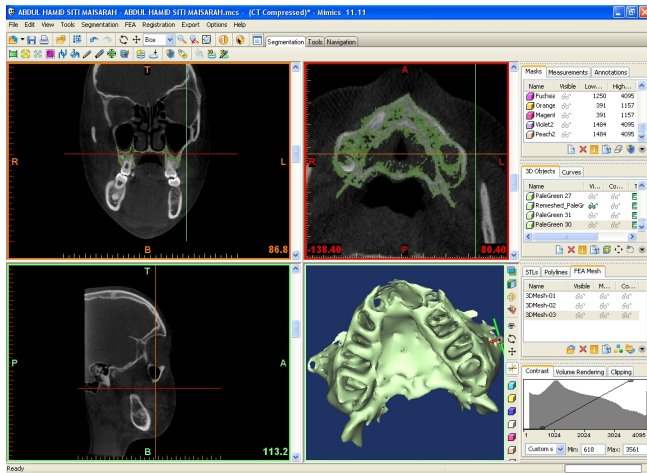


Fig. 2: View of the mask created in coronal , axial and sagittal, viewed in MIMICS

omic accuracy and assessment of all bony pathology in the maxillofacial region [15].

The acquired data from CT result were imported as DICOM image format into a three dimensional visualization software, Mimics 11.1 (Materialise, Leuven, Belgium) [16], to generate a 3-D surface model of the maxillofacial. MIMICS imports CT and MRI data in a wide variety of formats and allows extended visualization and segmentation functions based on image density threshold, thereby acting as the interface between the anatomical data to the finite element modeling software for processing. The system enables viewing from coronal, axial and sagittal perspectives. Fig. 2 is the working interface in MIMICS.

B. Thresholding

Based on the intensity of the anatomical data observed, we performed thresholding .Of essence in CT imaging is the knowledge on Hounsfield Unit which corresponds to normalised index of x-ray attenuation based on a scale -1000 , representing air to +1000 representing bone, with water being 0. To highlight the bone structure at the maxilla , a lower limit of 1250HU and an upper limit of 4000HU were defined. The teeth region with a lower limit of 2224HU and upper limit of 4000 were also identified.

C. Segmentation density masks

For the maxilla bone, we highlighted the region of interest, or created a mask. This process allows the generation of independent 3D models. Manual operations are performed to eliminate artifacts or residual pixels at the maxilla and mandible region. In order to focus on the maxilla bone region we performed Boolean operations, to segment the bone

and teeth region. This is done to separate areas or joints that appear to be connected on the CT image. The teeth region (2224HU) is subtracted from the bone region (1250HU) to obtain only the maxilla bone.

D. 3D Reconstruction

The mask is used to develop 3D model of the maxilla bone. The 3D reconstruction employs 3D interpolation techniques which transform the slices to a 3D model. For more accurate dimensional representation of the maxilla bone structure, we performed refining touch to the 3D model. The 3D model created after segmentation and thresholding process is further beautified from noises. The smoothing feature in Mimics Remesh (Figure 3) removes the noise, and therefore improves the quality of the surface generated. Smoothing and triangle reduction are performed to eliminate small inclusions and reduce the number of the mesh elements.

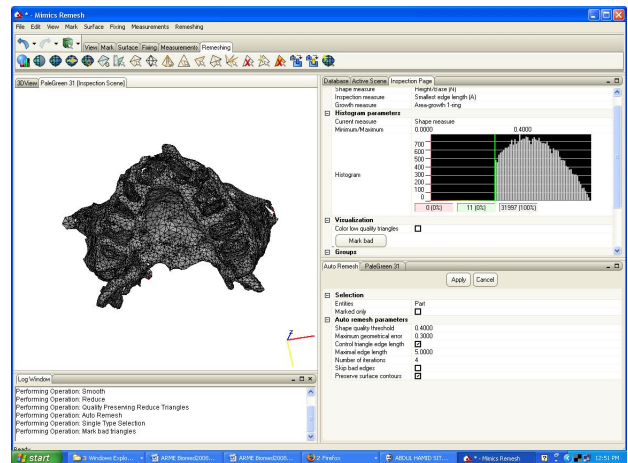


Fig. 3: Generating the mesh in Remesher mode

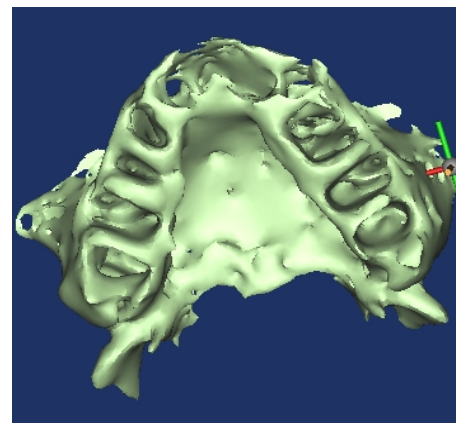


Fig. 4: Final 3D model of human maxillary (upper jaw)

III. DISCUSSION

The success of the expansion demand will be subject to a good many variations and exceptions when factors such as magnitude, direction and duration of the force are introduced.[17] Our main concern is the accurate representation of the human maxilla (in Figure 4) before mounting our new design of a rapid maxillary expander. The focus is based on the fact that the appliance will involve skeletal movement. As it expands, it is expected that the rate is consistent to the tissue morphology without causing too much tissue damage [18]. As previously mentioned, throughout the duration of expansion, remodeling and restructuring of the bone tissue occurs. This study focused primarily on 3D modeling to predict the response of the appliance (the mechanical load exerted) to the corresponding bone and tissue. As such, we need to first assess the actual anatomical representation of the human maxilla. Current progress includes stress and deformation analysis of the maxilla and possibly cranial structure in a simulated environment.

IV. CONCLUSIONS

The present investigation seeks to quantify the mechanism of opening the median suture employing rapid maxillary expander by identifying the correct anatomical region to be analyzed. Accurate modeling is essential in determining or diagnosing the best treatment plan. Once we are fully satisfied with the physiological representation, we have yet to simulate the environment for which the loading conditions are applied similar to the working of an automated rapid maxillary expander, ensuring uniformity of the pressure applied to the both halves of the maxilla.

ACKNOWLEDGMENT

This project is funded by e-ScienceFund grant, from the Ministry of Technology, Science and Innovation, Malaysia.

REFERENCES

1. Angle E.H (1860) Treatment of Irregularity of the Permanent or Adult Teeth, Dent Cosmos , vol 1, pp 540-544,
2. Hawley C.A(1912) A Study of Maxillary Movement, Items of Interest vol 34:426-451
3. Dewey M. (1914) Bone Development as a Result of Mechanical Force: Report on Further Treatment in Attempting the Opening of the Intermaxillary Suture in Animals, Items of Interest, vol 36, pp 420-438
4. Cleall J. F Bayne D.I et al,(1965) Expansion of the Midpalatal Suture in the Monkey, Ang Orthod. vol 35, pp 23-35.
5. Holberg C (2005), effects of rapid maxillary expansion on the cranial base-an fem analysis, j orofac orthop, vol 66, pp 54-66
6. Provatidis C. et al.(2007) On the FEM modeling of craniofacial changes during rapid maxillary expansion med eng phys, vol 29, pp 566-579
7. Boryor et al (2008) Stress distribution and displacement analysis during an intermaxillary disjunction – a three- dimensional fem study of a human skull , J Biomech , vol 41 , pp 376-382.
8. Jafari A, Sadashiva K.S, et al (2003) Study of Stress Distribution. and Displacement of Various Craniofacial Structures Following Application of Transverse Orth Forces- A 3D FEM Study, Ang. Otrhod, vol 73.
9. Isaacson R.j (1964) forces produced by rapid maxillary expansion: Design of the force measuring system ang orthod, vol.34,no.4, pp 256-270
10. Haas (1965) the treatment of maxillary deficiency by opening the midpalatal suture , Ang Orthod, vol. 35, pp. 200-217.
11. Zimring J.F, (1965) forces produced by rapid maxillary expansion. ang orthod, vol 35, no. 3
12. Gedrange T (2001), Hard Palate Deformation in An Animal Model Following Quasi-Static Loading to Stimulate That of Orthodontic Anchorage Implants , Eur J Orthod , vol 23, pp 349-354
13. Murray J.M , Cleall J.F (1971) Early Tissue Response to Rapid Maxillary Expansion in the Midpalatal Suture of the Rhesus Monkeys, J Dent Res
14. Figure of Human Palate from <http://www.orthonj.com/rpe.html>, 15 November 2007.
15. I-CAT Imaging Science International Inc. from <http://www.dmfua.com/16.html>
16. Mimics 11.1 Reference Guide (Materialise Software)
17. Graber T, W.B.Saunders, Co. (1969), Current Orthodontics Concepts and Tehniques vol 1 pp 56-58.
18. Karaman A.I (2002) The Effects of Nitanium Maxillary Expander Appliances on Dentofacial Structures Ang Orthod.,vol 72,pp 344-354.

Author: Fariza Ariffah Zabir
 Institute: University of Malaya
 City: Kuala Lumpur
 Country: Malaysia
 Email: farizab@perdana.um.edu.my