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Integration of CAD/CAE/RP Environment for Developing a New Product in Medical Field

Nabeel I. Allawy[a*], Amjad B. Abdulghafour[b]

[a] University of Technology, Industrial Engineering, Baghdad, Iraq, 71396@student.uotechnology.edu.iq

[b] University of Technology, Industrial Engineering, Baghdad, Iraq, dramjadbarzan@gmail.com
*Corresponding author.

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K E Y W O R D S

Rapid Prototyping; CBCT Scan; Reconstruction Mandible; Customized Design.

A B S T R A C T

Reconstruction of the mandible after severe trauma is one of the most difficult challenges facing oral and maxillofacial surgery. The mandible is an essential element in the appearance of the human face that gives the distinctive shape of the face, holds. This paper aims to propose a methodology that allows the surgeon to perform virtual surgery by investing engineering programs to place the implant by default and with high accuracy within the mandible based on the patient's medical data. The current study involved a 35-year-old man suffering from a traffic accident in the mandible with multiple fractures of the facial bones. Basically, an identification of the steps required to perform virtual surgery and modeling images from the CBCT technology has been done by using the software proposed in the research. The implant model is designed as a mesh model, allowing the patient to return to a normal position. Moreover, an application of FEA procedures using the Solidworks simulation software to test and verify the mechanical properties of the final transplant.

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1. Introduction

Rapid prototyping (RP) "refers to a set of techniques that make layer after layer 3D physical models directly from CAD". This technology to operate and allows the creation of prototypes for complex engineering design [1]. Considered reconstruction of the mandible shock or cancer, from of the most important challenges facing oral and maxillofacial surgery. The mandible plays a key role in protecting the respiratory tract, supporting the tongue, teeth, and the muscles of the bottom of the mouth, allowing chewing, speech, and breathing. The mandible deviates due to the tension caused by the remaining chewing muscles and the soft tissue contractions as well as the surgical scars [2]. The goal of mandible repair is to try to restore the patient to the previous functional situation, where a new methodology is proposed to restore functional anatomy and a new design that suits the appearance of the patient and helps to restore the functional state and psychological stability of the patient. The traditional process is to compensate and install pre-fabricated titanium sheets, which require considerable time and effort by the surgeon and greatly prolong surgery time. Progress in medical imaging such as cone, beam computed tomography (CBCT) has allowed the production of a 3D model of anatomical tissue and the design of surgical compensatory models. Currently, the process is proposed to be performed in a proposed virtual environment simulating the disease using the CAD environment. The results show that the surgical procedure in a proposed virtual environment simulates the patient using a more secure CAD environment. There are a little riskier and the surgical operation and surgical consequences can be observed at any time. This technique provides time, effort, and money as there is no need to print the forms before performing plastic surgery.

2. Literature Survey

This section describes some medical activities for the purpose of acquiring 3D models of tissues or human organs where they can be printed using a 3D printer. [3] Described the use of computer-aided design and RP technologies for preoperative planning as well as for patient-specific implant production based on patient medical data. [4] Discussed the classification and approach to the reconstruction of mandibular defects. We also elaborate upon four commonly used free osteocutaneous flaps, inclusive of the fibula, iliac crest, scapula, and radial forearm. [5] Discussed the relation of the common way of Computed tomography image data processing, and also an improving method of constructing the RP data of jawbones based on Computed tomography image has been proposed. A 3D model of the mandible defect is generated after the CT data processing. [6] Had a major role in supporting dental structures, chewing, expression, evacuation, and breathing. Progress in medical imaging, computer-aided design, and rapid prototyping techniques have helped to design and manufacture models for anatomical structures and patient implant fabrication. [7] Presented the clinical use of rapid prototypes, 3D models, and pre-curved reconstruction plates for mandibular reconstruction after cancer resection has been approved. Describes a new approach using similar techniques in managing complex mandibular fractures. [8] Presented a proposed methodology for designing and constructing a patient-specific transplant based on the patient's medical image data so that the methodology helps to investigate the match between medical data and the new design. [9] Presented AM advances applied to the structure and assembling of a bio model, actually, an embed for the careful remaking of a huge cranial imperfection. A progression of registered tomography information was acquired and programming was utilized to extricate the cranial geometry. The convention introduced was utilized for the formation of an anatomic bio model of the bone deformity for the careful arranging just as to structure and make of the patient-explicit embed. [10] Designed, and developed and manufactures cranial implants with mechanical properties close to the bone, greatly reduces implant failure, improves the aesthetic results of cranial surgery, and achieves a better quality of life. Customized cranial mesh implants are digitally designed based on digital imaging and communication of medical files and are manufactured using state-of-the EBM technology. [11] Assessed the accuracy and technical reproduction of surgical modeling using an open-source patient's mandible repair program. The evaluation was made by comparing the physical model with the 3D printer model and determining the accuracy. [12] Prepared the patient's medical data, a high-resolution computerized tomography CT scan was used for the purpose of data collection. Using Mimics software, the 2D image is converted to 3D and then the fragmentation process is done. The images are divided into four parts based on defects Conformity analysis was performed by calculating the distance compatible with the square root.

3. Methodology

In this work, the proposed methodology shown in Figure 1, focused on surgical planning, restoration, and improvement of surgery results. The main steps of the stages of applying the proposed methodology the curriculum is divided into four stages as follows:

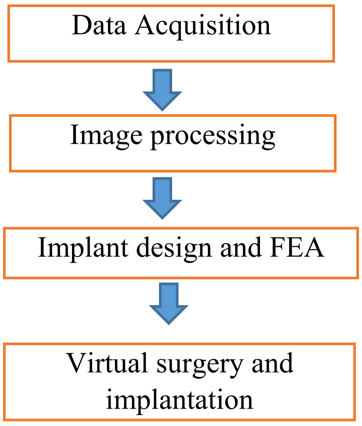

Figure 1: The methodology

4. Case Study

I. Background

Selected the case in Baghdad Medical City Martyr Ghazi Hariri Hospital. Male, 35 years. Performed CBCT scan obtained advised in Oral & Maxillofacial Surgery Section / Radiology Unit and 3D Printer. Detection partial fracture of the mandible on the left side, fracture of the teeth or alveolar on the front area of the maxilla and mandible.

II. Acquisition of patient data

The study conducted on a 35-year-old patient whose diagnosis indicates the presence of prickly human cancer cells in the right half of the alveolar process of the mandible. 2D images were obtained using the CBCT scan in Baghdad Medical City/ Al Shahid Ghazi Al Hariri Hospital / Oral and Maxillofacial Surgery Department / Radiology Unit and 3D Printer. The high-resolution scan obtained using the scanner (CBCT OnDemand3D) as shown in Figure 2 with the installation of standard parameters showing the accuracy. The dimensions of the image (468 * 468 * 407) mm are determined with a voxel size of (0.3) plus a voltage of 120 v/ s. Patient data imported into the workstation and the segmentation was automated using 3DSlicer. The patient was saved as Digital Imaging and Communications in Medicine (DICOM) data file.

III. Images Processing

CBCT examination contains data on the medical form and the affected area. In order to process the patient's medical data, we use the reverse engineering technique where there are many different software packages, such as 3DSlicer Figure 2a. The 2D data are converted into a 3D patient model that displays the entire skull model with the affected area using segmentation technology. Emphasis is placed on the defective areas of the parts of the face and jaws as well as on reducing the actual model size using fractionation. Figure 2b shows the model of the skull and maxillary parts of the face and jaws. To complete the isolation of the affected tissue and its surrounding areas, a threshold technique is used. Using the manual threshold technique, we can determine the density of the bone, ranging from (219-2.020). The threshold value causes data loss if the automatic threshold is used so that the manual threshold is used to obtain complete data. After that, the 3D model is exported STL file.

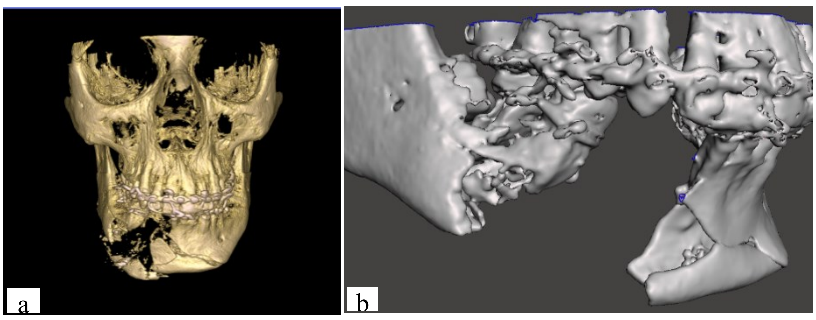

Figure 2: (a) The skull before the segmented. (b) Segmented mandible

IV. Customized Implant Design and FEA

1) Implant Design

Reconstruction involves exporting the 3D model created with CAD software (SolidWorks) for the purpose of implant design. Planar contours, which uses contour lines to approximate complex surfaces. In this paper, the (contour contours) method creates 3D models using the (Extrude) command in SolidWorks. Basic steps in the planar contour approach include capturing a 2D image of a medical image. A 2D image taken in the modeling process is imported into SolidWorks by a command (image drawing) as shown in Figure 3a. Create a (B-spline) curve with control points on each layer, using the curve synthesis technique as shown in Figure 3b. The next step is to use the (Flex) command features to bend the design at a certain angle, as shown in Figure 4. Finally, the 3D model saves as the STL file to export.

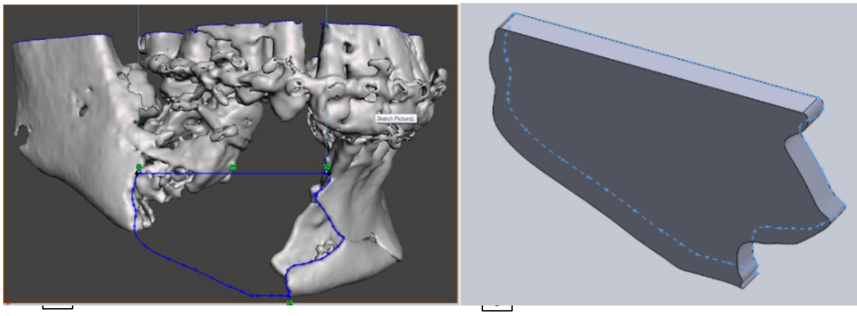

Figure 3: (a) Creating a B-spline curve. (b) 3D Reconstruction of the implant using extrude

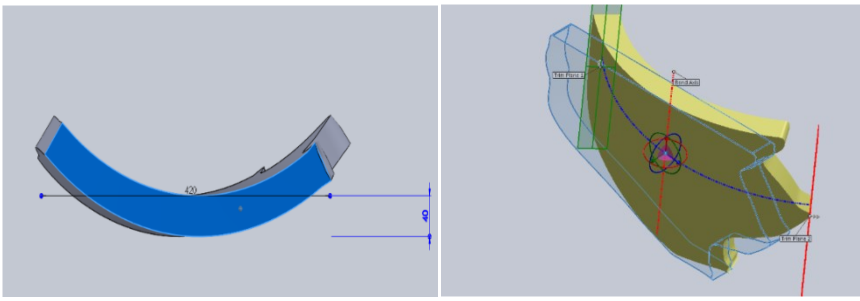

Figure 4: Illustrates the bending process

2) Finite Element Analysis

The FEA technique shows the distribution of the force attached to the reconstructed mandible. This procedure is done to check the strength of the mechanical properties of the implant. The pressure resulting from the strength of the chewing and compressing reaction is therefore very important. The properties and conditions of the material boundary of the implanted model are set and therefore the conditions of the force that is being bitten can be examined, for example, single left and hard biting. The chewing and biting strength of normal humans is 150 MPa. In this work, a force of 180 MPa was shed without any deviation in the model. The maxilla bones bear the maximum pressure resulting from chewing processes up to 200 MPa. The upper pressure on the model was subjected to a maximum pressure of up to 230 MPa prior to failure as shown in Figure 5. So the implantation process can withstand the pressures resulting from the general procedures of the maxilla. Useful data for successful and effective surgical reconstruction of jaw removal have been obtained by surgeons so that they may fully restore normal functions.

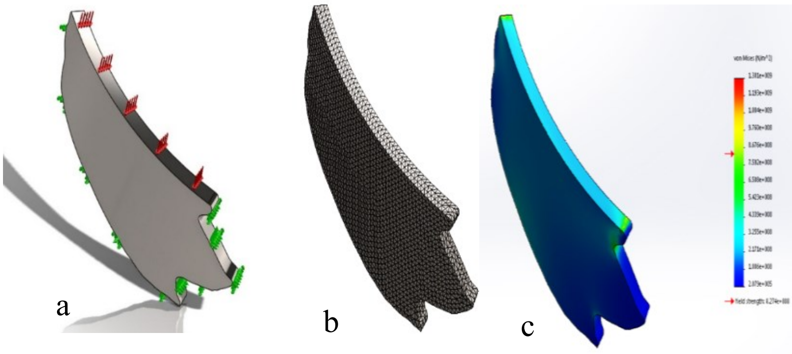

Figure 5: (a) mesh model of the implant. (b) Directional constraints (c) Color-coded analysis

V. Virtual Surgery and Implantation

Figure 6a illustrates the assembly process between the 3D models that were created are based on a CBCT scan and the implant designed in the CAD program depending on the missing part of the patient's mandible. Both of the two models are in the STL file. In the first stage, it is observed that there are ripples and overlapping of the surfaces due to the different environments. Distortions are processed on the surface using an order (Sculpt and Reduce) and passed on the surface using the mouse, the surface becomes smoother. In addition, sharp edges are treated so that they are more suitable for implantation, as shown in Figure 6b.

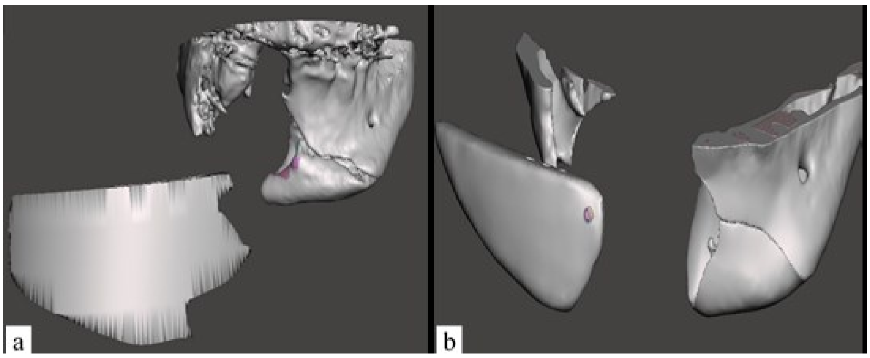

Figure 6: Assembly the models

Figure 7a shows a fracture on the right side of the mandible as a result of the accident. Where doctors advise that the part should be returned to the place and installed in a medical pin for the purpose of restoration. Using the (Transform) technique, the sloping part rotated at an angle (11.45) in the direction of left for the purpose of matching the mandible of the body as shown in Figure 7b. Reduces the material in the jaw and improves the appearance of the patient.

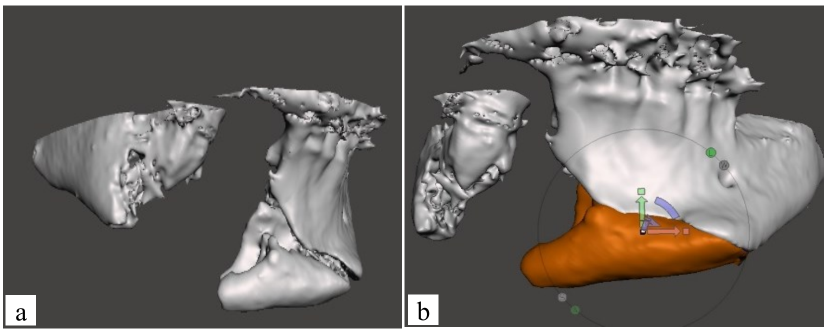

Figure 7: The process of lifting and rotating the lower part of the jaw bone

In addition, as shown in Figure 8a, the upper part of the implant cut using order (Plancut) from the list (Edit) for the purpose of reducing the weight of the implant. Use a (Hollow) order to make the body, hollow from the inside and your wall thickness (1.5mm). The mesh design allows for easy blood flow during implantation and the low resistance of the foreign body's immune system due to the lack of surface area. Moreover, Compensates for the accident and the psychological crisis caused him as shown in Figure 8b.

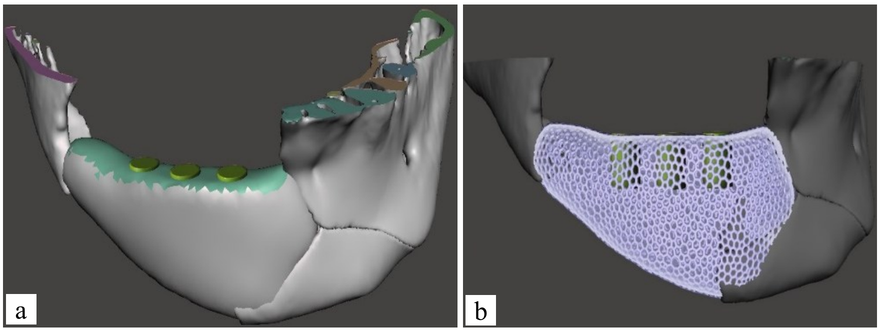

Figure 8: (a) implantation. (b) Mesh design

5. Results and Discussion

This study proposed the design of a compensatory model for any trauma or trauma with bone or tissue loss requiring surgical intervention and cosmetic and functional compensation. The basic idea of this paper is the ability to invest in engineering software for medical image processing, modeling, and simulation in the implementation of surgery in a virtual computer environment that simulates clinical reality. Several advantages, including the ability to achieve accurate compensatory models with dimensions close to the loss zone. It also offers the possibility of assessing the technique of surgical fixation and mechanical stability. Not possible in traditional ways. By applying segmentation and simulation technology using these programs, advantages have been added to surgical technology compared to conventional methods. The quality of the data packets used (Meshmixer and 3DSlicer) allows a wide view of the surgical area, allowing the surgeon to plan before the surgery, thus reducing the time of the surgery and ensuring the success of the operation.

6. Conclusion

Using advanced simulation software gives a high and clear image resolution around the affected area. The creation of physical RP models depends on the accuracy of the patient's medical data where they give clear, complete, concise, and accurate. Imaging using a CBCT device helps reduce patient exposure to radiation as well as surgery planning and reduced execution time. FEA gives increased design performance to ensure cost-effectiveness and within required performance standards. The (Meshmixer) software has the power of editing. Export of STL and gave high accuracy of the surface finish. The virtual computer environment that simulates clinical reality produces the successful anatomy of reconstructive surgery for the implementation of surgical work. The quality of these programs allows the surgeon to have a wider view of the position of the surgical area, allowing him to plan before surgery.

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