

# Modelling with Photogrammetry on Denture Prototyping Using Digital Light Processes (DLP) 3D Printer and Its Strength Analysis

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## ABSTRACT

Along with the development of the times until now technological advances are developing very rapidly, with the passage of time and the development of human thinking patterns. This also has an impact on the world of health which requires the latest and sophisticated medical equipment and devices as well as ease and efficiency in its use, several agencies and health/medical schools that need and utilize this mandibular structure prototype tool, including for world teaching aids. medicine explains about function tests and the components in the human lower jaw. This prototype form allows the material to have a minimum weight with very large strength and high power, but has a low production power, it is widely used for aircraft structures, building construction, shipping, automotive to minimize the amount of material used. In this design, the prototype model of the human mandibular denture is simulated. The results of the analysis on the mandibular denture using Ansys student software, namely the results of this meshing itself have 26445 nodes and 5525 elements with an element size of 2.5 mm, from the stress simulation, the reddest part of the mandibular denture is the support rod is slightly down because it receives enormous pressure. With a maximum value of 14.692 MPa in the blue part, that is, it does not affect the change in shape which is determined with a minimum value of 0.0020833 MPa from the simulation results.

Keywords: *Photogrammetry, Ansys Student, Simulation of Human Lower Jaw Dentures*

## 1. INTRODUCTION

Dental and oral health in Indonesia is one that needs attention. Based on the 2013 Basic Health Research Results (RISKESDAS) data, in 2007 as many as 23.2% of Indonesia's population experienced dental and oral health problems and the increase in these problems in 2013 was 25.9%. In 2013 there were 31.1% who received treatment from dental nurses, dentists or specialist doctors, while the other 68.9% did not receive treatment. Based on the 2013 Basic Health Research Results (RISKESDAS) data, the proportion of the population with dental and oral problems was 36.1%, but only 22.2% received treatment from dental medical personnel [1].

Ideally, lost teeth should be replaced to anticipate various disturbances that might occur, but the available data shows that not all lost teeth are replaced. Data from Basic

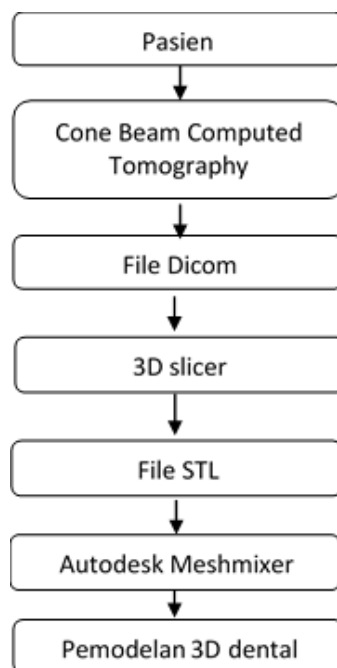
Health Research (RISKESDAS) 2013 shows that most people aged 65 years and over (23.48%) experience tooth loss, but unfortunately only 2.1% replace lost teeth. Tooth extraction was 18.1%, while only 0.3% replaced missing teeth with dentures, with a tooth extraction index (29.7%). From the data above it can be seen that the potential for developing dentures is still very large [2], [3].

From the explanation of the background above, there are several problems related to health and dental care. The problems that exist include:

1. There is still low public awareness of the importance of dental care;
2. The availability of health workers in the dental and oral health sector is still very limited;
3. Dependence on imported materials for the manufacture of dentures;
4. Indonesia's human resources are still limited in procuring dentures; and
5. It takes a long time to manufacture dentures conventionally, resulting in high costs.

Apart from the conventional way of making dentures, there is also another way of making dentures, namely by 3-dimensional printing [3]–[6]. Making dentures with 3D printing using 3D modeling in several ways. Several studies have used data from CT scans in the form of DICOM files to be processed into 3-dimensional models in the form of STL files which will be used as files that can be read by 3-dimensional printers [2], [6]. For applications in the manufacture of dentures DICOM data can be obtained from the cone beam Computed Tomography (CBCT)[8-10].

3D modeling with data sources from CBCT is very limited due to the complexity and high cost of scanning tooth structure. The following is the flow for processing data obtained from CBCT in the form of a DICOM file which is then processed into an STL file which can be used as a file for printing 3-dimensional dentures [7], [11].



**Figure 1.** The flow of data processing from CBCT to a 3D model for 3-dimensional printing [4]

As explained above that there are some drawbacks to the use of CBCT, the idea arose to utilize the photogrammetric method to produce 3d designs for making denture prototypes with Digital light Processes (DLP) printers. Photogrammetry is that which includes measuring and interpreting images to obtain a shape and location of an object from one or more photos of objects. In principle, the photogrammetric method can be applied in any situation where the object to be measured can be recorded photographically. The main goal of photogrammetric measurements is to reconstruct a three-dimensional object in digital form (coordinates and derived geometric elements) or in graphical form (images, photographs, maps). The photo or image is a store of information that can be accessed again.

Photogrammetry, as a proof of concept, works on the principle of obtaining reliable information about physical objects through the process of recording, measuring and interpreting photographic images. Recently photogrammetry has been gaining interest in the field of dentistry. It can be used as a more cost-effective alternative for diagnosis, treatment planning and fabrication of surgical guides and in maxillofacial prosthetics [1]. Photogrammetry can be applied to the manufacture of dentures. Several studies have been conducted to examine the use of photogrammetric methods for making 3D models used for 3-dimensional printing [2], [14]–[17].

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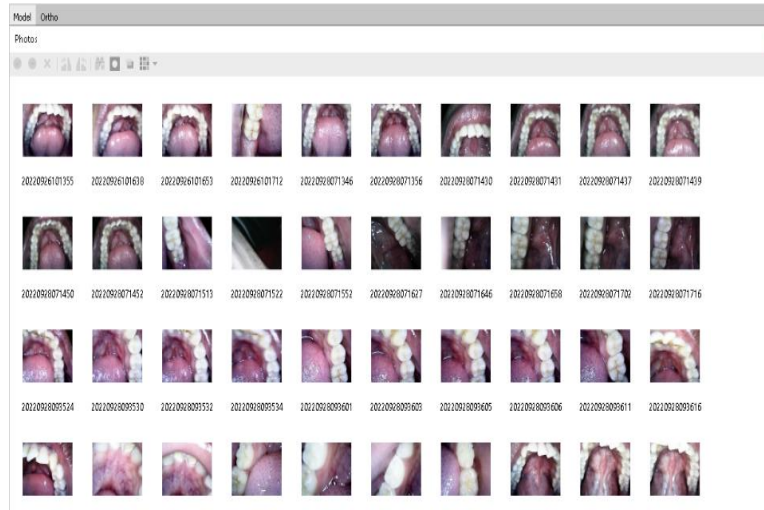
Photogrammetry has also been used in the field of dentistry to acquire digital models by taking intraoral and extra-oral images, and is also a very useful method for preparing and assessing the outcomes of maxillofacial surgery by providing a good soft tissue register.9 The digital camera was used to capture and record the images in this process. This article describes the use of a mobile phone camera to obtain 2D object images, and these images have been turned into a 3D digital model using free software, making it even more cost-effective [1].

## 2. MATERIAL AND METHOD

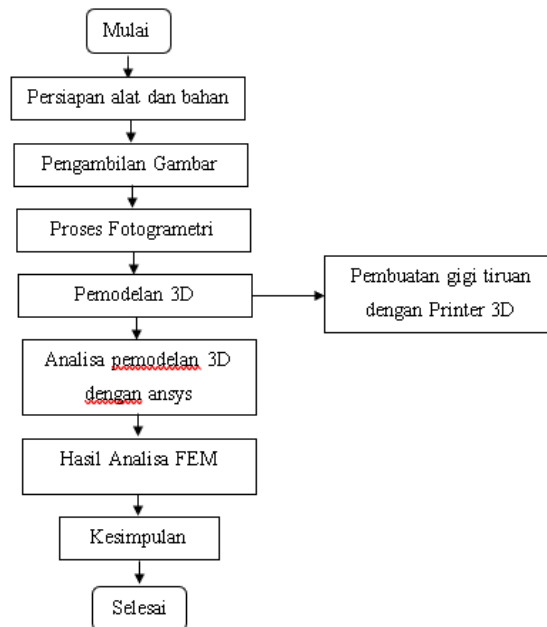
Photogrammetric 3d modeling involves hardware and software. The hardware used for data collection in this case is a 2D photo image. While the software is used to process the data into a 3-dimensional model.

### 2.1. Data collection

Data in the form of 2-dimensional photographs of the teeth to be made of dentures were taken using an intra-oral camera. The intraoral camera used was 2D images are taken from various angles, so they can be processed to form a 3D model.



**Figure 2.** A collection of 2D photographs taken from an intraoral camera  
 The following is the research flow:



**Figure 3.** Research flow

## 2.2. Intra-Oral Camera

This intra oral camera is a camera that can take pictures of human teeth. This tool is usually used by dental clinics or dentistry. The use of this intra oral camera is to make it easier for researchers to take pictures of human teeth to make dentures by taking as many photos as possible so that the results obtained are better.

## 2.3. Agisoft Metashape application

Agisoft is a software that can convert 2D images into 3D using several methods such as align photos, dense clouds, build mesh, build textures. In agisoft metashape is also a photogrammetric process of a collection of 2 (two) or more images so that the images can

become 3D images. The use of this Agisoft Metashape software can change 2D images into 3D images, can tidy up images from trash or stains in photos.

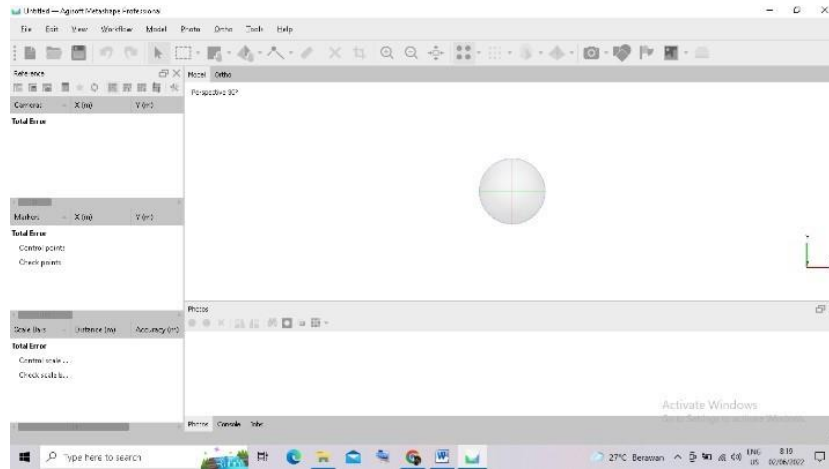


Figure 4. Agisoft metashape application

#### 2.4. Application Software

Blender is open source software for processing computer graphics in 3 dimensions. Blender can be used for 3D modeling, 3D animation, and 3D special effects. An application that functions to create 3D animation, visual effects, 3D objects.

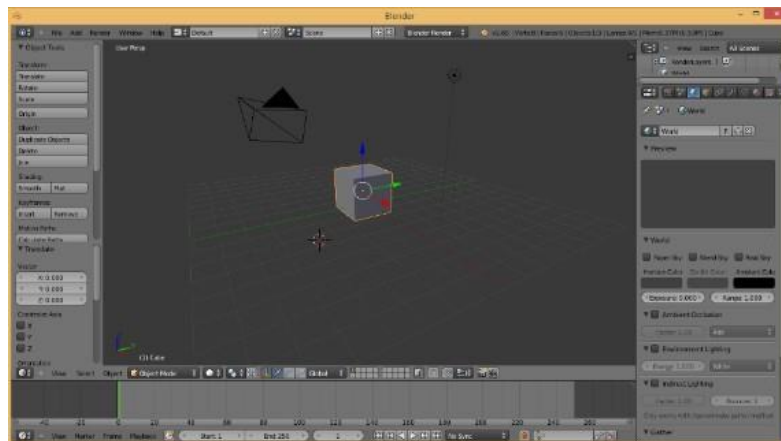


Figure 5. Software blender software

Ansys is a finite element analysis software with the ability to analyze a wide range of problems from very small elements, Ansys can analyze itself automatically.

The use of ansys student is that it can analyze a wide range, can mesh well, good stress results and total deformation.

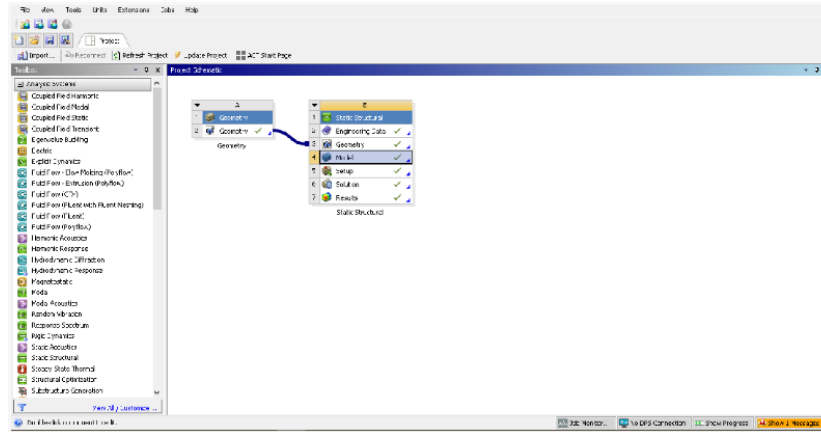


Figure 6. Ansys student software

### 3. RESULTS

Photogrammetry results in photogrammetry, the camera is one of the most important instruments, because the camera is used to make photos, which is the main tool in photogrammetry. Therefore, it can also be said that accurate photos (having high geometric quality) are obtained from careful cameras. In the shooting process, it requires several photos of 2 (two) or more. The more photos, the better and more perfect the results will be obtained.

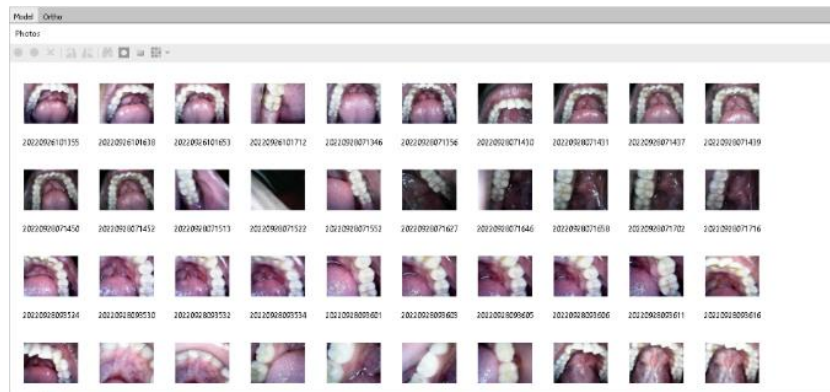
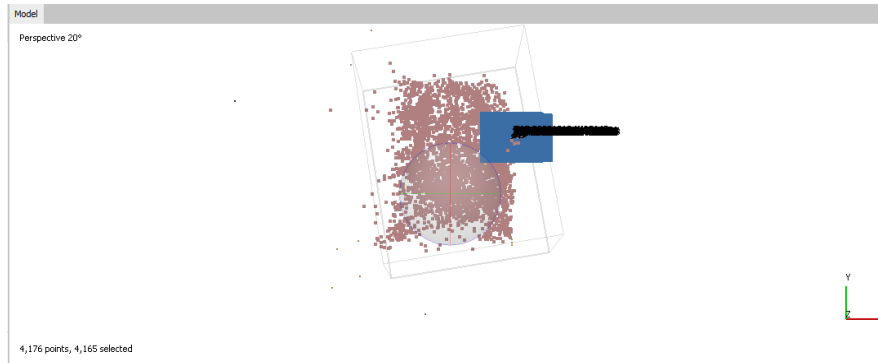


Figure 7. A collection of 2D photographs taken from an intraoral camera

#### 3.1. Align Photos Results

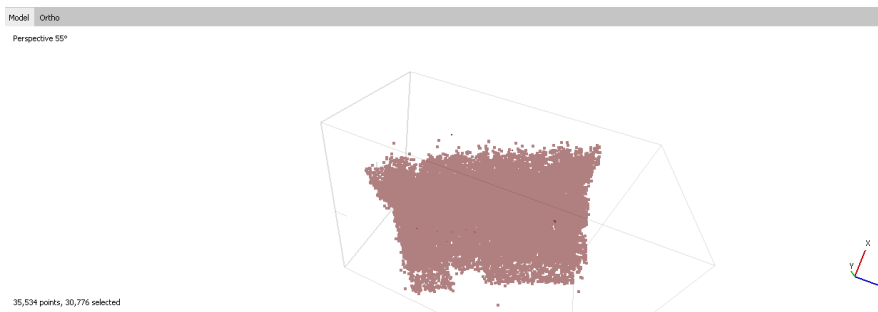
Align photos are a process used to identify the dots that appear in the image. This process, which combines matching points from 2 or more photos, can produce sparse point clouds and initial 3D models that will be needed at the stage of how to process 2D photos into 3D.



*Figure 8. Result of Align Photos*

### 3.2. Dense Cloud results

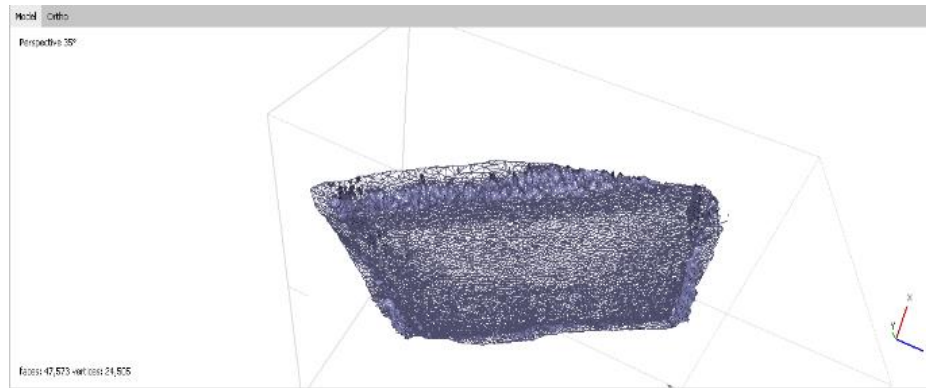
Dense cloud a collection of high points in the number of thousands to millions of points. Dense clouds can later be further processed to produce DSM, DTM and Orthophoto. The professional Agisoft metashape tool allows us to generate and visualize sparse point clouds into new, denser point clouds that are fixed based on the camera position Build dense cloud, this dense cloud build serves to clarify objects in aerial photography, especially cloud objects. The cloud object will appear as a cloud shadow.



*Figure 8. Result of Dense Cloud*

### 3.3. Result of Build Mesh

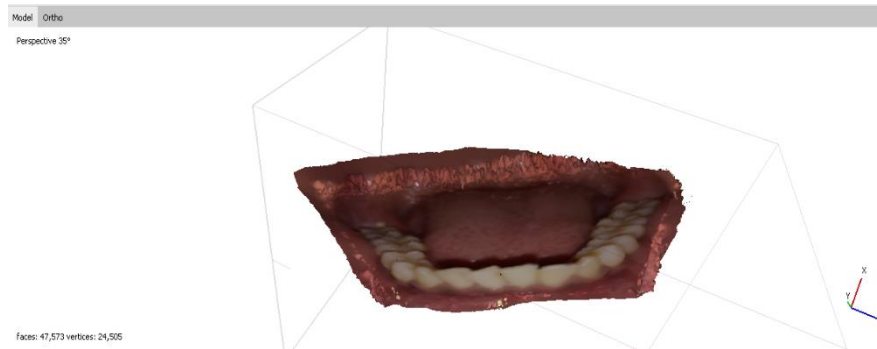
Mesh is a discretization of geometric space in the form of simple pieces such as triangles, quadrilaterals (two dimensions), hexahedrals or tetrahedrals (three dimensions). Meshes are used in various applied fields, such as geography, cartography, computer graphics, and are especially important in the numerical solution of partial differential equations. The creation of a triangular network (mesh) is at the core of any surface reconstruction program. An optimal triangulation is determined by measuring the angle, edge length, height or area of the element, whereas the error of the finite element approximation is usually related to the minimum angle of the element.



*Figure 9. Mesh result*

### 3.4. Build Texture Results

Textures can be defined automatically by selecting the image with the best visibility or manually by selecting the appropriate surface on the desired image. Build Texture is a 3D physical model of the appearance of the area covered by the photo, the process of building the texture itself is to give the texture the appearance of the resulting DSM, the result of this build texture is the appearance of the image in 3 dimensions.



*Figure 10. Build texture result*

#### 3.4.1. Results of mandibular denture models using agisoft metashape software

After carrying out several stages in the photogrammetry process by going through several methods, namely the Build Align Photos, Build Dense Cloud, Build Mesh and Build Texture methods. Modeling is in forming an object or object, creating and designing the object so that it looks like its original form. This whole process is done on the computer. Through the concept and design process, the whole object can be shown in 3 dimensions, so many call this result 3D modelling.

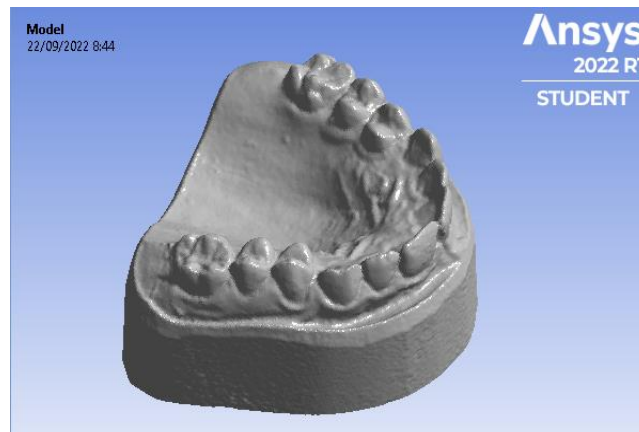




*Figure 11. Result of mandibular Denture model*

### 3.4.2. Results of the mandibular denture model in Ansys Student

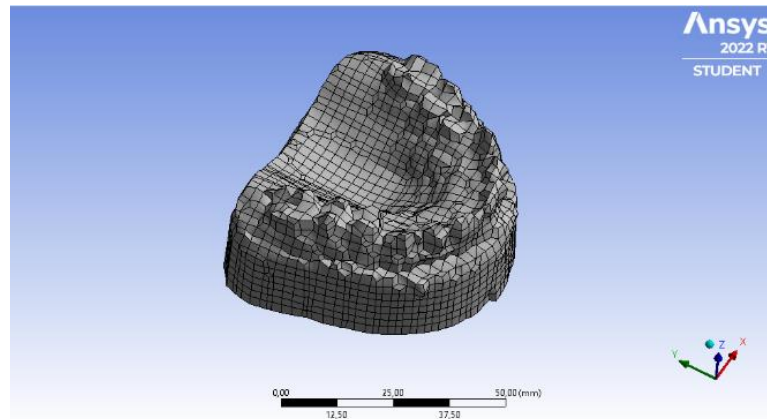
Before carrying out the analysis procedure, it is better to carry out the process of selecting orders in the structural statistics section with predetermined conditions and compressive strength that has been adjusted to strength.



*Figure 12. Mandibula models of Ansys Student*

### 3.4.3. Maxillary Denture Meshing Results

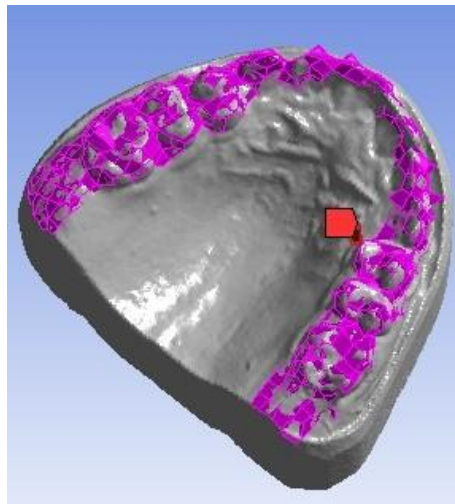
Before carrying out the simulation procedure, the meshing process is carried out first. The meshing process is an integral part of computer-assisted engineering simulation. Meshing affects the accuracy, convergence speed of the solution. The results of this meshing itself have 26445 nodes and 5525 elements with an element size of 2.5 mm. The results of the meshing process will be shown in Figure 13.



*Figure 13. Meshing*

#### 3.4.4. Results of the Best Mandibular Denture Model

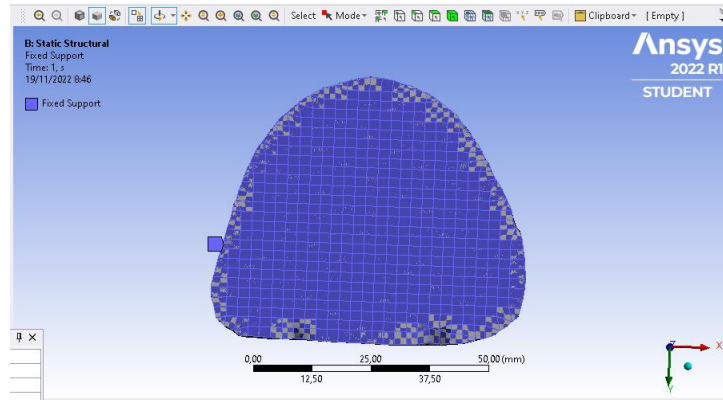
The best human mandibular design is the mandibular body design, because it has two good surfaces and two surface boundaries marked by a median line with a faint ridge. The inferior part of the body of the mandible has a curved and thick edge, which is a place of attachment. from the teeth.



*Figure 14. The best results of mandibular dentures*

#### 3.4.5. Support on the mandibular denture

Before carrying out the simulation procedure, a fulcrum process is carried out first on the part that will receive the compressive load. The process of giving support is the part that will get the results from engineering simulations assisted by computer processes.

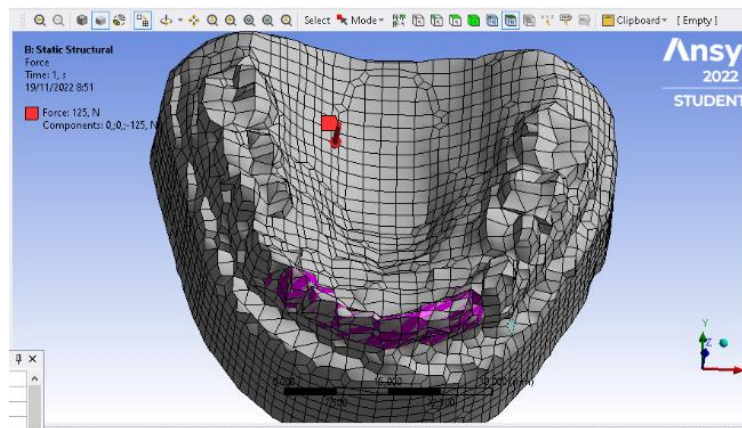


*Figure 15. The underside of the denture*

The part that is colored blue is the part of the pedestal that will hold it during the process of applying compressive loads with different loads.

#### 3.4.6. Loads on Mandibular Dentures

Before carrying out the simulation procedure, a compressive load is carried out first on the incisors. The process of applying compressive loads is a part that will get results from engineering simulations assisted by computer processes.

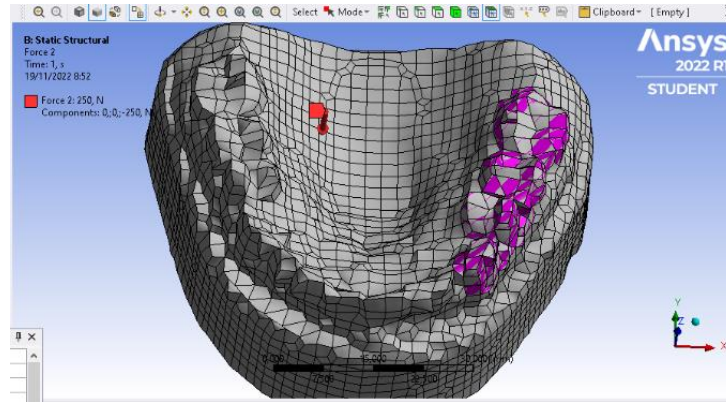


*Figure 16. Incisor Compressive Load*

The part that is colored pink is the part of the incisor that will be given a compressive load of 125N with a downward compressive force.

#### 3.4.7. Molar Section Load I

Before carrying out the simulation procedure, a compressive loading process is carried out first on the molar teeth or right gum. The process of applying compressive loads is a part that will get results from engineering simulations assisted by computer processes.

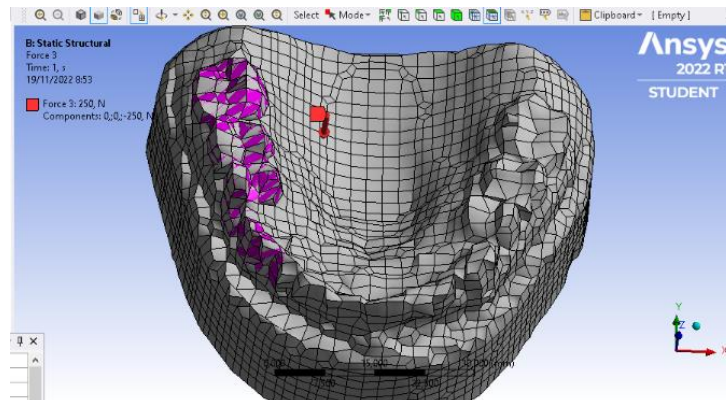


*Figure 17. Molar Compressive Load I*

After applying a compressive load to the incisors, the next step is giving a compressive load to the first molar which is shown in the pink image with a compressive load of 250N.

#### 3.4.8. Molar Section Load II

Before carrying out the simulation procedure, a compressive loading process is carried out first on the molar teeth or the left gum. The process of applying compressive loads is a part that will get results from engineering simulations assisted by computer processes.



*Figure 18. Molar Compressive Load II*

After applying a compressive load to Molar I, the next step is giving a compressive load to the molar II which can be seen in the pink image with a compressive load of 250N, the same as the compressive load to Molar I, the difference is where the compressive load is applied.

#### 3.4.9. Analysis of mandibular dentures

This mandibular design simulation uses the Ansys Student software which includes compressive forces and different types of designs by giving mandibular dimension specification values as shown below:

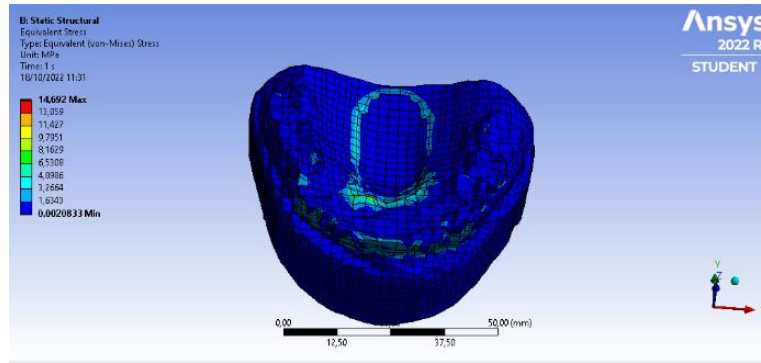


Figure 19. Analysis of mandibular denture results

The conclusion from the stress simulation, in the reddest part of the mandibular denture is the support rod which is slightly down due to the enormous pressure. With a maximum value of 14.692 Mpa in the blue part, that is, it does not affect the change in shape which is determined with a minimum value of 0.0020833 Mpa from the simulation results.

3.4.10. Test Results for Deformation of the Lower Jaw Dentures

After testing the deformation on the first specimen with a size of 80.00 mm. The compressive load results with time and the highest compressive load graph with a maximum value of 0.00046244 MPa are obtained as follows:

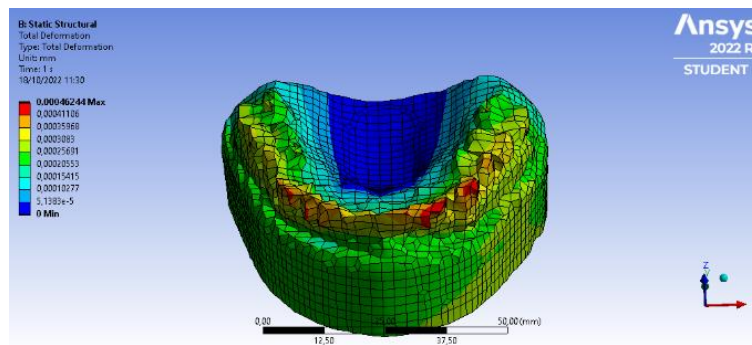
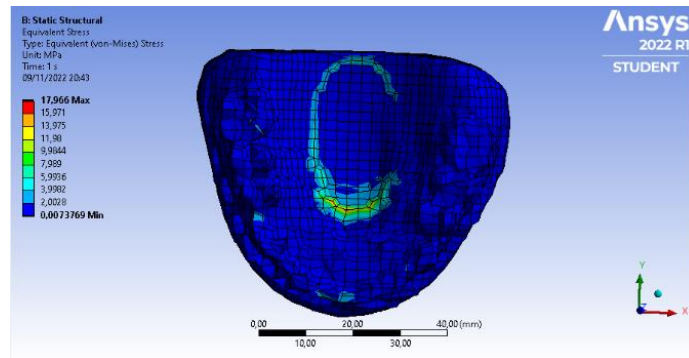


Figure 20. Deformation Analysis of the Lower Jaw Dentures

3.4.11. Comparison Results of Total Deformation Mandibular Dentures

From the simulation results of human mandibular dentures using a load of 50kg or 490N. The compressive load results with time and the highest compressive load graph of the total deformation with a maximum value of 0.0012004 Mpa and a minimum value of 0 Mpa can be seen as follows.



*Figure 21. Comparison of mandibular denture results*

#### 3.4.12. Results of Comparison of Equivalent Human Lower Jaw Dentures (von misses)

From the simulation results of human mandibular dentures using a load of 50kg or 490N. The compressive load results with time and the highest compressive load graph of the equivalent (von misses) with a maximum value of 28.389 and a minimum value of 0.0028582 Mpa can be seen as follows.

## 4. CONCLUSIONS

The conclusions in this studies are (1) the design of dentures / mandibles in humans can be generated using a photogrammetry system; (2) photogrammetry for making dentures using agisoft metashape software; (3) strength analysis of the structure with ansys shows the structure of the denture with PMMA material in the safe area.

## 5. ACKNOWLEDGMENT

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