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Design and simulation of Artificial arm

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Abstract: The shoulder joint is a complicated structure that can exist in the human body and performs momentary functions like lifting, holding, and throwing, which is necessary for better performance. The shoulder contains ball and socket structure for the rotatory motion and for the linear motion.
If this essential structure got damaged from some injury or from the rotator cuff tears, we need the same functional shoulder that can restore the same function. For that we designed a better ball and socket structure with more compatibility. Here, we created a 3-dimensional structure using solid works of the artificial shoulder which consists of the same ball and socket structure in the reversed direction. In this structure we have used Titanium -Ti-6Al-4V (titanium-aluminum-vanadium) as a material as its non-corrosive in nature and high tensile strength and durability.

We also calculated the material strength. And the safety which comes around the value 3. These results can reduce the pain and can lift the weight up to 300N. This operation depends on the body condition and response. This also has some disadvantages like infection, nerve damage and implant failure. We need qualified professional people to make this assembly for lesser risks.

1. Introduction

Artificial shoulders can be replaced by surgical method that involves the replacement of the damaged or diseased joint with reversed ball and socket structure. Here, we can see the natural shoulder structure in image 1 and the damaged structure with rotator cuff tear in image 2.

The normal image of the healthy person's shoulder is as shown below with all specifications that contains the humerus the arm bone with L-shape structure, Acromion the protective support structure that can prevent damage form the outsource. The clavicle is also called the collarbone that connects the shoulder as well as the neck spinal card. Lastly, the last scapula, the main shoulder blade that's the half part if the human body support for the better fixture **[1].**

Solid work is the best software to design and construct a better 3-dimensional image of model that can be easily recognize. In this solid work first, we designed the 2D model of the image and those 2D images are converted into 3D images by using the tool called extrude here we can extrude the worst variety of structures like circle rectangle square Polygon and except [2].

Furthermore, that design 3D model is then proceeded to cut down the extruded part into specific dimensions by using extrude cut.

2. Solid works

Solid work is the most effective way of designing 3-dimensional modeling. Moreover, it is the most sophisticated software where we can design a wide variety of structures like holes, thread, spring. Furthermore, we can also design curved surfaces and rectangular surfaces also lofted surface with the specific dimension. [4].

Here what we can do is once we design the two-dimensional image in the solid workwith this specific dimension, we are going to exclude those two-dimensional images into three-dimensional image by using the tool called extrude. Once we get the rough image and extrude that image into 3D structure, here we are again going to extrude cut the part unwanted part from the solid work.

Once we do this, then we successfully create one individual part of the whole structure. Furthermore, we are going to create the other part using the same idea with a different structure.The next part is going to extrude with a different idea of the same model. Here we're going to show me structural image of the four different shoulders structure that attaching together in order to create an artificial reverse shoulder joint.[7]. First and foremost, we create the humoral structure after three models using solid work. Here the humoral structure looks like an arm structure that's connected to a reverse shoulder joint cup. And this humorous structure is going to connect with the ball and socket structure.Moreover, these ball and socket structures havea minimum diameter of 50millimeter. [8]. This ball and socket structure uses the structure having a semicircularspear and that spear is attached to the humorous component which is structured as a circular cylindrical structure that connects scapula.

3. Assembly of the desighned part.

Once we create these different 4 structural designs as a 3D modeling, we are going to assemble these structures using the assembly tool by opening new part image in solid work.

Here the one humeral structure is inserted from the saved image. This humoral structure is going to be fixed.

Once this humoral structure is fixed, then we're going to insert the second part called glenoid structure. Here we use the tool called mate. This tool is going to help with coincident this surface I'm going to attach the two images into one image. Furthermore, again we insert the circular cylindrical structure called circular connector to the ball joint. Next, we're going to insert one more structure called scapula which is the bone structure. And we're going to use the tool again called mate in order to join the surface of the two different structures in order to make it together.

4. Type of design software

True dimensional image is an excellent type of modelling that can easily show deep structural image of the two-dimensional structure. Here we can use two different types of software in order to create a three-dimensional image. This two different software are mentioned below.

1. Creo parametric: this is one of the wonderful software where we can create avariety of structures with small changes in the tool. Creo- parametric is also a new version of creating a 3-dimensional image. There is not much difference between Creo parametric and solidwork.
2. Solid work: This is the extended new version where we can create the sophisticated image 3-dimensional image with the specific dimension by using the tool called extrude.

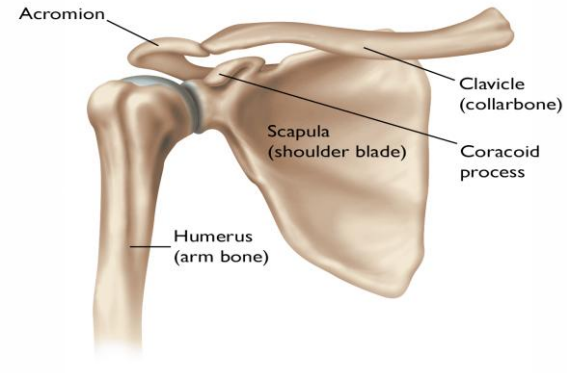
This two software do the same function with the different tool name. The purpose of usage of this software is the same.

5. Simulation

Simulation is the method that can test the strength of the material. In order to test the model, we need to provide material information. Then we are going to give the specific type of connection called bonding or penetration type of connection in order to make it bonded. Once these bonding happened then the model material is ready to apply the fixture.

Once we provide the fixture to one end in order to make it fixed. Once it is fixed there will be no movement of that material, we are making all three parts fixed except humerus part. Other than that, the glenoid sphere, scapula and the connector to the scapula are all fixed. Afterwards are going to study the static study like stress and strain of the material by applying the force on the other end in the reverse direction in order to study the deformation of the material.

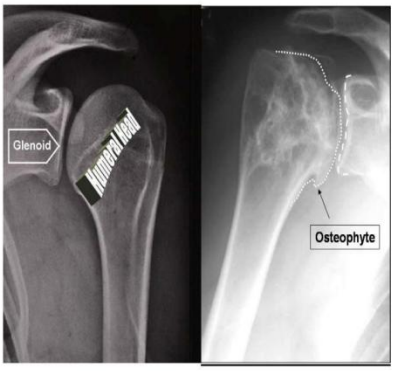
We are going to show the image of the complete shoulder structure with all specific names with proper dimensions. As mentioned, the average dimension of the glenoid diameter is 50 millimeters.



Picture 1- Normal human shoulder structure

The above image is the schematic representation of the normal and healthy image of the shoulder joint with the specific name.The normal image of the healthy person’s shoulder is as shown above with all specifications that contains the humerus the arm bone with L-shape structure, Acromion the protective support structure that can prevent damage form the outsource. The clavicle is also called the collarbone that connects the shoulder as well as the neck spinal card. Lastly, the last scapula, the main shoulder blade that’s the half part if the human body support for the better fixture.

Figure 1a: NORMAL SHOULDER JOINT Figure 1b: ARTHRITIC SHOULDER JOINT

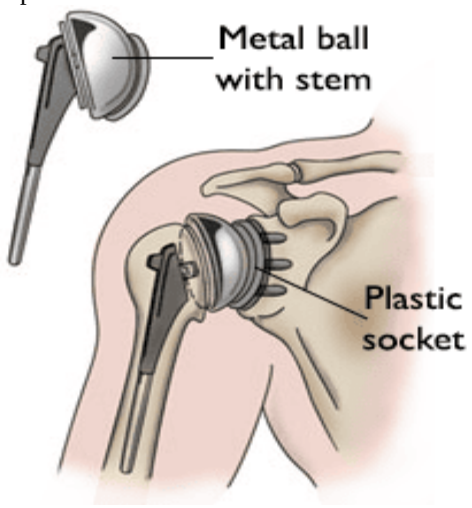


Picture-2- different image of the heathy and damaged shoulder

In this picture, the first image is the normal person's humeral and glenoid structure. [2]. And the second image is the damaged structure of the person's shoulder with osteophyte disease. For this kind of situation reversed ball joint structure will be the excellent way to make it work.

6. Solution for the damage:

In order to replace that osteophyte, we show the supportive image from the reference of the American academy of the orthopedic surgeon genial. That shows both conventional shoulder replacement in pic 3 as well as reversed shoulder replacement in picture.

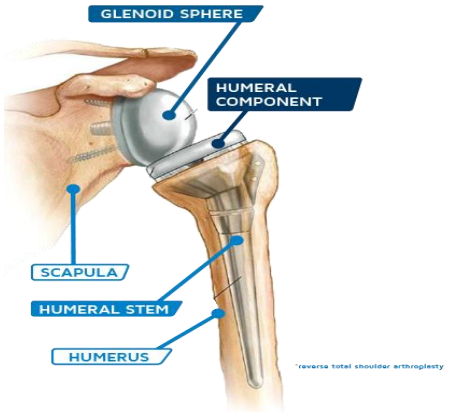


Picture-3 conventional artificial shoulder joint

The shoulder contains ball and socket structure for the rotatory motion and for the linear motion. If this essential structure got damaged from some injury or from the rotator cuff tears, we need the same functional shoulder that can restore the same function. For that we designed a better reversed ball and socket structure with more compatibility.[9]. In order to prevent further damage, we use reverse shoulder glenoid structure for the function. The below image shows the reverse ball and socket structure for damaged rotator cuff tears.

These two types of surgery can be used for two different variety of problems like:

1. For any accidental part repair where the rotator cuff functions well, we need only conventional artificial shoulder which looks exactly like a shoulder joint. Explained in figure 3.
2. However, if the rotator cuff of the person was torn then the conventional way is not going toward, for that we need to use the reversed shoulder joint, explained in figure 4.

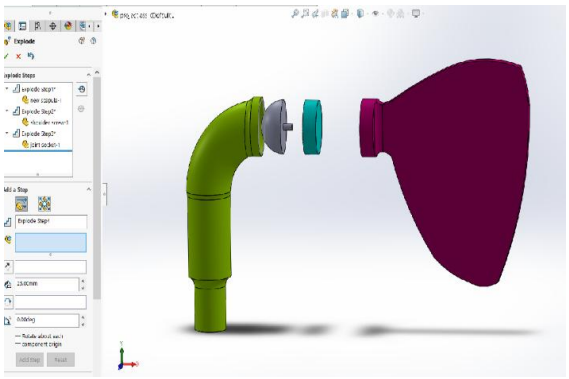


Picture-4 Reversed artificial shoulder joint

7. Methodology of the detail design.

For better rotatory movement reversed shoulder replacement is the excellent way of treatment as if the rotator cuff tendons are drastically damaged and cannot the repaired further. The main methodology of this project is to design and calculate the structure of the appropriate model and that is divided into four parts:

1. Humerus (Arm bone)
2. Glenoid spere (Ball joint)
3. Circular connector to the ball joint
4. Scapula structure



Picture-5 assembly of the Reversed artificial shoulder joint

Four different color explains the four variety of individual parts.

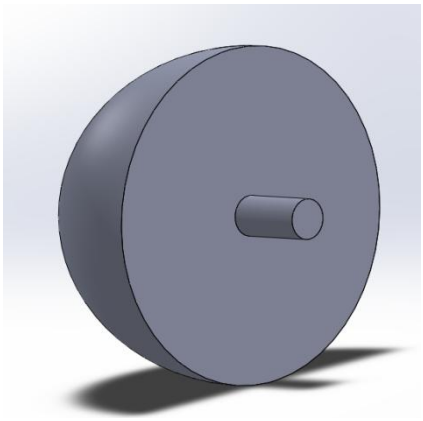
1. Humerus (Arm bone)

This is the main part of our solid work structure. Where this humeral used for testing the simulation of the assembly by applying the force of 10N. After we apply the force, we are going to study the stress and strain of the material. Once we apply run, we can also see the deformation of the titanium material.

Picture-6 humeral solid structure.

2. Glenoid Spere (Ball joint)

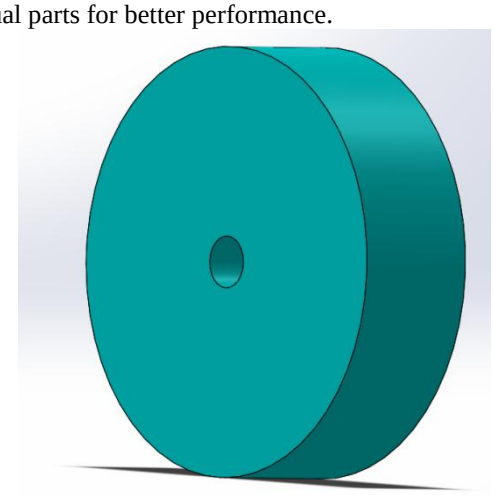
This is the rotator part of the shoulder where the strength of the material stays. Here, glenoid is the ball and socket structure. We used reversed ball and socket structure for rotator cuff tear.



Picture-7 glenoid solid structure

3. Circular connector to the ball joint

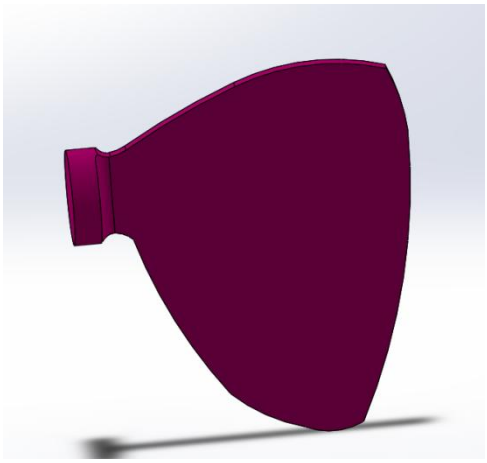
This is the connecting part for both the glenoid and the scapula structure. Here, we use bone cement for the better bonding of all individual parts for better performance.



Picture-8 Circular connector to the ball joint

4. Scapula structure

This is the human scapula structure designed in solid works. Here, this part is fixed and gave the material of titanium as this material is non- corrosive and with high tensile strength, these materials are bonded together with the help of liquid called bone cement.



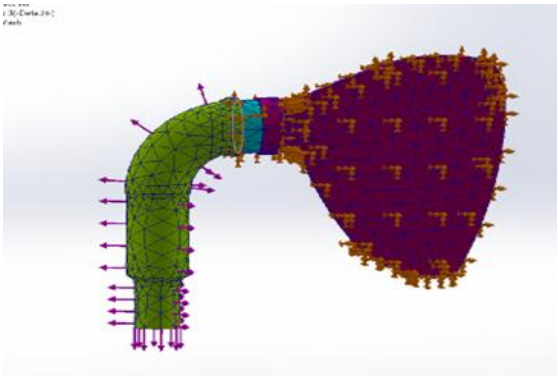
Picture 9—scapula strucure desighned using solid works

8. FEA of the model

The below picture 10 shows the fixture and the force applied direction and the schematic representation of the 3-dimentonal design. Here we gave titanium alloy as the material to the model in order to check the stress and the deformation of the material.

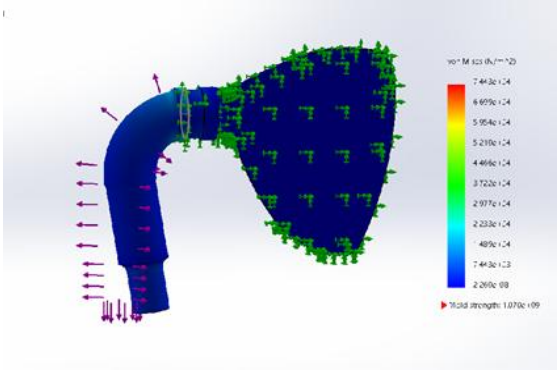
Moreover, we fixed the three models of the assembly component like glenoid sphere, circular connector and the scapula structure for better results. Then, we use Titanium-reinforced composites with calcium phosphate as bone cement content close to natural bone were developed. We used this bone cement for better bonding.

Then we applied force of 5N in order to check the stress and deformation. Furthermore, the results are mentioned in the below picture of 11 and 12.

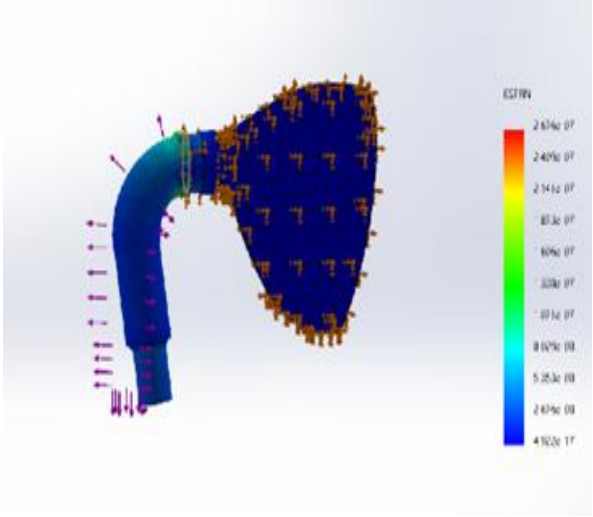


Picture 10- schematic representation of the applied fixture and force in simulation

Here picture 11 describes the stress distribution of the material. The yield strength of this material is 1.07x10^4. For that material safety is also calculated and the result is 2.5. Now the maximum material strength can be calculated, and the value is 128.67N/m^2.In the picture below we received the strain of 4. 9.



Picture 11 stress distribution of the material after deformation.



Picture-12 strain of the material

Simulation result: Picture 11 and picture 12 describe the deformation of the shoulder joint when we applied the force in the reverse direction with the value of 5N. Then after the applied force,the joint is going to bend towards the scapula. This is the deformation result of this experiment.

9. Calculation:

The average radius of curvature of the humeral head is 24± 1.2.
Therefore, R=25.2mm

Equation 1:

Area of semicircle = 1/2(π. R^2) where: r = radius of the humeral
=1/2(9.8 x 25.2^2)
=3111.69mm^2

A=3.11m^2

Equation 2

Force exerted by the arm is calculated as:

F= m × a
=1kg × 1m/s

F=10N

However, maximum force that can exerted by amen arm is F= 300N

Equation 3:

Stress of the titanium material=

$\sigma = {}^{F}/_{A}$ where F= max force
A= area of semicircle
=300N ÷ 3.111m^2

σ =128.65 N/m^2

Equation 4:

Torque of the arm when the rotation occurs:

$$\tau = rF \sin\theta$$

= 25.2×400×sin 90

τ=10K-kg-m^2 s-2

Equation 5:

Factor of safety:

FOS= material strength / yield stress where: safe stress in FEA=42 N/m^2
= 128.65 N/m^2 ÷ 42 N/m^2

FOS=3.06 that means, Titanium material is safer to use.

10.Conclusion:

1. The reverse ball joint method will be an excellent way of fixing the rotator cuff tear as it cannot be operated if the tendons of the shoulders are not supporting the conventional method of surgery.
2. The 3-dimensional design could explain the way better than the schematic representation of the artificial shoulder.
3. Finite element analysis provides the safety factor of 3.06 as it is safer to use these materials inside the human body for any sort of shoulder injuries.
4. This also has some disadvantages like infection, nerve damage and implant failure.
5. We need qualified professional people to make this assembly for lesser risks.

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