Design Project 2 – Hips Don't Lie

On the Hip Side

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 3

Team 30

YOUSIF FADHEL (fadhely)

OLIVIA GABRIEL (gabrielo)

RYAN LIU (liu1719)

CINDY CAO (caoc30)

Submitted: December 8, 2022

Course Instructors: Dr. McDonald and Dr. Sask

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Ryan Liu 400469017

(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Olivia Gabriel 400440754

(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Yousif Fadhel 400434747

(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Cindy Cao 400477327

(Student Signature)

Main Body

Summary of 3D Printing Process

Yousif Fadhel

There were a variety of limitations that needed to be addressed to ensure that the 3D printing operation proceeded smoothly. Ensuring that the parts are oriented on Prusa Slicer in a manner that provides optimal foundational support for the 3D printing procedure is imperative to a successful print. For our specific case this involved directing holes upward whenever they were present in parts such as in our ball component. Additionally, in order to meet the time restrictions placed upon us we had to reduce our print quality by 20% as this drastically decreased print time while maintaining in overall high quality of print. Furthermore, the distance between the objects on Prusa Slicer will also dictate the time of print and it is important to have the objected relatively centered and within the smallest distance from one another that will not result in any cross-interference.

Olivia Gabriel

When 3D printing, there is a lot of planning that goes into the setup of the pieces on the board and the supports. During The printing process we learned that it is necessary to keep all parts away from the edges of the board for the recognition of the printer. After trying to print our implant stem the first time, the print failed as the piece was too long. To fix this we scaled down the design and moved it to the centre of the board away from the edges. We also learned that it is necessary to print with holes facing up so that they are not filled in with supports. To optimize time, we found that scaling down our design in the slicer program was the most effective but choosing the print orientation with the least number of supports is also a possibility to reduce printing time.

Ryan Liu

The necessary adjustments made to CAD models address 3D printing limitations such as print time, chance of failure, and print resolution. Models were often scaled down to 40-70% of their original size to ensure that the print time was under 2 hours. Scaling the models down has a significant effect on how the individual components fit together. We utilized pegs and holes to connect pieces together but despite having the exact same dimensions, pegs would not fit into their respective holes when printed. A design consideration to remedy this issue is to make the peg slightly smaller in diameter to account for printing impreciseness at lower small scales. We had one of our prints fail when the initial layer of filament peeled off. By orientating components close to the center, this type of failure is less likely to happen.

Cindy Cao

The limitations of 3D printing required consideration of many factors, including part size and orientation. Since the stem piece was so long, we scaled down the implant and oriented it as far from the edges of the printing bed as possible. Decreasing the dimensions, however, resulted in some loss of detail, especially for our specific stem cross section. On the bright side, downsizing led to reduced printing time, as did choosing an orientation with minimal supports. Less supports and proper spacing eliminated interference and the need for excess material to be printed. Additionally, we discovered that orienting holes upwards prevented them from being filled with supports. In retrospect, we had to make many design changes to accommodate for 3D printing constraints, which opened our eyes to the many improvements that can still be made.

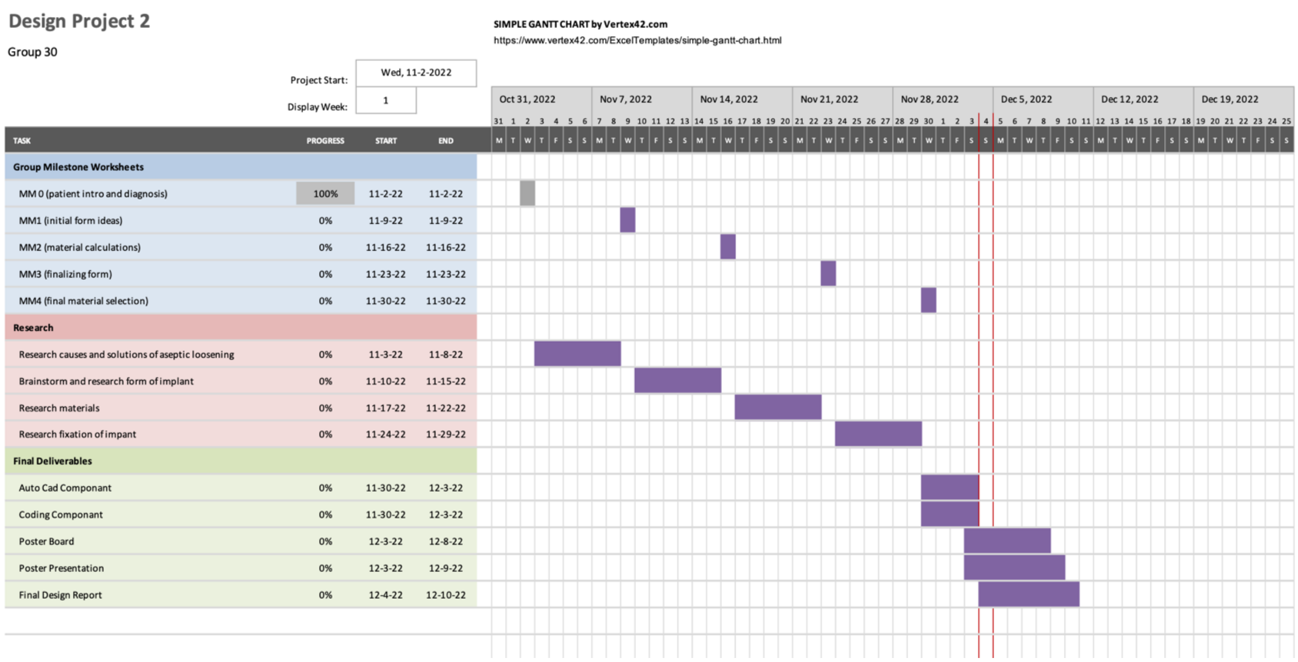
Summary of Contributions

Task	Yousif	Olivia	Ryan	Cindy
Final Design of AutoCAD Model			X	
Computing Troubleshooting	X			X
Posterboard Info (Fixation)	X	X		
Posterboard Info (Stem)	X			
Posterboard Info (Bearing)				X
Poster Diagrams and Figure Captions		X		
Poster Board Assembly		X		
Posterboard Layout		X		X
Report Layout and Formatting		X		X
Report Images and Captions		X		
Additional Information and Implant Measurements	X		X	
Presentation Script	X	X	X	X

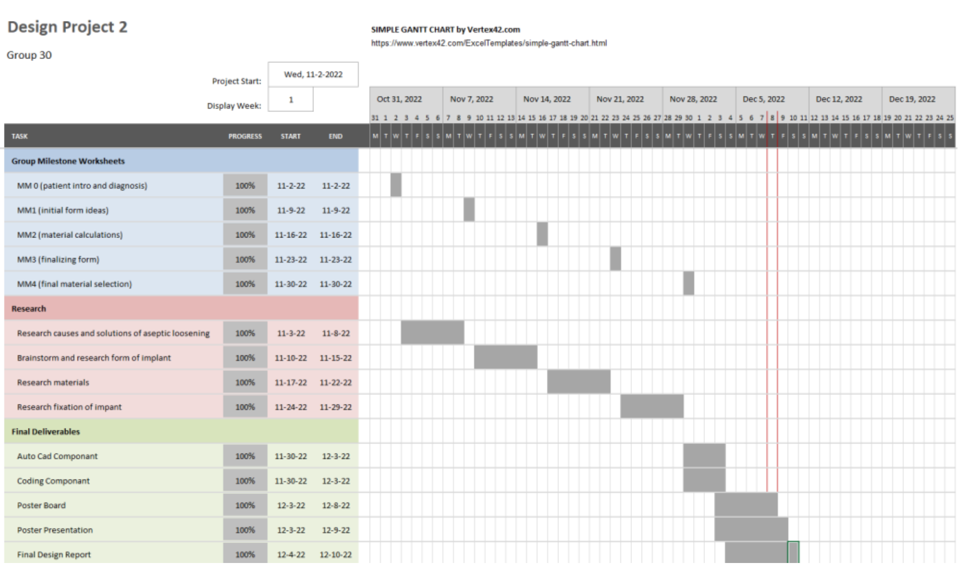
Appendices

Appendix A: Project Schedule

Preliminary Gantt Chart:



Final Gantt Chart:



Appendix B: Scheduled Weekly Meetings

Weekly Design Studio Agendas

November 9, 2022:

1. How can we improve our preliminary Gannt chart?
   - Do the dates look like a productive timeline?
   - Does it need more detail/ is it formatted correctly?
2. What was part of our need statement was worded awkwardly? How should we improve it for the final report?

November 16, 2022:

1. How important is it that our implant stands out from the rest of the class? Does each part need to be unique?
2. At what point should we begin prototyping/ in AutoCAD/ how long does that process usually take?
3. Discuss/ finalize shape of implant.

November 30, 2022:

1. Does the outside of our implant need to be coated if it cemented into the bone?
2. How do we model a cemented implant on AutoCAD?
3. Should lifestyle changes for our patient be included in the poster board?
4. Decide on our materials.
   - What materials will prevent further aseptic loosening
   - Should our implant be cemented?

December 7, 2022:

1. What is the best possible to split the presentation between group members?
2. Are there any changes that need to be done to the final copy oof the poster board (font size/ layout)?
3. Print our final poster design and assemble.

Meeting Notes

November 9, 2022:

- Need statement:
  - Content was all right
  - Word it better
    - Group ideas into smaller subgroups
    - Idea 1: what we want to do.
    - Idea 2: what is our patient's condition and what that means.

      - Idea 3: why are we doing it?
- Sketching:
  - Arthroplasty revision
    - Looking at it with a materials lens
  - Common ideas:
    - Longer stem
- Reminders:
  - Consider key details
  - Not all parts have to be novel.
    - Novelty can come with materials
      - Microstructures
      - Surface coatings
- For modelling team:
  - Most complex feature is graded.
  - Changing textures can represent varied materials.
  - Printing time is strict
    - Scaling can help with time
  - Gluing is allowed when putting components together
- For both teams:
  - It is required that both teams print as to get a better understanding for how it works
- Task action items:
  - Look ahead to future milestones

<u>November 16, 2022:</u>

- Innovation/creativity:
  - Level 4 is very hard and not achieving it does not necessarily mean that you did a bad job
  - Structure, materials, etc. There are different ways to be innovative.
- Suggestions for Ke:
  - Design that makes loosening occur less
    - Structure can't achieve that so it will look like a normal implant
    - Materials might be able to achieve that
  - Looking at one specific part of the implant
    - The part that is most relevant to our patient
    - Not every aspect has to be innovative
    - All right to solve the problem by looking at one part of the implant
  - Novel material:
    - Not creating new material
    - Taking existing materials "further"
    - Combinations of materials
      - Example: Material A and some microstructure
- Prototyping
  - Prototype ASAP
  - Look into how implants can be modelled in CAD
    - Use the given files for the patient's bones
  - Less stiff material will keep bone density
- Task action items:
  - Begin prototyping design
  - Complete individual material milestones

<u>November 30, 2022:</u>

TA Meeting:

- Modelling materials
    - Just model implant and show materials visually
- Posterboard:
    - Should be aesthetically pleasing
    - Presentation:
        - Include additional information as a sidepiece. May not be able to present all knowledge due to time constraint.
- Patient lifestyle changes
    - Mention further surgeries for the patient

Dr. J:

- Consider loosening on the acetabulum
    - Wear and tear of head and neck
- Address possibility of an allergic reaction
    - See what the previous material used is
    - Allergic to polyethylene?

<u>December 1, 2022: 2:30 Printing Session 1:</u>

Meeting summary:

- Sub team 1 printed model
- Task action items:
    - Start on posterboard

<u>December 2, 2022: 2:30 Printing Session 2:</u>

Meeting summary:

- Determined posterboard layout
- Worked on posterboard content
- Sub team 2 printed model
- Task action items:
    - Complete and print posterboard content
    - Finalize subteam work

<u>December 7, 2022</u>

- Modelling:
    - Just need assembly file to show what it looks like.
    - Does not have to be fully constrained
- Report:
    - Check rubric to see what is taken out.
- Task action items:

- Assemble posterboard
- Rehearse presentation

Appendix C: Comprehensive List of Sources

Preliminary Research

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Materials Selection

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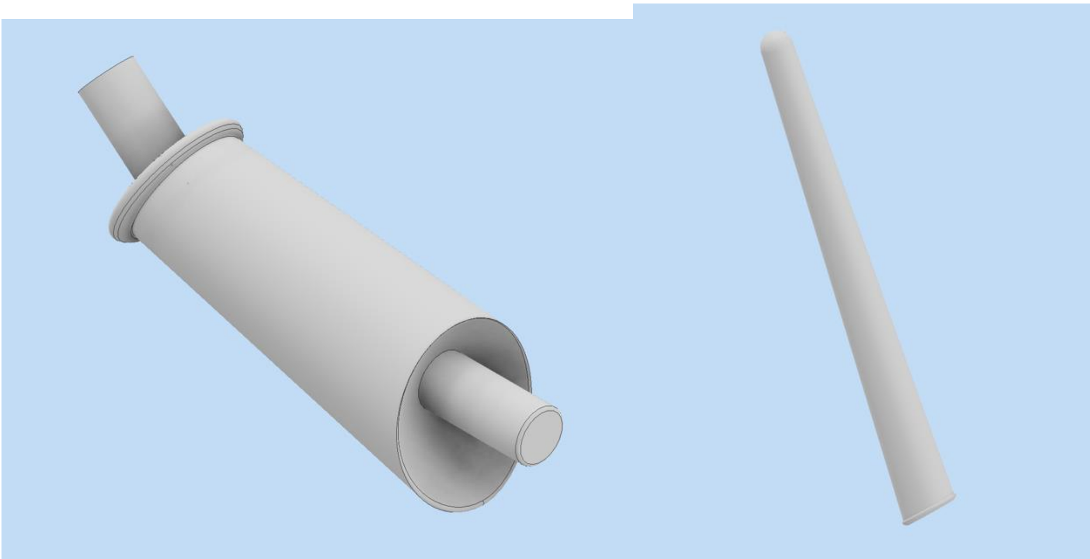
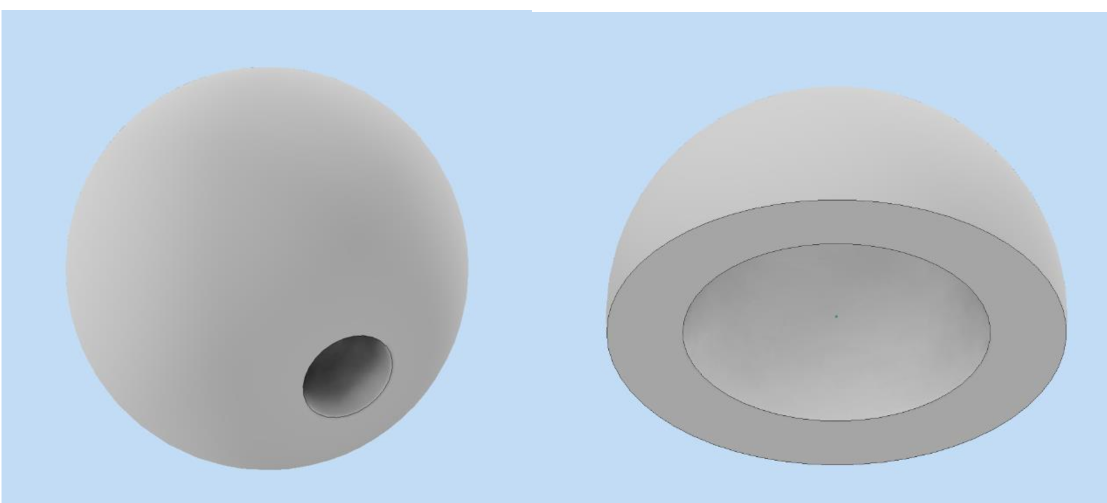
Appendix D: Additional Documentation

Prototype Iteration

Iteration 1:





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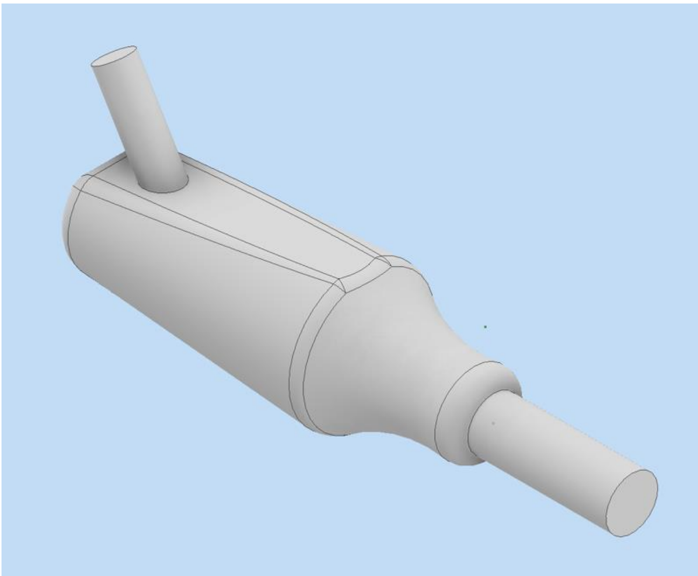

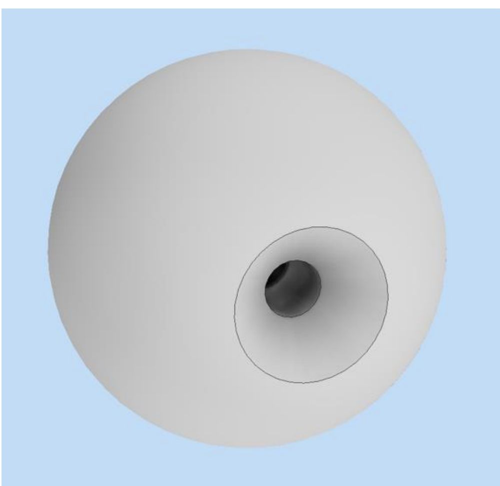

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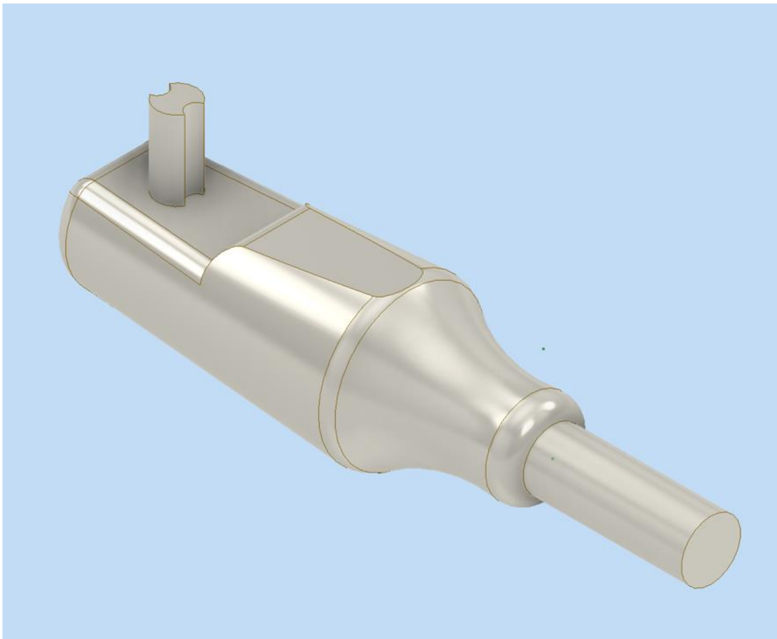



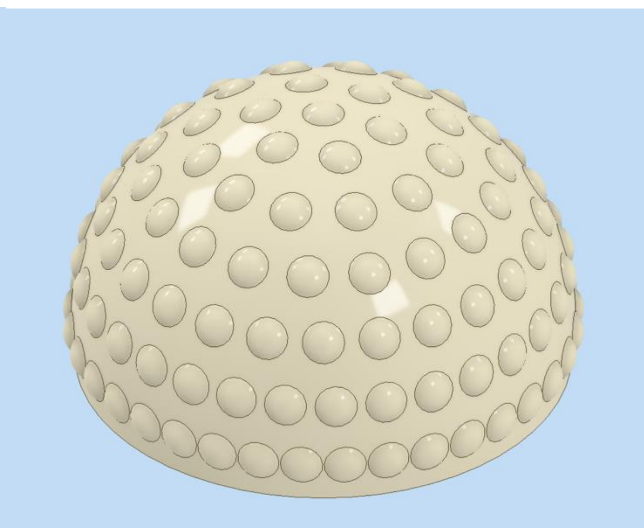

First iteration of 3D model. Test of the connection between bearing and stem. Printed by sub-team 1.

Second iteration of 3D model. Test of the connections between the stem pieces. Printed by sub-team 1.

Final 3D model of hip implant. Printed by sub-team 2.

AutoCAD Model

Measurements:

Diameter of ball: 41 mm

cylinder 1 (upper bone): diameter = 27.3mm, angle = 10.95 deg below x-axis, height = 69.3mm

Stem:

height right = 215 mm

diameter small = 18.67mm

large diameter = 38.55mm

angle left = 113.22 deg ccw

right = 117.27 deg ccw

27.27 deg from bottom angle from bottom

Left line = 206.56

Hole:

diameter = 10mm

18 mm deep

9.8 27.1

24mm from end

6.6

Appendix E: Design Studio Worksheets

Design Project Two Milestone TEAM Worksheets

Milestone 0 (Team) – Cover Page

Team Number: 30

Please list full names and MacID's of all *present* Team Members.

Full Name:	MacID:
Yousif Fadhel	fadhely
Olivia Gabriel	gabrielo
Ryan Liu	liu1719
Cindy Cao	caoc30

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-2 grade.

Please attach your Team Portrait in the dialog box below.

MILESTONE 0 – TEAM CHARTER

Team Number: 30

Incoming Personnel Administrative Portfolio: Prior to identifying **Project Leads**, identify each team members incoming experience from previous design projects.

	Team Member Name:	Project Leads
1.	Olivia Gabriel	☐M ☐A ☒C ☐S
2.	Yousif Fadhel	☐M ☐A ☐C ☒S
3.	Ryan Liu	☐M ☒A ☐C ☐S
4.	Cindy Cao	☐M ☐A ☒C ☐S
		☐M ☐A ☐C ☐S

To 'check' each box in the Project Leads column, you must have this document open in the Microsoft Word Desktop App (not the browser and not MS Teams).

Project Leads: *As a team*, come to an agreement on who will take the lead on each administrative task. Each role can only have one team member. In the event there are 3 students in a team, there will be no Subject Matter Expert

Role:	Team Member Name:	MacID & Signature
Manager	Olivia Gabriel	gabrielo
Administrator	Yousif Fadhel	fadhely
Coordinator	Ryan Liu	liu1719
Subject Matter Expert	Cindy Cao	caoc30

MILESTONE 0 – TEAM CHARTER

Team Number: 30

***Project Sub-Teams**:* Identify team member details (Name and MACID) in the space below..

Sub-Team:	Team Member Name:	MacID
Computing	Cindy Cao	caoc30
	Yousif Fadhel	fadhely
Modelling	Ryan Liu	liu1719
	Olivia Gabriel	gabrielo

*For a team of 5, we **strongly** recommend **3 students be placed on the computation sub-team**

Milestone 1 (Team) – Cover Page

Team Number: 30

Please list full names and MacID's of all *present* Team Members.

Full Name:	MacID:
Olivia Gabriel	gabrielo
Ryan Liu	liu1719
Yousif Fadhel	fadhely
Cindy Cao	caoc30

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-2 grade.

MILESTONE 1 – PATIENT DIAGNOSIS

Team Number: 30

1. Document all pertinent information related to your assigned patient in order to create a **PATIENT PROFILE**.

SYMPTOMS:	- Shortness of breath - Gait disturbance - Severe hip pain at the joint
IMAGING INDICATORS:	- Implant goes deep into the femur - Implant itself remained the same from 5-7 years - Notable decrease in bone density around the implant in those 7 years
PREVIOUS MEDICATIONS / DOCTOR VISITS:	- Has end-stage arthritis in left hip - OTC anti-inflammatories - OTC painkillers - Naproxen (220mg as needed) - Motrin (800 mg as needed)

MISCELLANEOUS NOTES:	- Put on weight after quitting smoking
	- Overall health is less than optimal
	- Unable to lose weight
	- Possible reason for pain: infection of the joint
	- Increase of weight as a result of diet could further stress the arthritis
	- Loss in bone density factors:
	    o Smoked in the past
	    o Bad diet
	    o Rheumatoid arthritis
	    o Anti-inflammatory medication
	
	Question for Guest Radiology Experts:
	- Ask about the differences between photos
	- Ask about infections in the artificial joint and how they are caused
	- Older/ weaker bone density??

Bone in 7 year is less dense

Smoking effect on bone health
Inflammation
Medications affect on bone health
Less dense bone around implant
Type of material can cause aseptic loosening
Design

- Longer stem
- Circled wires (to promote bone structural integrity)

2. Record your final diagnosis in the space below.

FINAL DIAGNOSIS: **Periprosthetic Osteolysis (aseptic loosening)**

** You must verify that your diagnosis is correct before you leave

MILESTONE 1 – OBJECTIVES AND CONSTRAINTS

Team Number:	30

As a team, identify a list of objectives, constraints, and functions for a proposed design solution. Your list should:

→ Focus on your assigned design challenge

→ Be comprehensive enough to fully define the given problem

OBJECTIVES	*List each objective as a separate bullet, add more if needed* • *Maximize lifespan of replacement* • *To relieve hip pain* • *Permits patient to be more active* • *Provides full range of motion* • *Increase flexibility in hip*

CONSTRAINTS	*List each constraint as a separate bullet, add more if needed* • *Must be sterile* • *Must not further deteriorate bone* • *Must support patient's weight* • *Material of implant needs to be biosafe and inert*

MILESTONE 1 – NEED STATEMENT

Team Number: 30

Need Statement

Write your Need Statement in the space below. Recall that your need statement should:

→ Have a clearly defined problem (*what* is the need?)

→ Indicate your end-user (*who* has the need?)

→ Have a clearly defined outcome (*what* do you hope to solve and *why* is it important?)

NEED STATEMENT:	Design a long-lasting hip replacement for Ke Huy-Quan that prevents bone deterioration and supports his body weight, as Ke's condition of periprosthetic osteolysis renders his current prosthetic ineffective, to relieve pain and allows him to move freely.

Milestone 2 (Team) – Cover Page

Team Number: 30

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Olivia Gabriel	gabrielo
Ryan Liu	liu1719
Yousif Fadhel	fadhely
Cindy Cao	caoc30

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MILESTONE 2 (STAGE 2) – DESIGN FEEDBACK

Team Number: 30

Document design revisions in the fields below for each team member's proposed concept solutions:

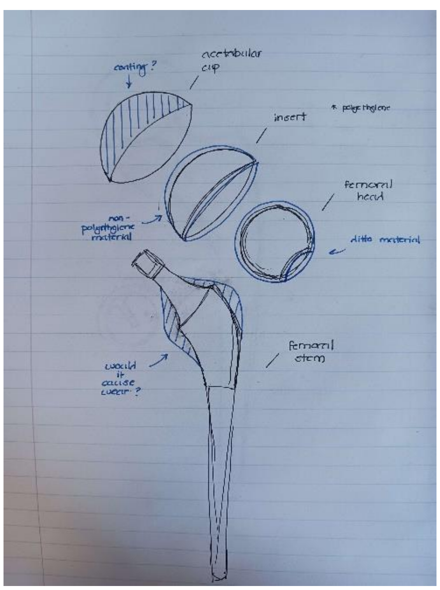
→ You can communicate your design revisions either by annotating directly on your team member's sketch or listing bullet-point descriptors

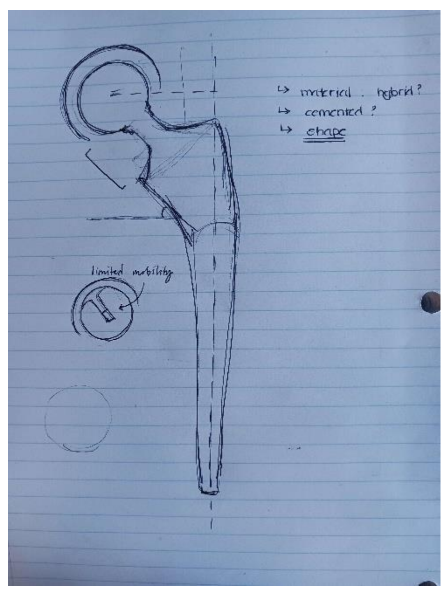
- If annotating directly on a sketch, save your file as a JPEG
- Insert your photo as a Picture (Insert > Picture > This Device)
- **Do not include feedback for more than one team member per page**
    - For each additional team member, copy and paste the table below

Design Feedback Entry

Your Name:	Cindy Cao
Your MacID:	caoc30

Design Feedback:





Yousif's feedback:

- Intrigued by your comments on the limitations of mobility of the femoral head. Design could impact the patient's range of motion

- Coating is a novel idea that could potentially reduce aseptic loosening due to erosion depending on the material used

Olivia's feedback:

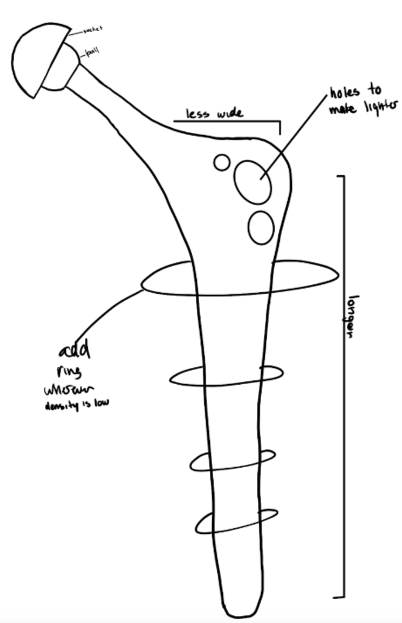
- Cup and insert design is innovative
- Good material ideas
- I like the blue part of the sketch; very unique

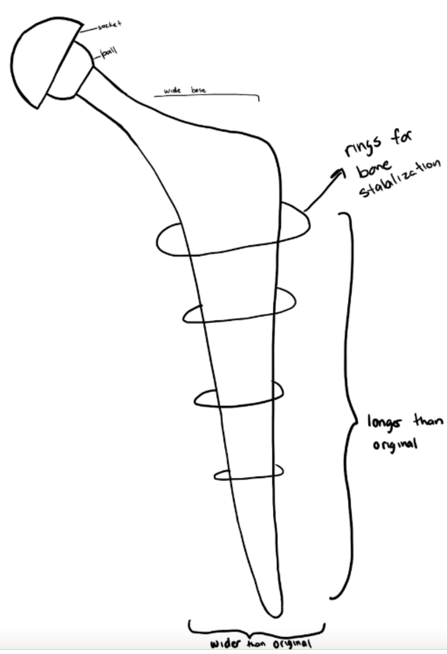
Ryan's feedback:

- Good consideration about how the shape of the prosthetic could cause wear onto the bone.
- How might we make it so the prosthetic securely attaches to the lower part of the patient's femur. Is this more difficult than if it was attached to a higher part of the femur?
    - Clips or barbs might help with security but they might be too intrusive to the bone.

Your Name:	Olivia Gabriel
Your MacID:	gabrielo

Design Feedback:





Yousif's feedback:

- Rings are a great idea regarding stabilizing the bone and would work to reduce loosening due to osteolysis
- Longer length of stem is imperative to the design and filling out the ever-hollowing bone.
- What ball and socket changes can be made to further enhance maneuverability of hip-implant

Cindy's feedback

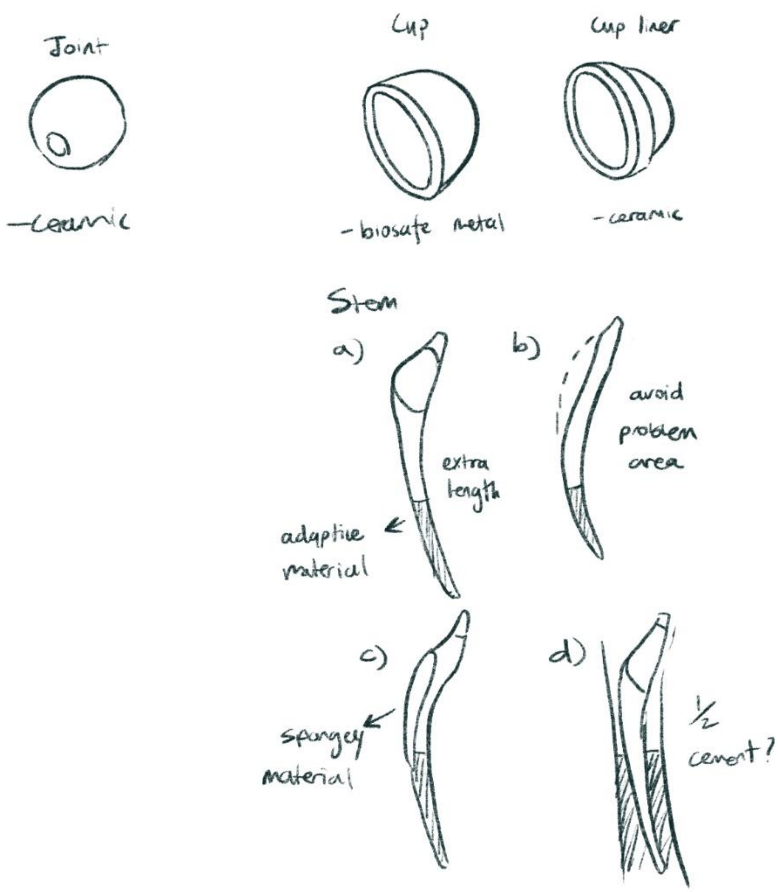
- good idea to use rings to combat low density
- if we use multiple holes would the ability to support weight decrease?
- Is there a specific reason for having a tapered shape?

Ryan's feedback

- Making holes is a great idea to make the entire prosthetic lighter while still maintaining structure integrity.
- Would the rings closer to where the bones are less dense cause wear and further deteriorate the bone?
    - Maybe more rings could more even distribute force so the bone is not as stressed.

Your Name:	Ryan Liu
Your MacID:	liu1719

Design Feedback:



Yousif's feedback:

- Unique materials that serve to eliminate the pain the patient feels while simultaneously reducing quantity of bone erosion through the decrease of friction
- Extra length of stem will help fill out the bone and is thus a good revision for the patient's aseptic loosening
- Interested by the shape of implant being specific to patient's body to help avoid implant to bone friction by eliminating / reducing contact.

Olivia's feedback:

- I like the use of hybrid materials
- What is the reasoning behind the differences in stem shape?
- How dense/ soft would the spongy material be?
- Need to compare the modules of elasticity to determine best material?

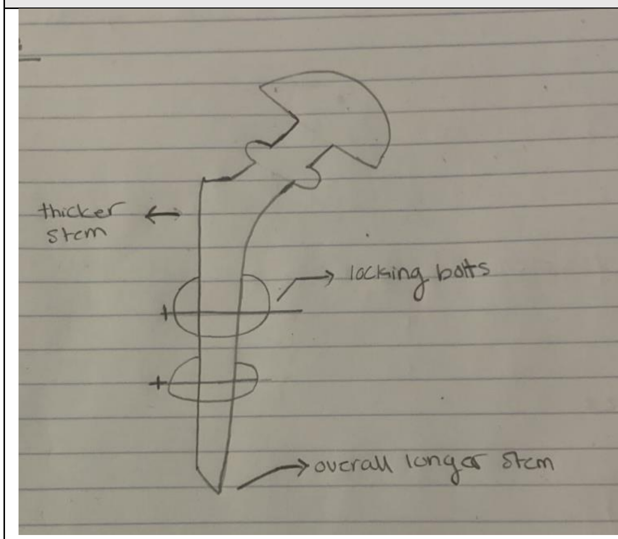
Cindy's feedback:

- I think it would be interesting to explore a hybrid cemented/uncemented approach (probably not used before)
- Could there be consequences to using ceramic on metal?

- Would using spongey material on the lateral side cause any issues with support?

Your Name:	Yousif Fadhel
Your MacID:	fadhely

Design Feedback:



Ryan's feedback:

- Locking bolts are a great idea
- The part where the prosthesis touches the bone on the left might further erode bone
    - If the shape there were different, would that help with the forces being exerted on the bone?

Olivia's Feedbak:

- Is both an increase in stem thickness and the rings needed
- Locking bolts is innovative
-

Cindy's feedback:

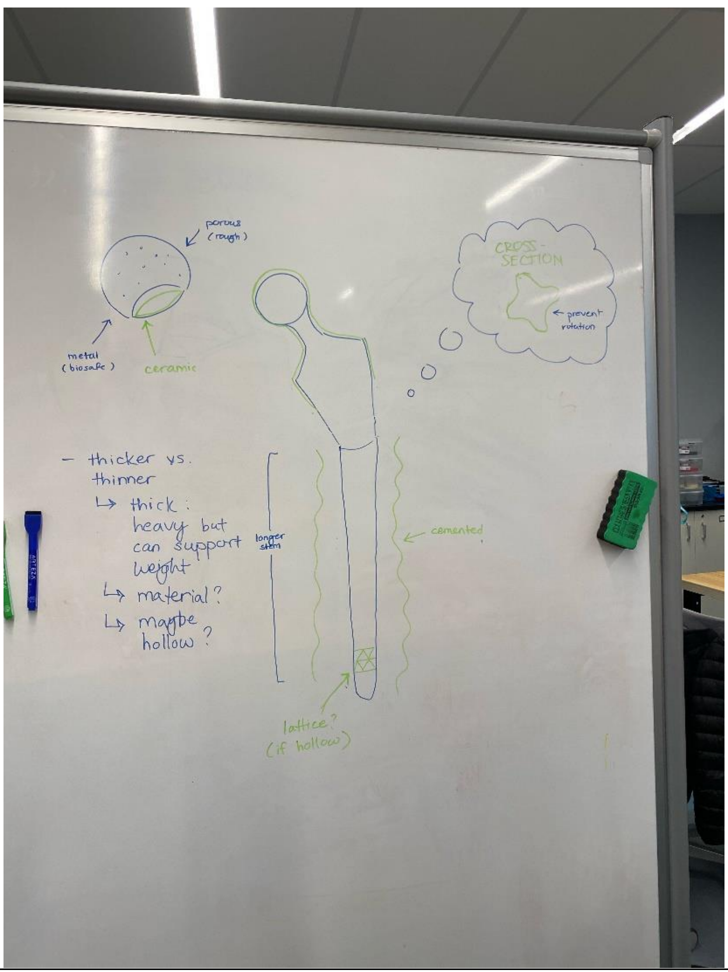
- Locking bolts would help create support, putting load on both bone & implant
    - Would they loosen over time?
- What's the reasoning behind both thickening and lengthening the stem?

MILESTONE 2 (STAGE 3) – REFINED CONCEPT SKETCH

Team Number: 30

1. Complete your refined sketch on a separate sheet of paper
2. Take a photo of your sketch
3. Insert your photo as a Picture (Insert > Picture > This Device)
4. **Do not include more than one sketch per page**

Insert photos / screenshot(s) of your ***refined concept sketch*** below



*For multiple photos / screenshots, please copy and paste the above on a new page

MILESTONE 2 (STAGE 4) – GROUP DISCUSSION

Team Number: 30

Discuss the advantages and disadvantages of your refined concept solution

Advantages	Disadvantages
• Longer stem to combat decreasing bone density • Materials to reduce friction, erosion, and overall loosening • Material of cup is porous to stimulate bone growth • Inner liner of cup and outer shell of ball is ceramic to reduce friction • Possibility of the non-circular cross section to prevent rotation	• Cemented bone might not last as long because bone could continue to deteriorate • Depends more on the lifestyle of the patient after the implant is put in • If hip bone (where the femoral head attaches) experiences bone degradation the porous mesh (non-cemented) part could begin loosening.

Discuss the extent to which your refined concept solution addresses the need statement

Ways it meets needs statement	Places to improve
- Ceramic lining should promote larger range of movement - With the many ideas of materials Ke's weight will be supported - Pain should be relieved with the addition of cement because the bone will be dense	- Does not address the issue of needing it to last longer as the cement will not prevent the bone from further deteriorating not providing a long-term solution

Milestone 3 (Team) – Cover Page

Team Number: 30

Please list full names and MacID's of all *present* Team Members.

Full Name:	MacID:
Olivia Gabriel	gabrielo
Ryan Liu	liu1719
Yousif Fadhel	fadhely
Cindy Cao	caoc30

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MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS
FRACTURE RISK

Team Number: 30

Calculate the fracture risk of the implant stem assuming a combined loading scenario. Don't forget to:

→ Compare tensile stress on the lateral side of the implant to the ultimate tensile strength of your assigned material

→ Show all of your work neatly and in detail (do not skip steps), include the correct number of significant digits, and correct units

Titanium Alloy

$$FR = \frac{\sigma_{total,tension}}{UTS_{implant}}$$

$$= \frac{-53.7\ N_{m^2} + 2128}{950}$$

$$\boxed{FR = 2.2}$$

axial = -ve

$$\sigma_A = \frac{3807.3}{\frac{\pi}{4}(90.25)}$$

$$\sigma_A = 53.7\ N/m^2$$

bending = +ve

$$\sigma_B = \frac{178952.5\ Nmm\ (0.5 \times 9.5)}{399.82\ mm^4}$$

$$\sigma_B = 2128.0\ N/mm^2$$

$$F = 3.5 \cdot BW \cdot g$$
$$= 3.5(111)(9.8)$$
$$= 3807.3\ F$$

$$A = \frac{\pi}{4} d^2$$
$$= \frac{\pi}{4}\left(\frac{19}{2}\right)^2$$
$$= \frac{\pi}{4}(90.25)\ mm^2$$

$$M = F \cdot L \qquad L = 47_{mm}$$
$$= 3807.3 \cdot 47_{mm}$$
$$= 178952.5\ Nmm$$

$$I = \frac{\pi}{64}(9.5)^4$$
$$= 399.82\ mm^4$$

MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS
FATIGUE LIFE

Team Number: 30

Calculate the fatigue life of your assigned material.

→ Show all of your work neatly and in detail (do not skip steps), include the correct number of significant digits, and correct units

$$\sigma_{amp} = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$\sigma_{max} = \frac{30(111)(9.8)}{\frac{\pi}{4}(9.5)^2}$$

$$\sigma_{max} = 460.3977$$

$$\sigma_{min} = -460.3977$$

$$\sigma_{amp} = \frac{460.3977 - (-460.3977)}{2}$$

$$= 460 \text{ MPa}$$

$$\boxed{\therefore 10^{4.75} \text{ cycles}}$$

MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS
BONE STRESS REDUCTION

Team Number: 30

Calculate the magnitude of bone stress reduction after implant reconstruction. Don't forget:

→ Calculations should not consider a combined loading scenario, like in Part 1 of this Milestone

→ Show all of your work neatly and in detail (do not skip steps), include the correct number of significant digits, and correct units

$$\sigma_{comp} = \frac{F}{A}$$

$$= \frac{3807.3\ N}{\frac{\pi}{4}(D_o^2 - D_i^2)}$$

$$= \frac{3807.3\ N}{\frac{\pi}{4}(33^2 - 17^2)}$$

$$= 57.13\ N/mm^2$$

$$\sigma_{reduc} = \sigma_{comp}\left(\frac{2 \cdot E_{bone}}{E_{bone} + E_{implant}}\right)^{\frac{1}{2}}$$

$$= 57.13\sqrt{\frac{2.17}{17+114}}$$

$$\boxed{= 29\ N/mm^2}$$

Milestone 4 (Team) – Cover Page

Team Number: 30

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Olivia Gabriel	gabrielo
Ryan Liu	liu1719
Yousif Fadhel	fadhely
Cindy Cao	caoc30

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MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

Team Number:	30

You should have already completed **Stage 1** of Milestone 4 individually *prior* to Design Studio 10.

1. Copy-and-paste each team member's **Preliminary Materials Selection** research from the individual worksheets in the tables on the following pages
   → Between the 4-5 team members, all tables should include a minimum of 4 candidate materials
2. Recalling that each team member only needed to consider **TWO** of the three criteria (structure, properties, processing) for **Stage 1**, your team should now fill in any tables not completed for each unique candidate material
   → For example, if a team member proposed *cobalt chrome* and *titanium*, researching the **structure** and **properties** of each, the *team* should then research the **processing** of each of these materials, filling in the appropriate table.

Implant Component:	femoral stem

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION
STRUCTURE

Team Number: 30

Fill in the Materials Selection table below related to the **STRUCTURE** of the material by *copy-and-pasting* each team members individual research. Discuss your findings as a team.

→ Note: some columns include headers (to help get you started) and some are left blank
- Add additional column headers as you feel are appropriate
- You only have to fill in the columns you think are relevant

→ If a candidate material proposed in one of the other tables is not included below, you should add it to this table and fill out the appropriate fields as a *team*

Material	Class	Atomic Arrangement	Interatomic Bonding	Description
Cobalt-Chromium-Molybdenum	Metal	Crystalline	Metallic	Metal alloy composed of 66% cobalt, 28% chromium, 6% molybdenum, & small amounts of other metals (Mn, Si, Ni, Fe and C)
PU-Ca-16G	Composite	Amorphous	Covalent	Polyurethane reinforced w/ 16 strands of fibreglass & 30% CaCO3 (calcium carbonate)
Polysulfone	Polymer	Amorphous	Covalent	Thermoplastic polymer that is hydrolytically stable and stable under steam sterilization
Stainless steel	Metal (type 316L stainless steel)	Crystalline (Face entered cubic)	Metallic bonding	austenitic stainless steel is most widely used for implants - The stainless steel most widely used in clinical applications is AISI 316L (0.03% C, 17–20% Cr, 12–14% Ni, 2–3% Mo)

Nylon 12	Polymer	Semi-crystalline	Covalent, H-bonding	Semi-crystalline polyamide; low amide concentration; strong stress & fatigue resistance
Nickel Alloy MP35N Alloy	Metal	Crystalline	Metallic bonding	-ultrahigh tensile strength - good ductility and toughness - (35% cobalt, 35% nickel, 20% chromium, and 10% molybdenum)
Ti-6AL-4V Titanium Alloy (Grade 5)	Metal	HCP Crystal Structure	Metallic bonding	Titanium alloy composed of 6% aluminum and 4% vanadium. This material features great strength, low modulus of elasticity and high corrosion resistance.
Hydroxyapatite	Ceramic Materia	Hexagonal Structure	Covalent bonding	Ceramic material comprised of calcium and phosphate, has been used as a biomaterial to promote tissue growth.

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

PROPERTIES

Team Number: 30

Fill in the Materials Selection table below related to the **PROPERTIES** of the material by *copy-and-pasting* each team members individual research. Discuss your findings as a team.

→ Note: some columns include headers (to help get you started) and some are left blank
  - Add additional column headers as you feel are appropriate
  - You only have to fill in the columns you think are relevant

→ If a candidate material proposed in one of the other tables is not included below, you should add it to this table and fill out the appropriate fields as a *team*

Material	Elastic Modulus	Ultimate Strength	Toughness, Fracture	Wear	Corrosion Resistance
Cobalt-Chromium-Molybdenum	210 to 250 GPa	780 to 1280 MPa	High	High	High
PU-Ca-16G	24.03 GPa	28.0 - 96.0 MPa*	High*	High*	Low – medium*
Polysulfone	0.0145-0.0153 Pa	94 - 104 MPa	1.89 - 4.69 MPa/ m^0.5	"Sand Wheel Wear/Abrasion Test": UHMW=100	Highly resistant to mineral acids, alkali, and electrolytes.
Stainless Steel	193 - 200 GPa	621 MPa	high	poor	high

Nylon 12 (Polyamide 12)	1.4 GPa	50 MPa	2.5-3.0 MPA/m^2	Resistant to abrasion	Resistant to corrosion
Nickel Alloy MP35N Alloy	2.33 - 2.3476649 GPa	1034.21 MPa	high	high	high
Ti-6AL-4V Titanium Alloy (Grade 5)	113.8 GPa	1861.58 MPa	75 MPa-m^1/2	Poor wear resistance due to low protection exerted by trioxides.	Excellent resistance to corrosion. Exhibits very low corrosion rates in chloride environments.
Hydroxyapatite	7.00 – 13.0 GPa	18 MPa	0.5 – 1 MPa	High Is not very prone to wearing (prevents aseptic loosening)	High

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION
PROCESSING

Team Number: 30

Fill in the Materials Selection table below related to the **PROCESSING** of the material by *copy-and-pasting* each team members individual research. Discuss your findings as a team.

→ Note: some columns include headers (to help get you started) and some are left blank
  - Add additional column headers as you feel are appropriate
  - You only have to fill in the columns you think are relevant

→ If a candidate material proposed in one of the other tables is not included below, you should add it to this table and fill out the appropriate fields as a *team*

Material	Coatings	Drug Delivery Options	Corrosion Resistance
Cobalt-Chromium-Molybdenum	cross-linked poly-γ-glutamic acid + CaCl2 → forms apatite layer	N/A	- very resistant: Cr particles form protective oxide layer on surface
PU-Ca-16G	PU can also act as a coating	N/A	- somewhat resistant: only to oils, solvents, and weak acids/bases
Stainless steel	Cr2O3 - strongly adherent - Self-healing - Corrosion resistant	N/A	Very Resistant -Resistant to a wide range of corrosive agents because of to their high Cr content (more than 12%).
Nickel Alloy MP35N Alloy	Hydroxyapatite coating - osteogenic properties - form strong bonds with the host bone tissues	N/A	Excellent stress corrosion and cracking resistance -improved fatigue strength over present cast implant material.

Polysulfone	aromatic polyamide 3, PSU-N,N-dimethylformamide (DMF)	Polysulfone capillary fiber (PCF)	Highly resistant to mineral acids, alkali, and electrolytes.
Nylon 12 (Polyamine 12)	Can also act as a coating	N/A	Resistant to corrosion
Ti-6AL-4V Titanium Alloy	Hydroxyapatite coating to form bonds with bone	N/A	Very resistant to corrosion
Hydroxyapatite	Acts as a coating	N/A	Very resistant to corrosion

MILESTONE 4 (STAGE 3) – PROPOSED MATERIAL

Team Number: 30

Based on the previous tables, identify the material you consider as being most appropriate for this component

Proposed Material:	Ti-6AL-4V Titanium Alloy (Grade 5) with hydroxyapatite coating

Explain why you selected this material based on the structure, properties and processing:

We selected the material Ti-6AL-4V because our patient desires a replacement material that is completely biologically inert. Additionally, this material has immense ultimate strength which will ensure that our patient's greater weight is supported through his daily use. The elastic modulus is also closer to bone than the other metals, lessening the probability of stress shielding. This is especially important as our patient has limited physical activity.

Comment on why the material selected makes the most sense ***for your patient***

- Biologically inert: does not cause infection
- High ultimate strength: supports larger weight of patient
- Stem will be cemented: prevents toxic ion release
- Hydroxyapatite: prevents toxic ion release which can cause aseptic loosening
- Ream out bone to expose new bone that has not been exposed to polyethylene
- Fill remaining space with allograft bone as it will stimulate bone growth in combination with the hydroxyapatite coating