Design Project 2 – Hips Don't Lie

The HIP-ocratic Oath

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 02

Team 26

COLIN MCDONALD (cmcdona)

KYLA SASK (ksask)

MARIA-JULIANA RIVERA-MADRINAN (riveramm)

PARMVEER BOLA (bolap1)

Submitted: Thursday 8, 2022

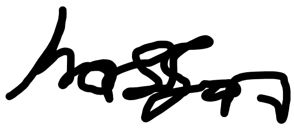
Course Instructors: Dr. McDonald and Dr. Sask

Table of Contents

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.

Hassan Bokhari, 400443298



(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.

Eloise Nguyen 400442253

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.

Rory Sucharov-Gluck 400472393

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.

Sohail

Summary of 3D-Printing Process

Eloise Nguyen

Due to a lack of experience with 3D printing components, my group and I were experimenting with the scales and limitations of the implants in Prusa slicer. We decided to scale ours down by 20% to avoid losing details, reducing the printing time to 2 hours. We also auto oriented the implants on the printing bed so that less filaments will be used for the model and supports. Since our acetabular components and bearing are concave in shape, they were oriented upwards to prevent the supports from tempering with their openings. After, we transferred our stl files onto an SD card and inserted it into the 3D printer. With frequent supervision, we removed the printing from the printing bed after letting it cool down. For the first printing, the stem had to much support attached to its surface. Hence, we reduced the support by earring the components closer together.

Rory Sucharov-Gluck

Originally, our design was projected to take THIS MANY HOURS to print, so we scale it down to THIS PERCENT. Following the lead of the modeling team, we assessed which orientation would lead to the least number of supports, thereby producing the most efficient print and saving the most time. Still, when our print was complete, we were unable to completely remove the excess filament, resulting in rough edges and a less precise fit. This indicated to me that it is important to account for the extra material when creating 3D parts that fit together. Additionally, we experienced a few failures with the older 3D printer, which were beyond our control. 3D printing can be a tedious process, and even with an ideal model, the printers will not always perform perfectly, so multiple attempts (and a lot of time) is often necessary.

Hassan Bokhari

The 3D printing component of this assignment was completed upon completion of the CAD design of the knee implant. By exporting our file as an STL in millimeters and importing into Prusa slicer we were able to adjust the approximate size of the 4 parts to be 65% of the original size to decrease the print time. Due to our overhanging parts, we added supports everywhere and furthermore added a brim to help our parts not slide around. To reduce need for support material (and reduce time) we placed the parts on their optimal faces. Upon completion of the adjustments, we uploaded our file onto a SD card and brought it over to the printer to print. Initially our first 3 attempts failed as material started to roll up onto itself. After switching printers, we were able to print a successful prototype of our design.

Sohail Persaud

3D printing was an enjoyable process overall but provided key challenges, especially in terms of scaling. Our CAD design incorporated a lot of physical grooves and semi-round aspects, and we were initially curious about if the design was too complex for the printer. However, when we added supports and a brim underneath, it seemed like less of a problem which made me relieved. Our team had to scale down our 4-part design to 65% of the original size, which was the only way to make it fit within our time parameters. We also had troubles laying out the four parts on the PRUSA slicer software, but with the help of the 'auto-arrange' feature this problem was resolved. While the true size and appearance of our CAD model had to be compromised, the overall experience of learning to use these specific 3D printers was simple and enjoyable.

Summary of Contributions:

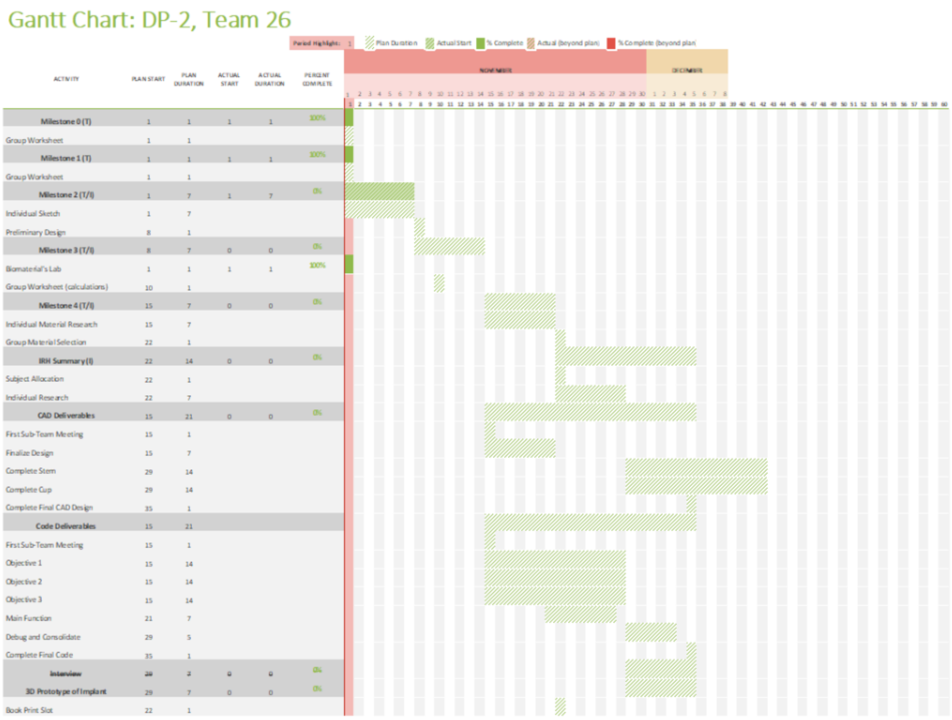
Name	***Project Role***	***Summary of Contributions***
Hassan Bokhari	Reference Manager	- Coding Sub-team member - Created template for final deliverables (poster template) - Assembled final posterboard using printed pieces of paper and tape - Planned final presentation (everyone's parts etc.) - Helped facilitate 3D printing of object (Converting to STL/exporting to prusaslicer etc.) - Consolidated references and allowed for easy access to sources
Eloise Nguyen	Administrator	- CAD Sub-team member - Edited and submitted milestone worksheets - Contributed to creating the poster board

		- Researched on diamond coatings, cobalt-chromium-molybdenum, the un-directional design, and hydrodynamic lubrication. - Completed the final gantt chart
Sohail Persaud	Coordinator	- CAD Sub-team member - Took notes at every weekly TA meeting - Researched LCPD and fixation methods for the poster presentation
Rory Sucharov-Gluck	Manager	- Planned meetings and helped maintain contact between team members - Made preliminary Gantt Chart - Consolidated patient profile - Researched materials - Coding Sub-team member

Appendices

Appendix A: Project Schedule

Preliminary Gantt Chart:

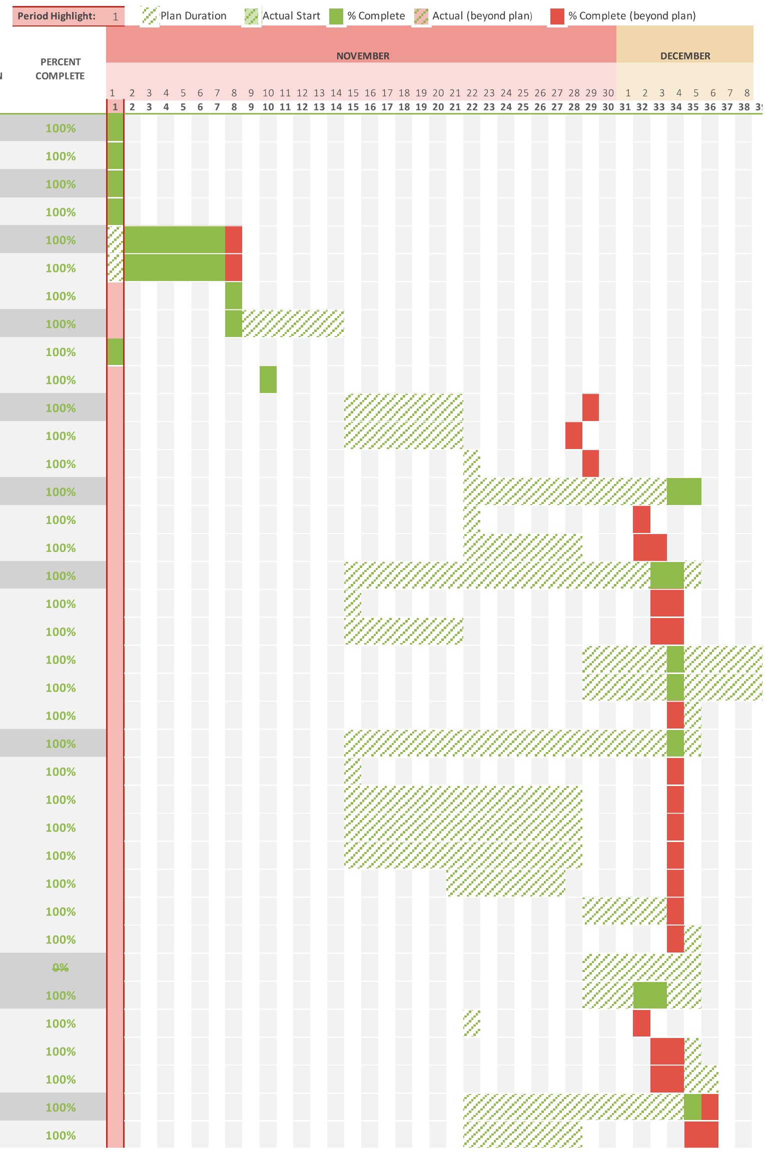


ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (T)	1	1	1	1	100%
Group Worksheet	1	1			
Milestone 1 (T)	1	1	1	1	100%
Group Worksheet	1	1			
Milestone 2 (T/I)	1	7	1	7	0%
Individual Sketch	1	7			
Preliminary Design	8	1			
Milestone 3 (T/I)	8	7	0	0	0%
Biomaterial's Lab	1	1	1	1	100%
Group Worksheet (calculations)	10	1			
Milestone 4 (T/I)	15	7	0	0	0%
Individual Material Research	15	7			
Group Material Selection	22	1			
IRH Summary (I)	22	14	0	0	0%
Subject Allocation	22	1			
Individual Research	22	7			
CAD Deliverables	15	21	0	0	0%
First Sub-Team Meeting	15	1			
Finalize Design	15	7			
Complete Stem	29	14			
Complete Cup	29	14			
Complete Final CAD Design	35	1			
Code Deliverables	15	21			
First Sub-Team Meeting	15	1			
Objective 1	15	14			
Objective 2	15	14			
Objective 3	15	14			
Main Function	21	7			
Debug and Consolidate	29	5			
Complete Final Code	35	1			
~~**Interview**~~	~~28~~	~~3~~	~~0~~	~~0~~	0%
3D Prototype of Implant	29	7	0	0	0%
Book Print Slot	22	1			

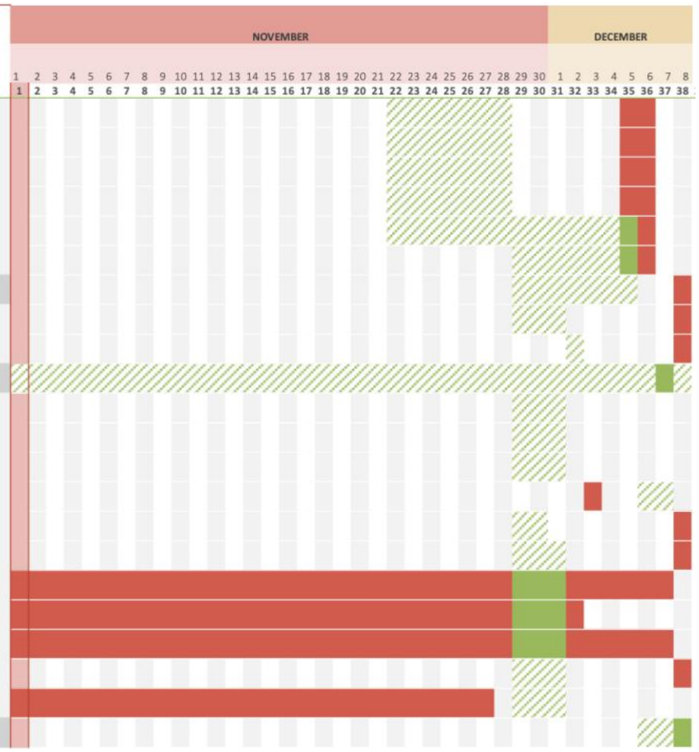
Final Gantt Chart (continue next page):

Gantt Chart: DP-2, Team 26

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (T)	1	1	1	1	100%
Group Worksheet	1	1	1	1	100%
Milestone 1 (T)	1	1	1	1	100%
Group Worksheet	1	1	1	1	100%
Milestone 2 (T/I)	1	7	2	7	100%
Individual Sketch	1	7	2	7	100%
Preliminary Design	8	1	8	1	100%
Milestone 3 (T/I)	8	7	8	1	100%
Biomaterial's Lab	1	1	1	1	100%
Group Worksheet (calculations)	10	1	10	1	100%
Milestone 4 (T/I)	15	7	29	1	100%
Individual Material Research	15	7	28	1	100%
Group Material Selection	22	1	29	1	100%
IRH Summary (I)	22	14	34	2	100%
Subject Allocation	22	1	32	1	100%
Individual Research	22	7	32	2	100%
CAD Deliverables	15	21	33	2	100%
First Sub-Team Meeting	15	1	33	2	100%
Finalize Design	15	7	33	2	100%
Complete Stem	29	14	34	1	100%
Complete Cup	29	14	34	1	100%
Complete Final CAD Design	35	1	34	1	100%
Code Deliverables	15	21	34	1	100%
First Sub-Team Meeting	15	1	34	1	100%
Objective 1	15	14	34	1	100%
Objective 2	15	14	34	1	100%
Objective 3	15	14	34	1	100%
Main Function	21	7	34	1	100%
Debug and Consolidate	29	5	34	1	100%
Complete Final Code	35	1	34	1	100%
~~**Interview**~~	~~29~~	~~7~~	~~0~~	~~0~~	~~0%~~
3D Prototype of Implant	29	7	32	2	100%
Book Print Slot	22	1	32	1	100%
Scale 3D Design	35	1	33	2	100%
Print Prototype	35	2	33	2	100%
Poster Board	22	14	35	2	100%
Patient Profile	22	7	35	2	100%



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Material Justification	22	7	35	2	100%
Component Justification	22	7	35	2	100%
Fixation Justification	22	7	35	2	100%
Overall Design Advantages	22	7	35	2	100%
References	22	14	35	2	100%
Organize Physical Board	29	7	35	2	100%
Poster Presentation	29	7	38	1	100%
Plan Key Speaking Notes	29	3	38	1	100%
Assign Parts	32	1	38	1	100%
Design Project Report	1	38	37	1	100%
~~Summary of Objectives~~	~~29~~	~~3~~	~~0~~	~~0~~	0%
~~Summary of Design Process~~	~~29~~	~~3~~	~~0~~	~~0~~	0%
~~Summary of Design~~	~~29~~	~~3~~	~~0~~	~~0~~	0%
Summary of 3D Printing Process (I)	36	2	33	1	100%
Summary of Contributions	29	2	38	1	100%
Reference List	29	3	38	1	100%
Appendix A: Schedule	29	3	1	37	100%
Appendix B: Weekly Meetings	29	3	1	32	100%
Appendix C: List of Sources	29	3	1	37	100%
Appendix D: Additional Documentation	29	3	38	1	100%
Appendix E: Design Studio Worksheets	29	3	1	27	100%
Self-and-Peer Evaluation	36	3	38	1	100%



Appendix B: Scheduled Weekly Meetings

Week 1 – 11/01/22

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	**Yes**
Administrator	**Eloise Nguyen**	**nguyt126**	**Yes**
Coordinator	**Sohail Persaud**	**persas29**	**Yes**
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	**Yes**
Guest			**N/A**

AGENDA ITEMS

1. Delegate administrative roles
2. Assign sub-team positions
3. Establish a diagnosis
4. List objectives and constraints
5. Write a need statement

MEETING NOTES

1. Legg-Calve-Perthes Disease (LCPD) is the final diagnosis
    a. Started at around 10 years old was the biggest piece of evidence towards narrowing down options
    b. LCPD causes flattening/deformation of the femoral head, causing bad movement between socket and femur which leads to pain
2. Objectives are based on **reducing overall pain**, **increasing range of motion** and **being able to stand up consistently without having the urge to rest**
    a. These are the goals which the design should achieve
3. Constraints revolve around **changing both socket and femoral head (ball)**, **made of biosafe material**, **sterility**, **safety of implant**, and **must allow hip motion and mobility**
    a. Must allow hip motion and mobility because wouldn't want to apply a solution that completely inhibits any motion instead of solving problem and increasing motion
    b. Focus on not causing larger problem instead solving problem

POST-MEETING ACTION ITEMS

1. Submit Milestone 0 and Milestone 1
2. Complete individual preliminary sketches before next design studio (11/08/22)
3. The manager needs to complete the Preliminary GANTT Chart (Rory)

Week 2 – 11/08/22

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	**Yes**
Administrator	**Eloise Nguyen**	**nguyt126**	**Yes**
Coordinator	**Sohail Persaud**	**persas29**	**Yes**
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	**Yes**
Guest			**N/A**

AGENDA ITEMS

1. Attendance & Updates
2. Review points from previous meeting
3. Share preliminary sketches
4. Determine a first design
5. Wrap up and plan for the next week

MEETING NOTES

1. Conclusions from last week
    a. Need statements were better than DP1, Jackie Chiles has LCPD
2. What were patient-specific considerations?
    a. Age (65) -> Range where the hip replacement may last until end of his life? Or if it doesn't last long enough implications of another hip replacement early at such an old age?
    b. Not very active patient à Not expected to have to run marathons, high stress on the hip replacement isn't a key consideration, okay assumption to make
    c. Materials -> e.g ceramic seen as brittle, may be okay in this case (less risk in consideration of materials), how the material is manufactured, post-processing (changing surface structures for specific objectives) e.g coatings that can add properties
    d. Real life patients might address both legs in this situation, but this project only requires consideration of the affected leg -> something we CAN do, not EXPECTED
3. Consider osteoarthritis in the left hip (caused by the LCPD)
    a. No space in between the femoral head and connecting hip which was caused by the flattened femoral head to begin with

1. Cushioning
2. If bone is rounded out, there still has to be some fixation added in to not change the original shape/size of the socket (coating or glue)
3. Titanium with some sort of rough coating because patient already has a lot of healthy bone to work with

POST-MEETING ACTION ITEMS

1. Submit milestone
2. Research novel hip concepts

3. Maintain communication with group

Week 3 – 11/15/22

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	**Yes**
Administrator	**Eloise Nguyen**	**nguyt126**	**Yes**
Coordinator	**Sohail Persaud**	**persas29**	**Yes**
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	**Yes**
Guest			**N/A**

AGENDA ITEMS

1. Updates
2. Review main learning outcomes from Biomaterials Lab
3. Complete calculations for Milestone 3
4. Finalize Milestone 3
5. Establish plan and delegate tasks for the coming week

MEETING NOTES

- Implant can be any material as long as explained and justified --> not just the three used in this milestone activity
  - Activity used to help with familiarizing with calculations (e.g fracture risk, axial stress, bending stress)
- A material with a high ultimate tensile strength will be important
  - Jackie Chiles is a HEFTY individual, a relatively larger load will need to beared
-

POST-MEETING ACTION ITEMS

1. Communicate with sub-team member to plan meeting
2. Review technical deliverables
3. Begin materials research

Week 4 – 11/22/22

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	**Yes**
Administrator	**Eloise Nguyen**	**nguyt126**	**Yes**
Coordinator	**Sohail Persaud**	**persas29**	**Yes**
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	**Yes**
Guest			**N/A**

Agenda Items

1. Updates
2. Mental Health Check-in- How is everyone doing?
3. Review feedback from prior Milestones
4. Begin research for Milestone 4
5. Establish plan and delegate tasks for the coming week

Meeting Notes

- Material chosen for milestone 4 doesn’t HAVE to be the final choice for this design project
    - Moreso meant to get us thinking about weighing the pros and cons of each prospective material
- What our material SHOULD be able to do:
    - Support a large load
    - Doesn’t need to move very well
    - Fixate into the bone relatively smoothly
    - Bio integrates fast for minimal chances of complications
    - Be safe for interacting with slightly weaker bones

Post-Meeting Action Items

1. Finish individual research for milestone 4
2. Continue working on technical deliverables
3. Begin work for IRH

Week 5 – 11/29/22

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	
Administrator	**Eloise Nguyen**	**nguyt126**	
Coordinator	**Sohail Persaud**	**persas29**	
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	
Guest			

Agenda Items

1. Attendance & Updates
2. Share materials research
3. Make materials selection
4. Complete Milestone 4 (Team)
5. Wrap up and plan for the next week

Meeting Notes

- How to approach CAD and computing aspects
  - Everyone should know how things are done and have a general understanding
  - Even if objectives or responsibilities are split up, the other person should still know what was done
  - For coding, using comments is important to explain the code as you write it
  - Keep checking the rubric and ask teammates
- Presentation
  - Posterboard is a bit more content heavy compared to 3MT
  - Less stressful in a group environment

Post-Meeting Action Items

1. Submit milestone
2. Work through technical electives
3. Delegate tasks with sub team members

Week 6 – 12/06/22

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Rory Sucharov-Gluck**	**sucharor**	**Yes**
Administrator	**Eloise Nguyen**	**nguyt126**	**Yes**
Coordinator	**Sohail Persaud**	**persas29**	**Yes**
Subject Matter Expert	**Hassan Bokhari**	**bokharh**	**Yes**
Guest			**N/A**

Agenda Items

1. Attendance & Updates (& mental health check-ins)
2. Scale model and 3D print
3. Work through poster board and allocate tasks
4. Plan presentation and allocate roles
5. Wrap up and assign final tasks

Meeting Notes

- How formal does our presentation need to be?
  - TA Response: presentation should cover everything in the rubric but its best not to treat it as a straight up presentation
  - Try to keep it casual but also show confidence and almost sell the product
  - Keep the audience engaged is a rule of thumb

Post-Meeting Action Items

1. Finish assigned poster roles
2. Plan next team meeting
3. Print poster items and assemble
4. Practice parts of the presentation

Appendix C: Comprehensive List of Sources

All references are numbered in accordance with how they were used in the document highlighted

Milestone 4 citations

Hassan Bokhari
316L AISI Alloyed Stainless Steel

[1] "Stainless steel | Definition, Composition, Types, & Facts | Britannica." https://www.britannica.com/technology/stainless-steel (accessed Nov. 28, 2022).

[2] E. Bévillon, J. P. Colombier, B. Dutta, and R. Stoian, "Ab initio nonequilibrium thermodynamic and transport properties of ultrafast laser irradiated 316l stainless steel," Journal of Physical Chemistry C, vol. 119, no. 21, pp. 11438–11446, May 2015, doi: 10.1021/ACS.JPCC.5B02085.

[3] K. W. Dong, J. Kong, Y. Peng, Q. Zhou, and K. H. Wang, "Thermoplastic bonding of TC4 and 316L stainless steel with a Ti-based bulk metallic glass as the filler metal," Journal of Materials Research and Technology, vol. 11, pp. 487–497, Mar. 2021, doi: 1 0.1016/J.JMRT.2021.01.042.

[8] "Specification Sheet: Alloy 316/316L," Jun. 2014. https://www.sandmeyersteel.com/images/316-316l-317l-spec-sheet.pdf (accessed Nov. 28, 2022).

[9] H. Alsalla, L. Hao, and C. Smith, "Fracture toughness and tensile strength of 316L stainless steel cellular lattice structures manufactured using the selective laser melting technique," Materials Science and Engineering: A, vol. 669, pp. 1–6, Jul. 2016, doi: 10.1016/J.MSEA.2016.05.075.

[10] N. S. Al-Mamun, K. Mairaj Deen, W. Haider, E. Asselin, and I. Shabib, "Corrosion behavior and biocompatibility of additively manufactured 316L stainless steel in a physiological environment: the effect of citrate ions," Addit Manuf, vol. 34, p. 101237, Aug. 2020, doi: 10.1016/J.ADDMA.2020.101237

Zirconia-Toughened Alumina - 14

[4] T. Tateiwa et al., "Burst Strength of BIOLOX®delta Femoral Heads and Its Dependence on Low-Temperature Environmental Degradation," Materials 2020, Vol. 13, Page 350, vol. 13, no. 2, p. 350, Jan. 2020, doi: 10.3390/MA13020350.

[5] Md. A. Gafur et al., "Structural and Mechanical Properties of Alumina-Zirconia (ZTA) Composites with Unstabilized Zirconia Modulation," Materials Sciences and Applications, vol. 12, no. 11, pp. 542–560, Nov. 2021, doi: 10.4236/MSA.2021.1211036.

[6] "Z I R C O N I A-T O U G H E N E D A L U M I N A : W H Y," 2021, Accessed: Nov. 28, 2022. [Online]. Available: h ttps://www.ceramics.net/sites/default/files/stc-white-paper-zta-zirconia-toughened-alumina-01062021.pdf

[11] C. Piconi, "Oxide Ceramics for Biomedical Applications," Encyclopedia of Materials: Science and Technology, pp. 6595–6601, 2001, doi: 10.1016/B0-08-043152-6/01165-7.

[12] "Zirconia Toughened Alumina (ZTA) - INSACO Inc." https://www.insaco.com/material/zirconia-toughened-alumina-zta/ (accessed Nov. 28, 2022).

Sohail Persuad
Carbon Fiber

[1] S. Dimitrievska, J. Whitfield, S. A. Hacking, and M. N. Bureau, "Novel carbon fiber composite for hip replacement with improved in vitro and in vivo osseointegration," J Biomed Mater Res A, vol. 91A, no. 1, pp. 37–51, Oct. 2009, doi: 10.1002/JBM.A.32175.

[2] D. B. Bennett et al., "Metal carbon fiber composite femoral stems in hip replacements a randomized controlled parallel group study with mean ten year followup," Journal of Bone and Joint Surgery - American Volume, vol. 96, no. 24, pp. 2062–2069, Dec. 2014, doi: 10.2106/JBJS.M.01542.

[3] C. Y. Hu and T.-R. Yoon, "Recent updates for biomaterials used in total hip arthroplasty - biomaterials research," *BioMed Central*, 05-Dec-2018. [Online]. Available: https://biomaterialsres.biomedcentral.com/articles/10.1186/s40824-018-0144-8. [Accessed: 08-Dec-2022].

[4] "Hip anatomy," *Physiopedia*. [Online]. Available: https://www.physio-pedia.com/Hip_Anatomy. [Accessed: 08-Dec-2022].

[5] M. D. Jonathan Cluett, "Why the bearing surface is critical to hip replacement longevity," *Verywell Health*, 02-Nov-2022. [Online]. Available: https://www.verywellhealth.com/hip-replacement-part-material-4157864. [Accessed: 08-Dec-2022].

Rory

Ceramic Alumina

[1] "Alumina (al2o3) ceramics at best price," *Advanced Ceramic Materials*. [Online]. Available: https://www.preciseceramic.com/products/alumina-al2o3/#:~:text=Alumina%2C%20or%20aluminum%20oxide%20Al2O3%2C%20with%20a%20molecular,common%20technical%20ceramic%20material%20and%20relatively%20traditional%20material. [Accessed: 08-Dec-2022].

[2] G. Franks and Y. Gan, "[PDF] crystal structure of alumina oxide and hydroxide phases . (after Levin and Brandon , 1998): Semantic scholar," *[PDF] Crystal Structure of Alumina Oxide and Hydroxide Phases . (After Levin and Brandon , 1998) | Semantic Scholar*, 01-Jan-1970. [Online]. Available: https://www.semanticscholar.org/paper/Crystal-Structure-of-Alumina-Oxide-and-Hydroxide-.-Franks-Gan/d023e11d9352c7c8d65ef6c2567f310d88c04f72. [Accessed: 08-Dec-2022].

[3] J. Schaler, R. Papsik, M. Vojtko, and T. Csandi, "Micro-scale fracture toughness of textured alumina ceramics," *Journal of the European Ceramic Society*, 10-Jun-2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0955221922004782. [Accessed: 08-Dec-2022].

[4] "Modulus of elasticity and Poisson's coefficient of typical ceramic materials," *Ceramic materials elastic modulus and Poisson ratio | Sonelastic®*. [Online]. Available: https://sonelastic.com/en/fundamentals/tables-of-materials-properties/ceramics.html. [Accessed: 08-Dec-2022].

Molybdenum

[5] AZO Material, "Properties: Molybdenum (MO) - properties, applications," *AZoM.com*, 08-Dec-2022. [Online]. Available: https://www.azom.com/properties.aspx?ArticleID=616. [Accessed: 08-Dec-2022].

[6] C. Redlich, P. Quadbeck, B. Kiebeck, and M. Thieme, "Molybdenum – a biodegradable implant material for structural applications?," *Acta Biomaterialia*, 09-Jan-2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1742706119308694#:~:text=In%20addition%2C%20molybdenum%27s%20role%20in%20human%20cell%20metabolism,behavior%20of%20a%20molybdenum%20bioresorbable%20implant%20material%20probable. [Accessed: 08-Dec-2022].

[7] I. M. O. A. I. M. Association, *Molybdenum properties*. [Online]. Available: https://www.imoa.info/molybdenum/molybdenum-properties.php. [Accessed: 08-Dec-2022].

[8] "Molybdenum," *The Cambridge Crystallographic Data Centre (CCDC)*. [Online]. Available: https://www.ccdc.cam.ac.uk/Community/educationalresources/PeriodicTable/Molybdenum/. [Accessed: 08-Dec-2022].

Eloise
Material 1

[1] "Home - PMC - NCBI," National Center for Biotechnology Information. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/. [Accessed: 08-Dec-2022].

[2] "Home," MERSEN. [Online]. Available: https://www.mersen.com/products/anticorrosion-equipment. [Accessed: 08-Dec-2022].

[3] "Home," MERSEN. [Online]. Available: https://www.mersen.com/products/anticorrosion-equipment. [Accessed: 08-Dec-2022].

[4] J. Olofsson, T. M. Grehk, T. Berlind, C. Persson, S. Jacobson, and H. Engqvist, "Evaluation of silicon nitride as a wear resistant and resorbable alternative for Total Hip Joint Replacement," Biomatter, 2012. [Online]. Available gov/pmc/articles/PMC3549862/. [Accessed: 08-Dec-2022].

Material 2

[5] J. Olofsson, T. M. Grehk, T. Berlind, C. Persson, S. Jacobson, and H. Engqvist, "Evaluation of silicon nitride as a wear resistant and resorbable alternative for Total Hip Joint Replacement," Biomatter, 2012. [Online]. Available: ticles/PMC3549862/. [Accessed: 08-Dec-2022].

[6] "The Online Materials Information Resource," MatWeb. [Online]. Available: https://matweb.com/search/DataSheet.aspx. [Accessed: 08-Dec-2022].

[7] "PubMed," National Center for Biotechnology Information. [Online]. Available: https://www.pubmed.ncbi.nlm.nih.gov/. [Accessed: 08-Dec-2022].

[8] "Silicon carbide material properties," Imetra, Inc., 10-Jun-2020. [Online]. Available: https://www.imetra.com/silicon-carbide-material- properties/. [Accessed: 08-Dec-2022].

[9] "Silicon carbide material properties," Imetra, Inc., 10-Jun-2020. [Online]. Available: https://www.imetra.com/silicon-carbide-material-properties/. [Accessed: 08-Dec-2022].

[10] T. Wu, J. Su, Y. Li, H. Zhao, Y. Zhang, M. Zhang, and B. Wu, "Wear resistance mechanism of alumina ceramics containing gd_2o_3," Materials (Basel, Switzerland), 21-Oct-2018. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6213477/. [Accessed: 08-Dec-2022].

IRH Citations

Rory (ethics)

[1] W. H. Bronson *et al.*, "The Ethics of Patient Risk Modification Prior to Elective Joint Replacement Surgery," *JBJS*, vol. 96, no. 13, 2014, [Online]. Available: https://journals.lww.com/jbjsjournal/Fulltext/2014/07020/The_Ethics_of_Patient_Risk_Modification_Prior_to.19.aspx

[2] D. L. Snell, R. J. Siegert, L. J. Surgenor, J. A. Dunn, and G. J. Hooper, "Evaluating quality of life outcomes following joint replacement: psychometric evaluation of a short form of the WHOQOL-Bref," *Quality of Life Research*, vol. 25, no. 1, pp. 51–61, 2016, [Online]. Available: http://www.jstor.org/stable/44849691

[3] A. D. Hanchate *et al.*, "Massachussets health reform and disparities in joint replacement use: difference in differences study," *BMJ: British Medical Journal*, vol. 350, 2015, [Online]. Available: https://www.jstor.org/stable/26518308

[4] S. C. Kim *et al.*, "Patterns and predictors of persistent opioid use following hip or knee arthroplasty," *Osteoarthritis Cartilage*, vol. 25, no. 9, pp. 1399–1406, 2017, doi: https://doi.org/10.1016/j.joca.2017.04.002.

[5] C. Shadbolt *et al.*, "Preoperative opioid use and complications following total joint replacement: a protocol for a systematic review and meta-analysis," *BMJ Open*, vol. 10, no. 6, p. e035377, Jun. 2020, doi: 10.1136/bmjopen-2019-035377.

Sohail (Challenges)

[1] R. Vaishya and H. Lal, "Challenges, controversies, and innovations in arthroplasty," J Clin Orthop Trauma, vol. 9, no. 1, pp. 1–2, Jan. 2018, doi: 10.1016/J.JCOT.2018.01.004.

[2] R. Hasija et al., "Nerve injuries associated with total hip arthroplasty," J Clin Orthop Trauma, vol. 9, no. 1, pp. 81–86, Jan. 2018, doi: 10.1016/J.JCOT.2017.10.011.

[3] S. Akil, J. M. Newman, N. v. Shah, N. Ahmed, A. J. Deshmukh, and A. v. Maheshwari, "Metal hypersensitivity in total hip and knee arthroplasty: Current concepts," J Clin Orthop Trauma, vol. 9, no. 1, pp. 3–6, Jan. 2018, doi: 10.1016/J.JCOT.2017.10.003.

[4] R. Anand et al., "What is the benefit of introducing new hip and knee prostheses?," J Bone Joint Surg Am, vol. 93 Suppl 3, pp. 51–54, Dec. 2011, doi: 10.2106/JBJS.K.00867.

Eloise (Medica

[1] Derar H, Shahinpoor M. Recent Patents and Designs on Hip Replacement Prostheses. Open Biomed Eng J [Internet]. 2015 Apr 15 [cited 2022 Dec 2];9(1):92. Available from: /pmc/articles/PMC4397822/

[2] Dalli D, Buhagiar J, Mollicone P, Schembri Wismayer P. A novel hip joint prosthesis with uni- directional articulations for reduced wear. J Mech Behav Biomed Mater. 2022 Mar 1;127:105072.

[3] Fernández Palomo LJ, González Pola R, Castillo Vázquez FG. Iliopsoas Hematoma after Total Hip Arthroplasty Using a Minimally Invasive Modified Direct Anterior Approach: A Case Report. JBJS Case Connect. 2022 Mar 16;12(1).

Hassan

[1] "Joint Replacement Surgery," American College of Rheumatology, Feb. 2022. https://www.rheumatology.org/I-Am-A/Patient-Caregiver/Treatments/Joint-ReplacementSurgery (accessed Nov. 30, 2022).

[2] L. E. Bayliss et al., "The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study," Lancet, vol. 389, no. 10077, p.1424, Apr. 2017, doi: 10.1016/S0140-6736(17)30059-4.

[3] C. B. Chang, J. H. Yoo, I. J. Koh, Y. G. Kang, S. C. Seong, and T. K. Kim, "Key factors in determiningsurgical timing of total knee arthroplasty in osteoarthritic patients: age, radiographic severity,and symptomatic severity," J Orthop Traumatol, vol. 11, no. 1, p. 21, Mar. 2010, doi:10.1007/S10195-010-0086-Y.

[4] M. Fang, N. Noiseux, E. Linson, and P. Cram, "The Effect of Advancing Age on Total JointReplacement Outcomes," Geriatr Orthop Surg Rehabil, vol. 6, no. 3, p. 173, Sep. 2015, doi:10.1177/2151458515583515.

[5] P. Dieppe, K. Lim, and S. Lohmander, "Who should have knee joint replacement surgery forosteoarthritis?," Int J Rheum Dis, vol. 14, no. 2, pp. 175–180, May 2011, doi: 10.1111/J.1756-185X.2011.01611.X.

Presentation Board

[1] Legg-Calve-Perthes Disease," Mayo Clinic, 17-Jun-2022. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/legg-calve-perthes-disease/symptoms-causes/syc-20374343. [Accessed: 08-Dec-2022].

[2] S. Mills and K. E. Burroughs, “Legg Calve Perthes Disease - statpearls - NCBI Bookshelf,” National Library of Medicine, 11-Jul-2022. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK513230/. [Accessed: 08-Dec-2022].

[3] D. Dalli, J. Buhagiar, P. Mollicone, and P. Schembri Wismayer, “A novel hip joint prosthesis with uni-directional articulations for reduced wear,” Journal of the Mechanical Behavior of Biomedical Materials, vol. 127, p. 105072, Mar. 2022.

[4] S. Konan, M. P. Abdel, and F. S. Haddad, “Cemented versus uncemented hip implant fixation,” Bone & Joint Research, vol. 8, no. 12, pp. 604–607, Dec. 2019.

[5] D. S. Khokhar, “Cemented and cementless knee replacement,” Complete Orthopedics | Multiple NY Locations, 03-Nov-2022. [Online]. Available: https://www.cortho.org/knee/cemented-and-cementless-knee-replacement/. [Accessed: 08-Dec-2022].

[6] N. C. Paxton, M. C. Allenby, P. M. Lewis, and M. A. Woodruff, “Biomedical applications of polyethylene,” European Polymer Journal, vol. 118, pp. 412–428, Sep. 2019.

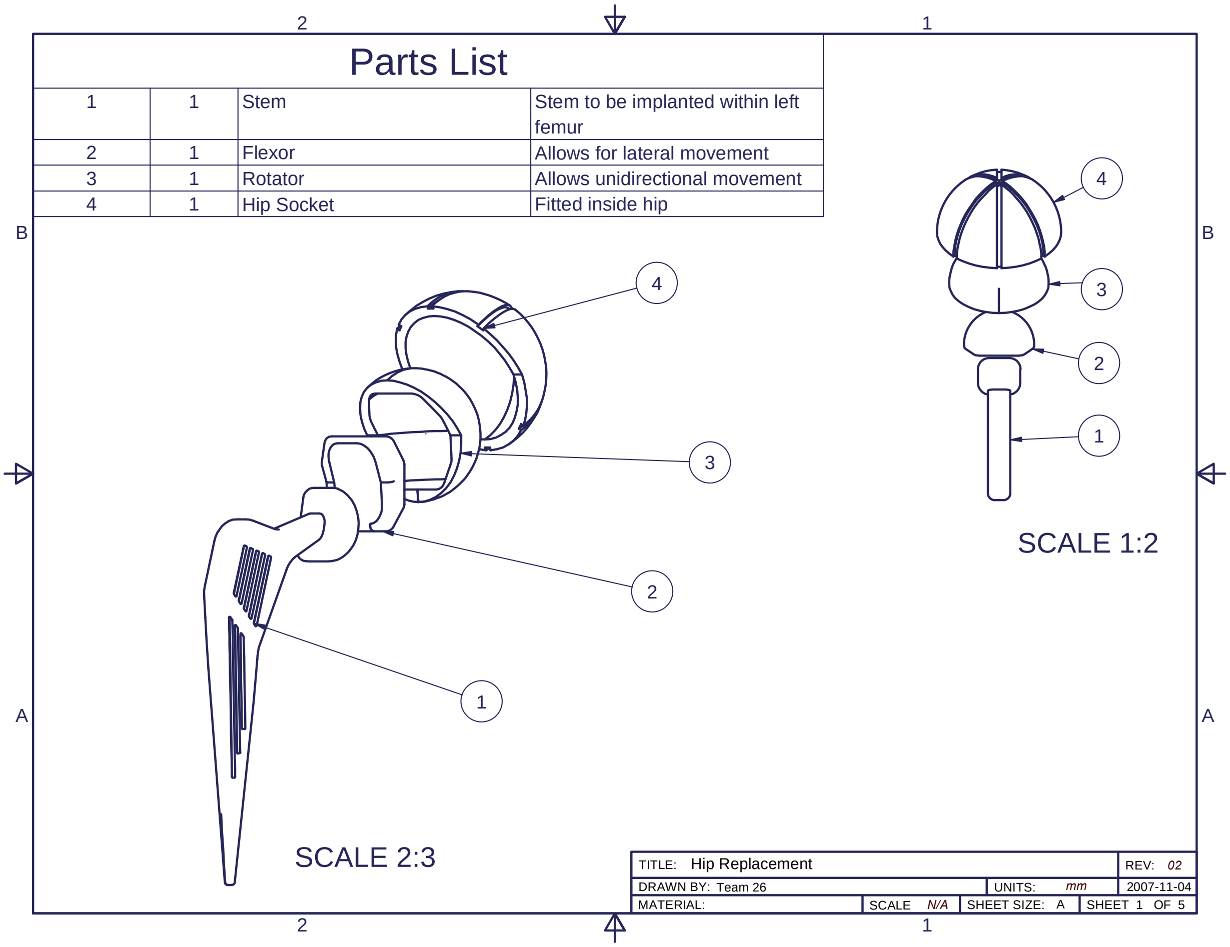
[7] H. Derar and M. Shahinpoor, “Recent patents and designs on hip replacement prostheses,” The Open Biomedical Engineering Journal, vol. 9, no. 1, pp. 92–102, 2015.

[8] Q. Chen and G. A. Thouas, “Metallic implant biomaterials,” Materials Science and Engineering: R: Reports, vol. 87, pp. 1–57, Jan. 2015.

Appendix D: Additional Documentation

Figure 1- Coordinator Sohail Persaud Earning the Golden Duck for his Hard Work

Figure 2- First 3D Print Attempt



1	1	Stem	Stem to be implanted within left femur
2	1	Flexor	Allows for lateral movement
3	1	Rotator	Allows unidirectional movement
4	1	Hip Socket	Fitted inside hip

Figure 3 – Engineering drawings of the final hip implant

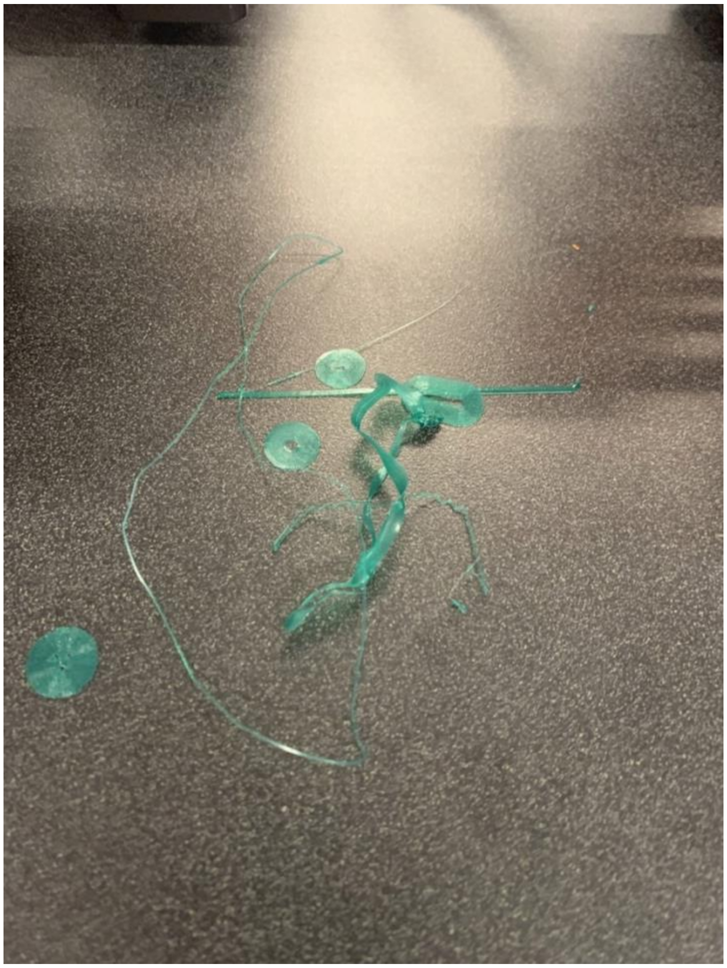


Figure 4- Failed 3D Print Attempt

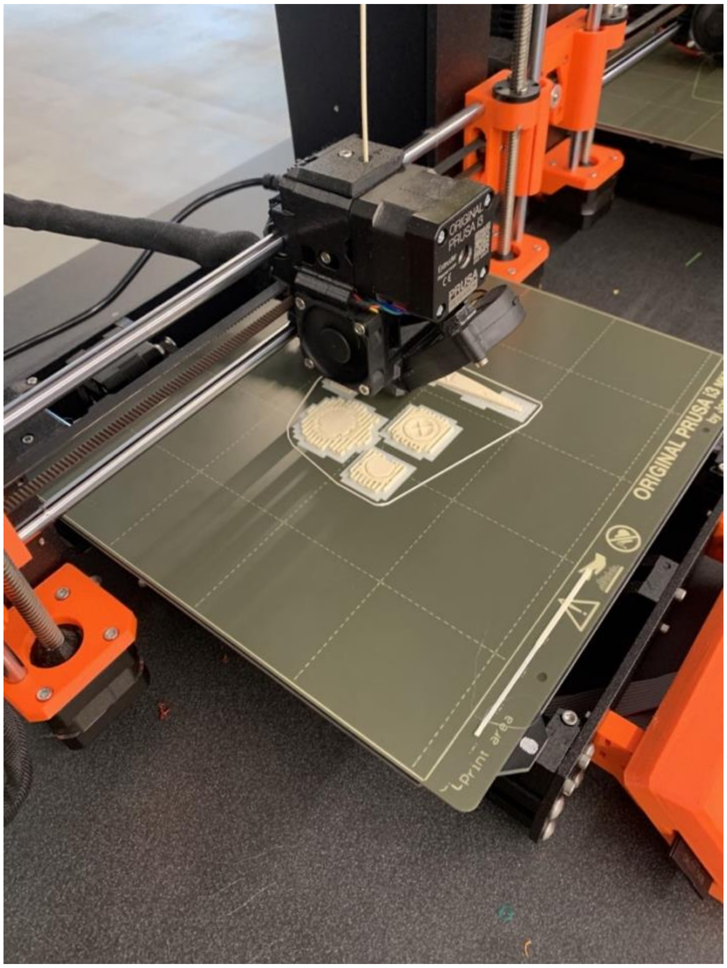


Figure 5- Final 3D Print

Figure 6- Final 3D Printed Implant

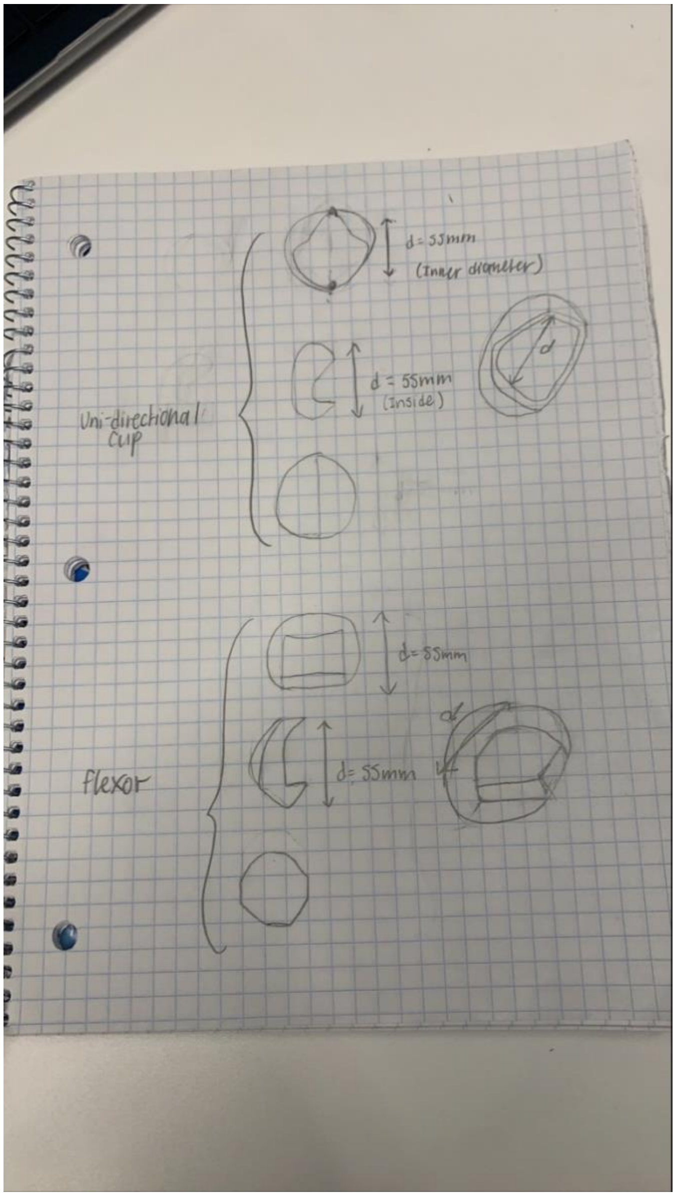


Figure 7 – Rough draft of the hip implants in multipview 1

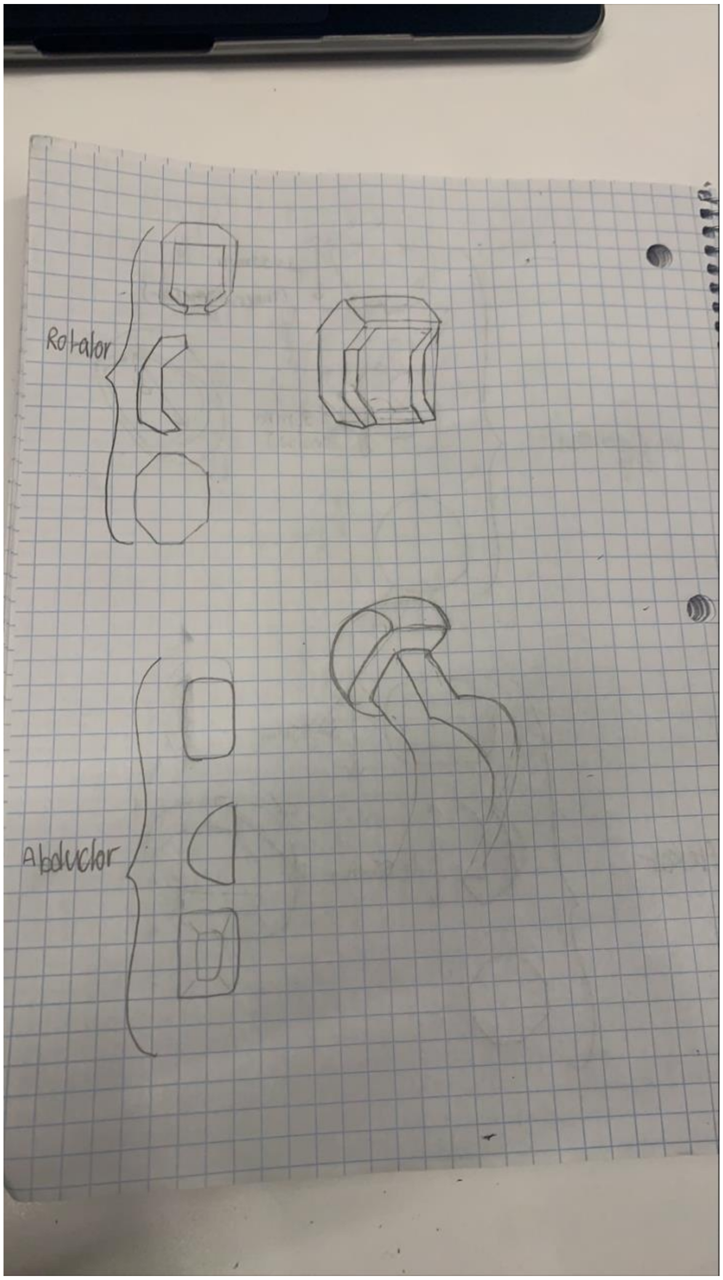


Figure 8 – Rough draft of the hip implants in multipview 2

Figure 9 – CAD modelling of the hip implant

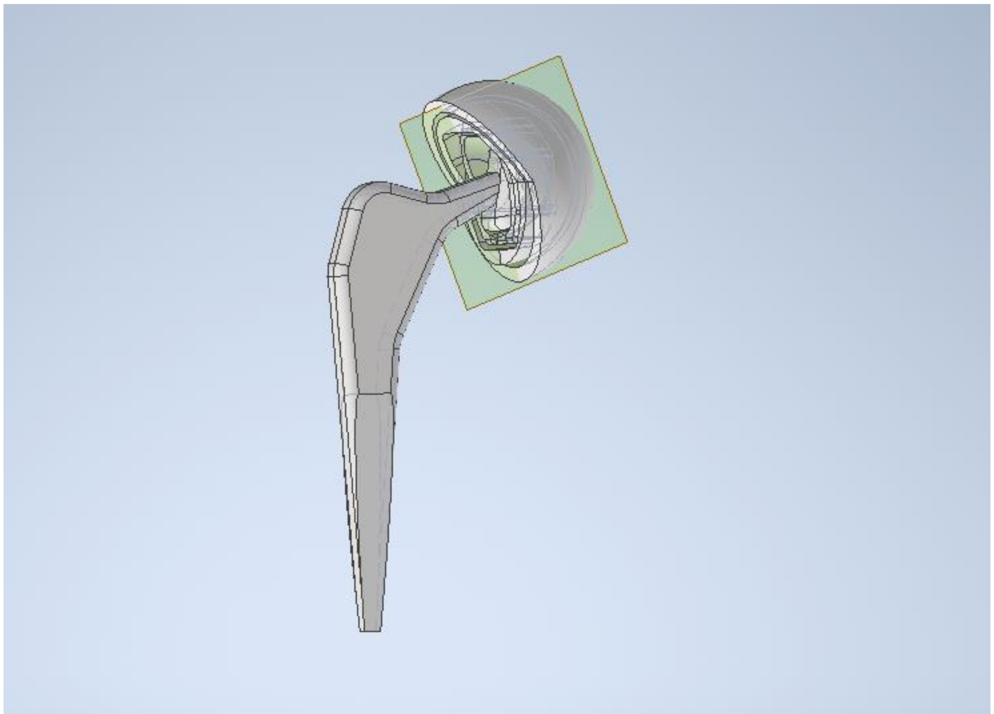


Figure 10 – CAD modelling with of the hip implant with sketches visible

Figure 11 – 3D prototype

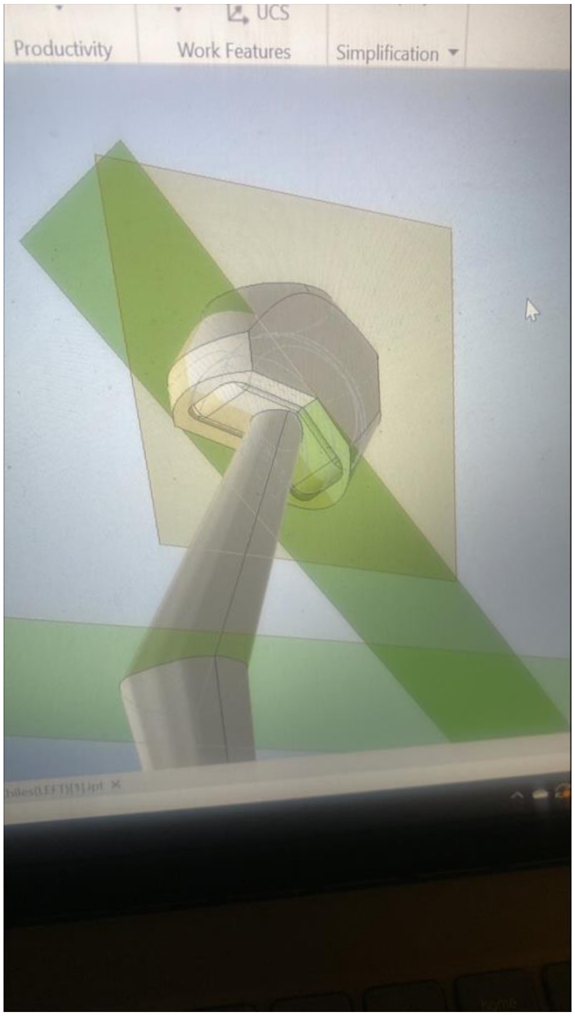


Figure 12 – 1st iterations of the CAD model

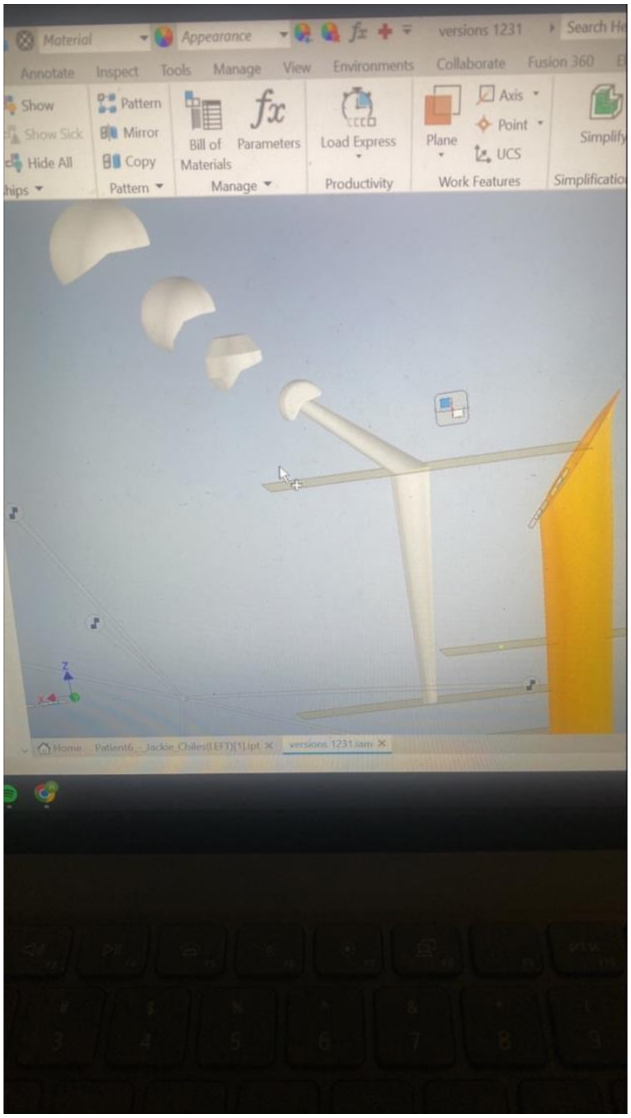


Figure 12 – 2nd iterations of CAD model

```
#Subprogram One
def min_stem_dia():
    min_stem_dia=0
    canal_d_range=[]

    for i in range (1,1900):
        canal_d_range.append(float(i)/100.0) #input all possible diamters up to canal diameter

    for d in canal_d_range: #run through all the diameters to see which produces a tensile stress that equals the ultimate tensile stress
        force = 3.25 * body_weight
        area =(math.pi/4) * ((d)**2)
        moment = force * femoral_head_offset
        y= 0.5 * d
        i = (math.pi/64) * (d**4)
        axial_stress = force/area
        bending_stress = (moment * y)/i
        app_ten_stress = int(axial_stress + bending_stress)

        if app_ten_stress == ult_ten_strength: #if the applied stress equals ultimate strength, dia is at its minimum
            min_stem_dia = d
```

Figure 13 – First step of coding program for minimum stem diameter

```python
#Subprogram Two
def convert_to_int(dataset): #converts data to integers
   data = []
   for row in dataset:
       row_list = []
   for col in row:
       value = float(col)
       row_list.append(value)
   data.append(row_list)
   return data

def failed_cycles_adj_stress():
    force=10*body_weight
    area=(math.pi/4)*(stem_dia**2)

    max_stress = force/area
    min_stress = -force/area

    amplitude_stress = (max_stress - min_stress)/2

    file = open('SN Data - Sample Metal.txt','r')
    failed_cycles = []
    for line in file:
        cycles = line.split()
        failed_cycles.append(cycles)

    failed_cycles = convert_to_int(failed_cycles)

    for i in range(len(failed_cycles)):
        kn = 9.25 + (math.log(failed_cycles[i][1],10)**((0.65*team_number)/40))
        adjusted_stress_amplitude = kn * amplitude_stress

        if adjusted_stress_amplitude > failed_cycles[i][0]: #if the adjusted stess amplitude is greater than the stress amplitude S, it corresponds to failure
            print('Number of cycles before failure:',failed_cycles[i][1], '\nAdjusted stress amplitude:',adjusted_stress_amplitude, 'N/mm^2\n')
```

Figure 14 – Second step for find the number of cycles and adjusted stress before failure

```python
#Subprogam Three
def years_before_risk():
    area = (math.pi/4) * ((outer_dia - canal_diameter) ** 2)
    force = 28 * body_weight
    comp_strength = force/area
    stress_reduc = comp_strength * (((4 * modulus_bone)/(modulus_bone + modulus_implant)) ** (1/3))
    E_ratio = math.sqrt(modulus_implant/modulus_bone)

    for i in range(0,20): #hip implants usualy last for 10-20 years, i represents the years from post-surgery to 20 years
        stress_fail = ((0.0012 * (i ** 2))-(3.725 * i * E_ratio) + 186.42)
        if stress_fail>stress_reduc:
            print('Stress failure:',stress_fail, 'N/mm^2')
            print('Number of years before femoral fracture:', i, '\n')
```

Figure 15 – Third step for finding the life span of the implant before failure

Appendix E: Design Studio Worksheets

See next page for Milestones

Milestone 0 (Team) – Cover Page

Team Number: 26

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

Full Name:	MacID:
Hassan Bokhari	bokharh
Eloise Nguyen	nguyt126
Sohail Persaud	persas29
Rory Sucharov-Gluck	sucharor

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: 26

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.	Eloise Nguyen	☐M ☒A ☐C ☐S
2.	Sohail Persaud	☐M ☐A ☒C ☐S
3.	Rory Sucharov-Gluck	☒M ☐A ☐C ☐S
4.	Hassan Bokhari	☐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	Rory Sucharov-Gluck	sucharor
Administrator	Eloise Nguyen	Nguyt126
Coordinator	Sohail Persaud	persas29
Subject Matter Expert	Hassan Bokhari	Bokharh

MILESTONE 0 – TEAM CHARTER

Team Number: 26

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

Sub-Team:	Team Member Name:	MacID
Computing	Hassan Bokhari	Bokharh
	Rory Sucharov-Gluck	sucharor
Modelling	Sohail Persaud	persas29
	Eloise Nguyen	Nguyt126

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

Milestone 1 (Team) – Cover Page

Team Number: 26

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

Full Name:	MacID:
Hassan Bokhari	Bokharh
Sohail Persaud	persas29
Eloise Nguyen	Nguyt126
Rory Sucharov-Gluck	sucharor

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: 26

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

SYMPTOMS:	- Persistent left hip pain and occasional waves of surging right hip pain starting at age 10 - Limp that became more pronounced over time
IMAGING INDICATORS:	- Figure 1: indicates an asymmetry in the femur bones, with the left proximal femur being more compressed and pushed up. - Figure 2: lesion in the femur joint, potential damage to the femur bone - Figure 3: Lack of cartilage space compared to normal - Figure 4: The femur bone has direct contact with the hip sockets
PREVIOUS MEDICATIONS / DOCTOR VISITS:	- Physio regimen from childhood until early teenage years - Tramadol, 100mg per day (ineffective) - Oxycodone, 2.5mg per day
MISCELLANEOUS NOTES:	- Negative family situation made physio less prioritized and impacted his wellbeing as well as the attention put towards helping his pain

2. Record your final diagnosis in the space below.

FINAL DIAGNOSIS:	- Legg–Calvé–Perthes Disease (LCPD)

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

MILESTONE 1 – OBJECTIVES AND CONSTRAINTS

Team Number: 26

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	• Should reduce constant hip pain • Should allow him to walk without need for rest • Should extend his range of motion without a cane

CONSTRAINTS	• Must replace both the hip socket and the femoral head (due to the deformity of both components) • Must be composed of bio-safe material and be non-toxic • Must be sterile • Must be able to be implanted safely • Must allow hip motion and mobility

MILESTONE 1 – NEED STATEMENT

Team Number: 26

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 hip replacement for Mr. Chiles, an individual with LCPD, which will reduce hip pain and improve his ability to walk without resting.

Milestone 2 (Team) – Cover Page

Team Number: 26

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

Full Name:	MacID:
Eloise Nguyen	Nguyt126
Rory Sucharov-Gluck	sucharor
Sohail Persaud	persas29
Hassan Bokhari	Bokharh

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 2 (STAGE 2) – DESIGN FEEDBACK

Team Number: 26

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

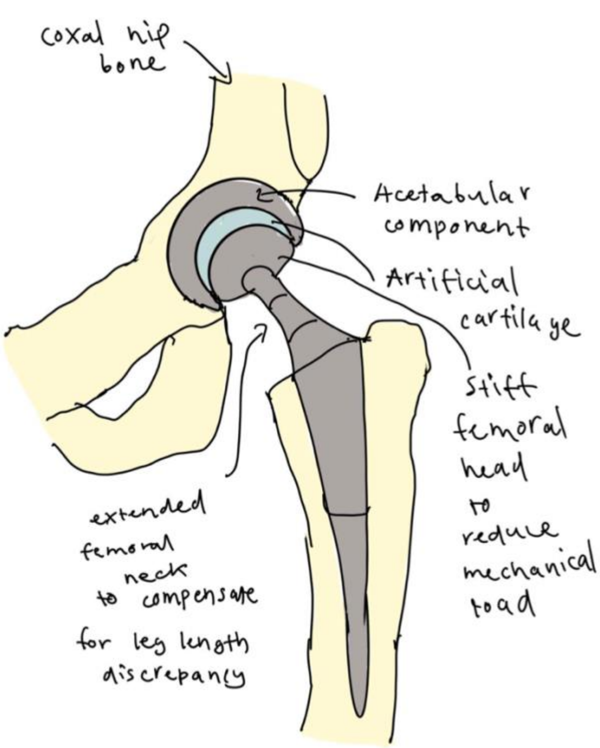
→ You can communicate your design revisions either by annotating directly on your team member's sketch or listing bullet-point descriptors

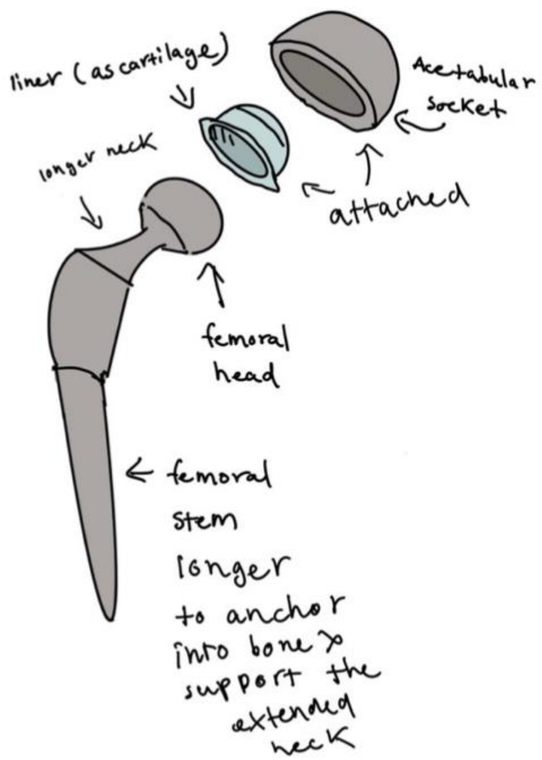
- If annotating directly on a sketch, save your file as a JPEG
- Insert your photo as a Picture (Insert > Picture > This Device)
- **Do not include feedback for more than one team member per page**
    - For each additional team member, copy and paste the table below

Design Feedback Entry

Your Name:	Eloise Nguyen	**Colleague's Name:**	ALL
Your MacID:	Nguyt126	**Colleague's MacID:**	ALL

Design Feedback:





Constraints:

- Left leg 1cm shorter than right
- Flattened acetabulum
- Biocompatible, safe for surgical implantation

Ideas:

- Liners can be grown from partient's cartilage to mimic its function. Can secretes lubrication to reduce friction and wear. Improve mobility.

Feedback- Rory:

- Considers biocompatibility and materials- very important
- Introduces method of implantation
- Accounts for the shortened leg
- Should also explain how the socket will be modified to accommodate the new joint

Feedback- Sohail:

- Well thought out with lots of details and colour differences to show 3D modelling
- Takes into consideration the different leg heights and shape of existing bones considering the LCPD
- **Revision:** cartilage can be more of a cement fixation/glue instead to integrate into natural bone structure

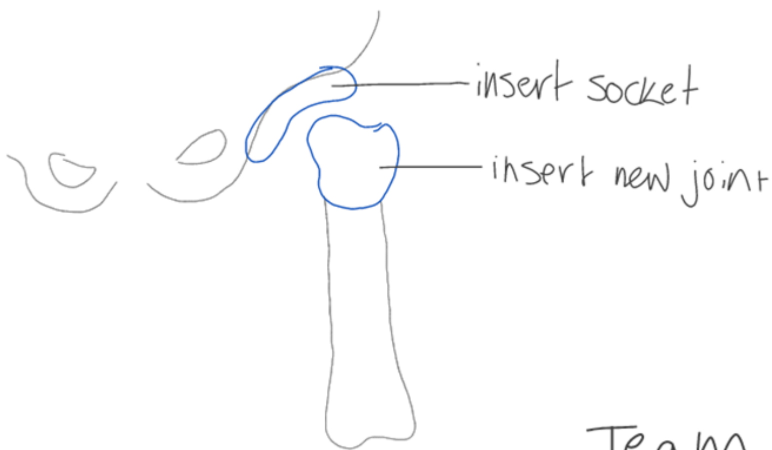
Feedback- Hassan:

- Very well detailed and love the color.
- The various things taken into consideration such as leg uneven and shape
- **Revision:** Possibly make it less thin at the end near the bearing as it could be a possible weak point for the device to fracture.

Design Feedback Entry

Your Name:	Rory Sucharov-Gluck	Colleague's Name:	ALL
Your MacID:	sucharor	Colleague's MacID:	ALL

Design Feedback:



Team 26
Rory Sucharov-Gluck
sucharor

Feedback- Eloise:

- The insertion of a new (artificial) socket is very innovative. We would need to consider how that will change the proportion and symmetry of the hip bone as it's adding thickness onto the flattened socket.
- The new joint is a good idea, however, further elaboration on how it would be attached to the leg bone.
- **Revision:** adding attachment to the new joint and bone to anchor it. It can be cement or a femoral stem.

Feedback- Sohail:

- Added material to socket is a potentially good idea to use for design solution
- Different colours make the key parts of design clear
- **Revision:** add a layer in between that acts as a cartilage to connect the head and socket

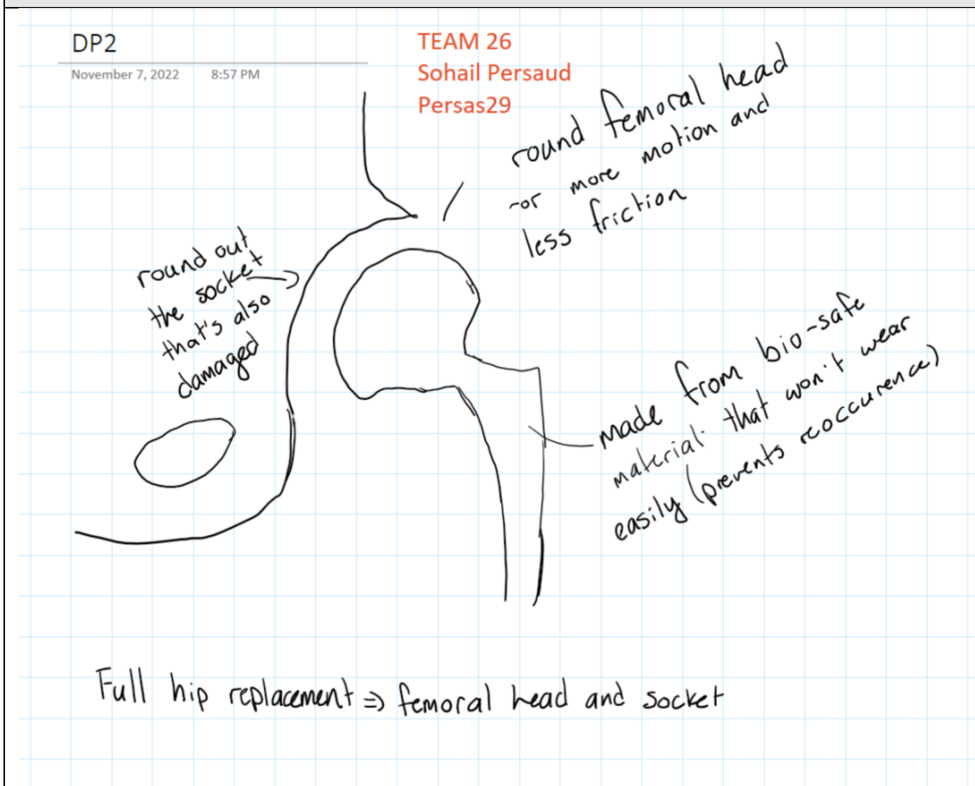
Feedback- Hassan:

- Shows an idea of like a joint where it is more compact and less extended
- **Revision:** Including a more specific and tighter method to anchor the socket and head to prevent it from sliding and stay in socket.

Design Feedback Entry

Your Name:	Sohail Persaud	**Colleague's Name:**	ALL
Your MacID:	persas29	**Colleague's MacID:**	ALL

Design Feedback:



Feedback-Eloise:

- A safe solution that ensures 100% compatibility since you're not introducing new materials. It might take some time to shave down the bone which can extend the surgery time.
- **Revision:** consider some sort of cushion between the hip socket and the femoral head such as a plastic liner.

Feedback-Hassan:

- Good consideration of materials
- Interesting to consider how procedure towards how it would be installed with the rounded bone
- **Revision:** Consider a more prominent socket within the hip as it doesn't seem like enough to really anchor the point

Feedback-Rory:

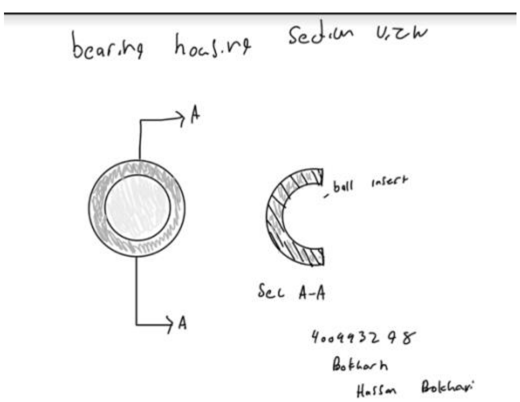
- Takes great care in considering effects of motion (e.g. frictional forces)
- Considers materials

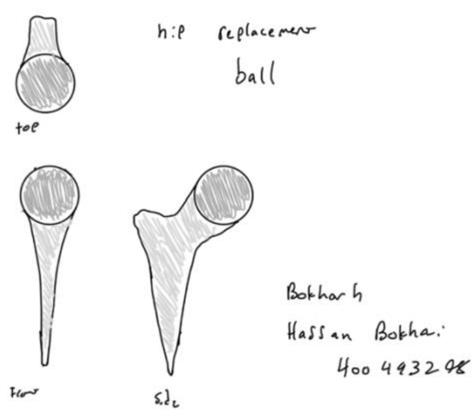
- Solid plan to round out socket- need to figure out how
- **Revision:** How will the new joint attach to the femur? Perhaps including nails/glue to anchor the new joint

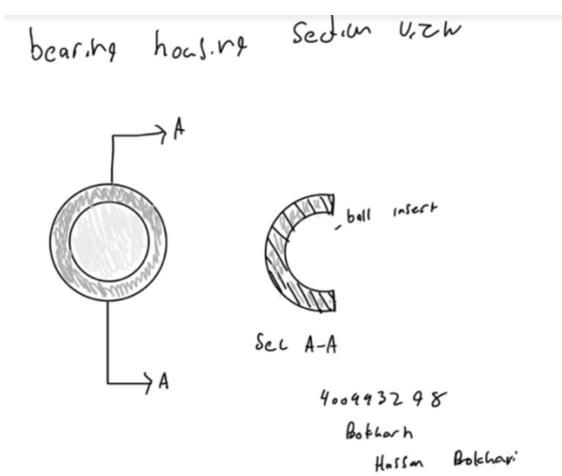
Design Feedback Entry

Your Name:	Hassan Bokhari	Colleague's Name:	All
Your MacID:	Bokharh	Colleague's MacID:	ALL

Design Feedback:







Feedback-Rory:

- Considers both pieces of the replacement

Feedback-Sohail:

- Bearing is an interesting idea that would allow for rotational motion
- While a good idea, considering integration with new materials would be important
- **Revision:** consider a biosafe material that the femoral head will be made out of (maybe titanium with some sort of coating)

Feedback-Eloise:

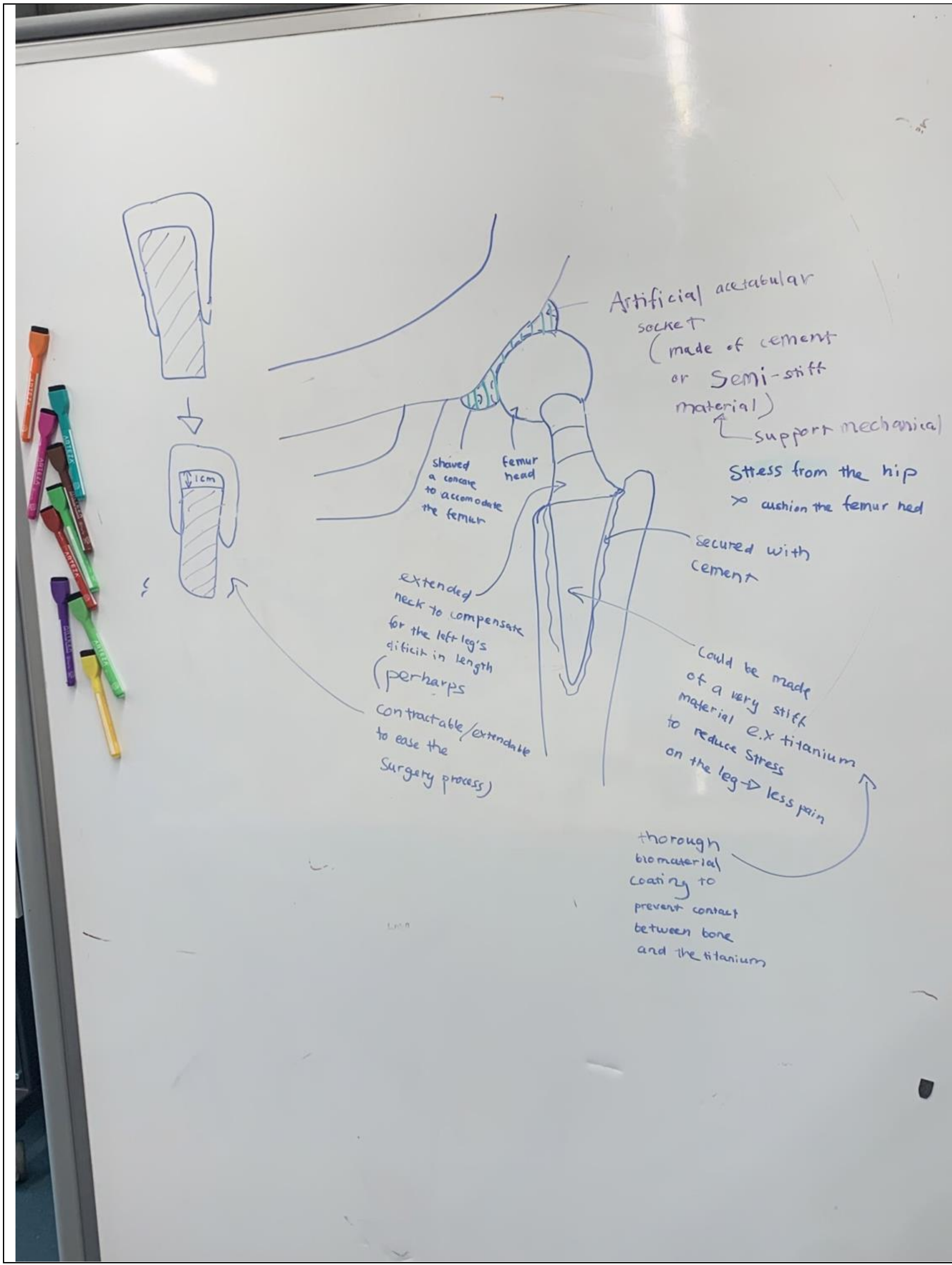
- Bearing is a really good idea. Try considering how there can be cushion to the artificial femur head and the bearing socket.
- **Revision:** add in a plastic liner between the femur head and the bearing.

MILESTONE 2 (STAGE 3) – REFINED CONCEPT SKETCH

Team Number:	26

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: 26

Discuss the advantages and disadvantages of your refined concept solution

Advantages	**Disadvantages**
• Allows the socket and joint to fit in place • Joint will be able to rotate in the socket while limiting pain • Compared to anchoring, cement fixation has increased longevity and reduced risk of creating new problems • Allow adjustment with the length of the device post-surgery	• Cementing the socket may not be extremely long-lasting • Joint can still erode socket • May require shaving the bone to insert the socket • Cement is susceptible to fractures, which can affect the actual bone of the patient

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

Conclusion:

The design solution would allow the socket and the joint to mesh properly, reducing stress and bone erosion. As the two components of the bone will fit in place, Mr. Chiles' ability to walk will be improved. Additionally, this accommodates objectives of being able to walk longer distances with reduced pain. This design will incorporate biosafe materials (e.g., cement) and materials to allow load bearing and range of motion. The integration of the artificial cement socket also minimize stress being applied onto the device and hip socket as its material is so stiff. The femoral head also help to reduce stress on the leg bone as it can be made of a stiff metal like titanium. This will overall alleviate the pain that Mr. Chiles feels around his left hip, as less compressive stress can be generated.

Overall, this solution combines preliminary sketches of the joint replacement, while incorporating a synthetic socket.

Milestone 3 (Team) – Cover Page

Team Number: 26

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

Full Name:	MacID:
Eloise Nguyen	Nguyt126
Sohail Persaud	persas29
Rory Sucharov-Gluck	sucharor
Hassan Bokhari	bokharh

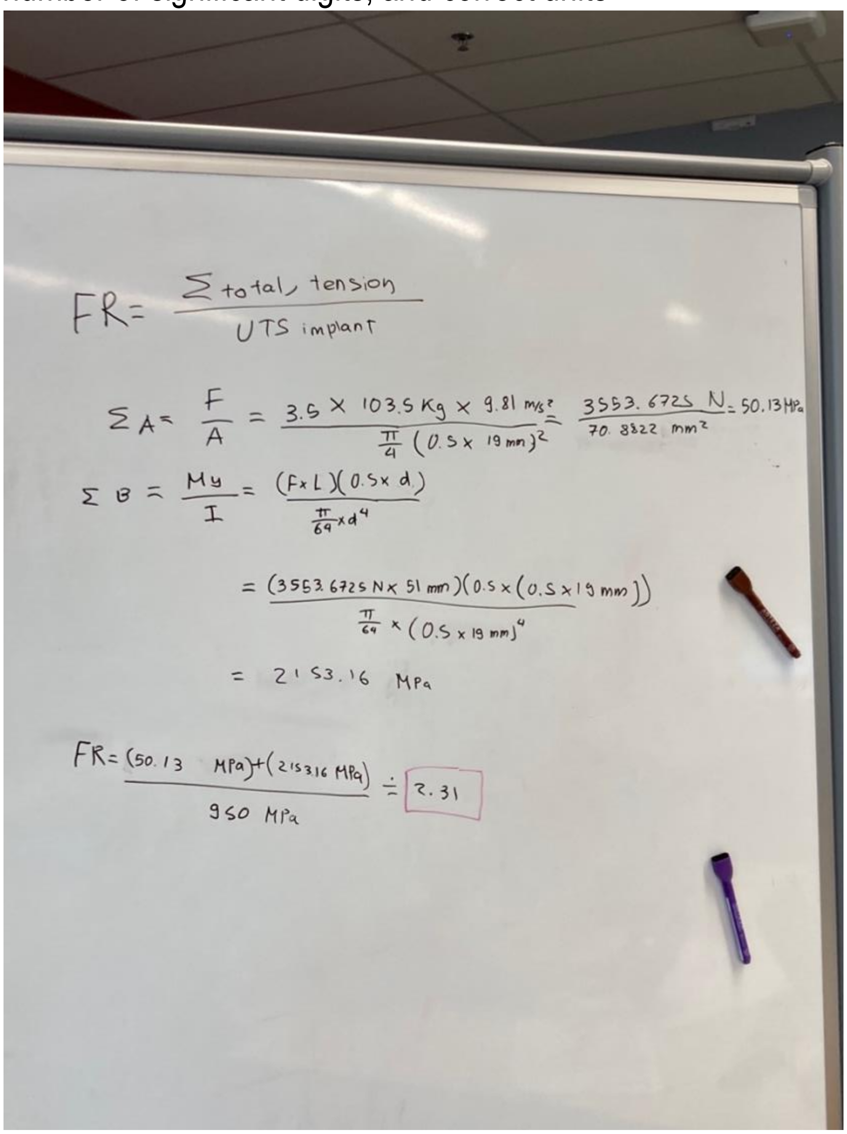
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-2 grade.

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

Team Number: 26

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



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

Team Number: | 26

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

$$\text{Stress Amplitude} = \frac{\Sigma max - \Sigma min}{2} = \frac{429.72\,\text{MPa} - (-429.72\,\text{MPa})}{2} = 429.72\,\text{MPa}$$

$$F_{max} = (103.5)(9.81)(30)$$

$$= 30\,460.05\,\text{N}$$

$$\Sigma_{max} = \frac{F_{max}}{A} = \frac{30\,460.05\,\text{N}}{70.8822\,\text{mm}^2} = 429.72\,\text{MPa}$$

$$F_{min} = -(103.5)(9.81)(30)$$

$$= -30\,460.05\,\text{N}$$

$$\Sigma_{min} = \frac{-30\,460.05\,\text{N}}{70.8822\,\text{mm}^2} = -429.72\,\text{MPa}$$

Looking at S-N curve,

Fatigue life $= 10^{5.25}$ cycles

MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS

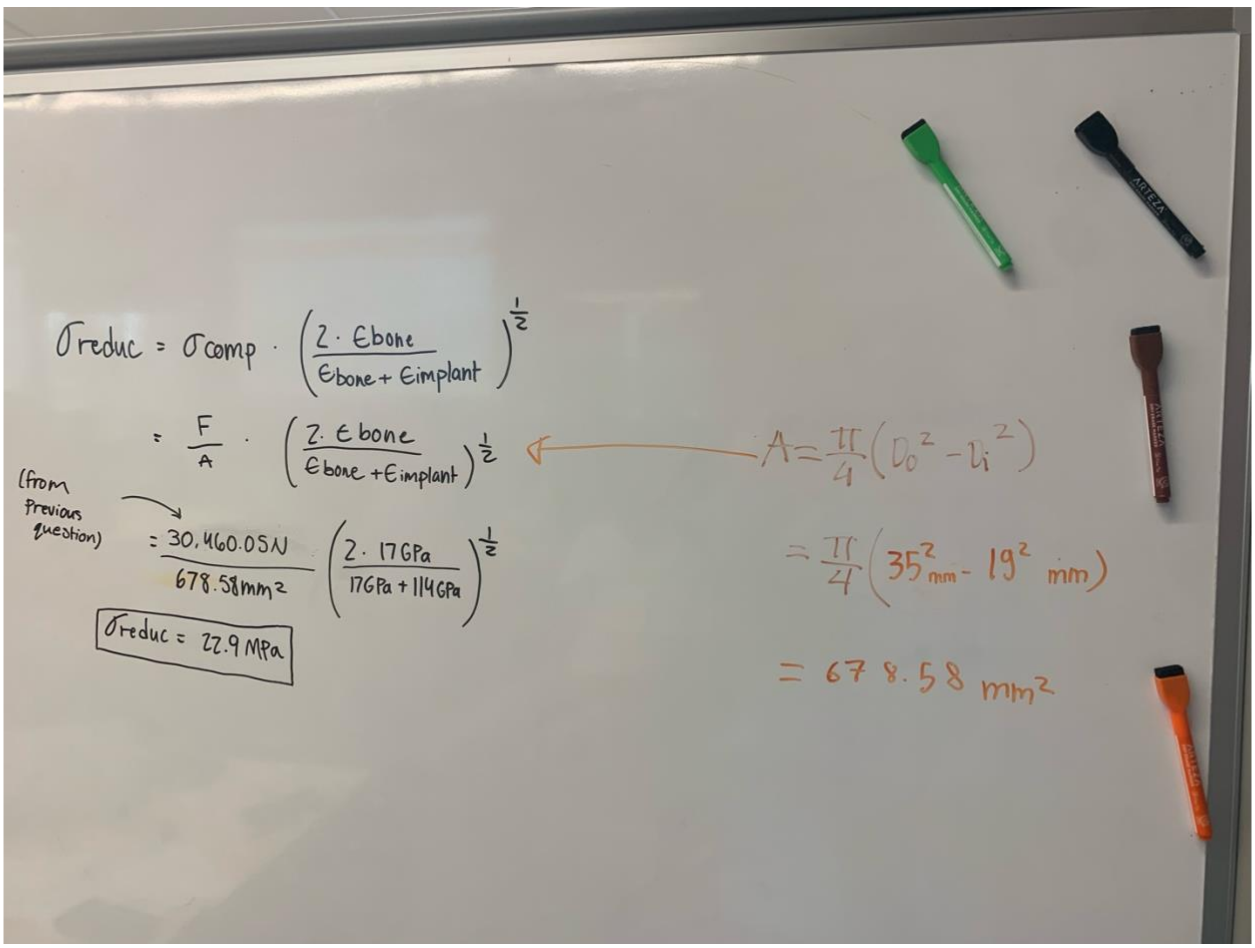
BONE STRESS REDUCTION

Team Number: 26

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



Milestone 4 (Team) – Cover Page

Team Number: 26

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

Full Name:	MacID:
Eloise Nguyen	Nguyt126
Rory Sucharov-Gluck	sucharor
Sohail Persaud	persas29
Hassan Bokhari	Bokharh

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 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

Team Number:	26

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 Head

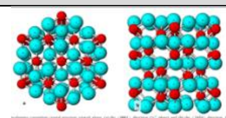
MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION
STRUCTURE

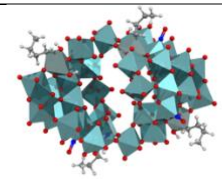
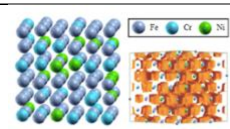
Team Number: 26

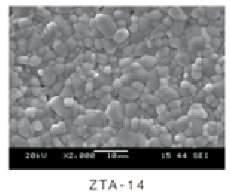
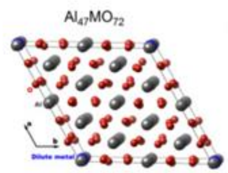
Fill in the Materials Selection table below related to the **STRUCTURE** of the material by *copy-and-pasting* each team members individual research. Discuss your findings as a team.

→ 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	Formula		
Ceramic alumina	Ceramic	 - Arranged in crystalline form, repeating structure (Lattice)	- Ionic bonding (metal and non-metal) - Not a hydrogen bond donor (computed)			

Molybdenum	Metallic	 - Body-centered cubic [6] - Lattice constant: a = 3.1470 Å [6]	- Metallic Bonding - Closely Packed atoms			
Ceramic Zirconia	Ceramic	- hexagonal structure - Monoclinic crystalline structure	Ionic bonding between Zr and O			
Carbon Fiber	Polymer	Carbon nanotubes made of hexagons (only carbons present)	Non-polar covalent bonds with the other Carbon atoms			
316L AISI Alloyed Stainless Steel	Metal alloy/ Ferritic	 Figure 1: The 108 atoms supercell of 316L stainless steel generated with the SQS method (left). [2]	- Metallic Bonding - Method towards creating alloy and metallic bonds involves Thermoplastic Bonding (TPB) creating atomic	Fe73Cr21Ni14 [2]		

		Ferritic – cube, shape, crystal, structure [2]	diffusion at high temperatures [3]			
BIOLOX Delta (patented name) Professionally known as Zirconia-toughened alumina – 14 (ZTA – 14)	Composite Ceramics	 [6]  [7] Monoclinic crystalline structure transformed from compressed tetragonal crystal structure [6]	- Zr-O bonds quantify many strength properties of material. [7] - Strong interatomic bonding in comparison with other RE's (reactive elements) [7] -Ionic bonding [6]	Zr-Al_2O_3 [6]		

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

PROPERTIES

Team Number: 26

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	
Silicon Carbide	410 GPa	390 MPa	4.60 MPa*m$^{1/2}$	Si_3N_4 sliding against Si_3N_4 showed low wear rate in both bovine serum and PBS. High wear resistance [3]	It resists against common acids: (hydrochloric acid, sulfuric acid, hydrobromic acid, and hydrofluoric acid). Resistant	

					against bases (amines, potash and caustic soda) and solvents and oxidizing media.	
Ceramic alumina	380GPa	325MPa	2.3 ± 0.2 MPa $m^{1/2}$	High wear resistance In Alumina ceramics, the wear rate is as low as 0.00052%	High corrosion resistance Resistance of alumina in aqueous solutions containing 0.1 mol/kg H_2SO_4, H_3PO_4 or HCl at T = 240°C–500°C is at p = 27 MPa	Excellent
Molybdenum alloy	343GPa	2100 MPa	40 MPa.m1/2	Very good	High corrosion resistance	Good
316L AISI Alloyed Stainless Steel	200 GPa [8]	586 MPa [8]	112-278 MPa m1/2 [9]	High wear resistance that can be increased with	Superior corrosion resistant	- Studies show biocompatibility of metal inside human body

				surface coating [10]	compared to other metals [8] -Performs well against corrosion in fresh water and saltwater systems [8] -Studies do show slight susceptibility to corrosion in biological environment long term. [10]	applications of implants etc. [10] - Adequate osteointegration [10] - Demonstrates superior biocompatibility [10]
BIOLOX Delta (patented name) Professionally known as Zirconia-toughened alumina – 14 (ZTA – 14) [4]	338 GPa [6]	689 MPa [11]	5-7 MPa. m1/2 [11]	Very hard and wear resistant [11]	-Very high corrosion strength even when put under pressure in different temperature environments [11]	-Relatively low volume to weight ratio advantageous to medical applications [11] -Suitable for orthopedic load-bearing components [12] -No adverse tissue reactions after implantation [12] -Great biocompatibility [12] -Chemical inertness [12]

						-Doesn't account for osteointegration [12]

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

Team Number: 26

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			
Ceramic Alumina	– Polyaleuritate coatings, self-esterized from naturally occurring	-surgical implantation of the femoral head made of this material	- Hard to corrode by HCl, easier by hydrofluoric and hydrochloric acid			

	fatty polyhydrodroxyacids. – Organic coating (formed by carbon-based polymeric chains derived from natural or synthetic matter) – Alclad (corrosion-resistant aluminum sheet to strengthen alumina)	attached to a femoral stem, both being coated with a protective barrier and assembled with the socket in the body.				
Silicon carbide	- Can be used as coating for hip replacement - Plasma spray coatings for biocompatibility and protection against corrosion and wear	- surgical implantation of the femoral head made of this material attached to a femoral stem, both being coated with a protective barrier and assembled with the socket in the body.	- Plasma spray - The material itself is resistant to corrosion			

Ceramic Zirconia	Possible zirconia coatings on stainless steel through laser/sol-gel technique	Mesoporous zirconia nanoparticles (MZNs) due to high surface area and biocompatibility	Relatively high corrosion resistance along with relatively high wear resistance			
Carbon Fiber	Vaporizing hydrocarbons can create pyrolytic carbon, a carbon fiber coating	Carbon Nanotubes (CNTs) have an ideal structure for drug delivery options	High resistance to corrosion, which makes it great for bio-integration			

MILESTONE 4 (STAGE 3) – PROPOSED MATERIAL

Team Number: 26

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

Proposed Material:	Carbon coating around

	Cobalt – Chromium - Molybdenum

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

The material has high biocompatibility, good wear (with carbon coating), high corrosion resistance, high ultimate strength, high corrosion resistance and reduces friction.

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

Due to the patient's lifestyle, the implant must be designed to be long lasting and accommodate the patient's weight. Cobalt – Chromium – Molybdenum has good wear, meaning that it could last a long time without need for replacement. The material has a high ultimate strength, which would endure the patient's weight.