Design Project 2 – Hips Don’t Lie - Hip Arthroplasty

C.H.I.L.E.S.

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 04

Team 06

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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.

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(Student Signature) *

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David Segal-Pillemer 400378130

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(Student Signature) *

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Marco Tan 400433483

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(Student Signature) *

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Ronav Roy Chowdhury 400438474

________ ___________________ (Student Signature) *

Main Body

Summary of 3D Printing Process:

Safana's Summary:

In terms of layout for the 3D printed components, the most efficient configuration was selected for each component. For instance, for the femoral head and stem, it was laid on its side to allow the 3D printer to print it in a balanced way that would adhere to the printing bed. Additionally, for the liner and acetabular cup, they were oriented in a way that allowed their sockets to face upwards and away from the printing bed. This aided in easily removing the supports following the printing process. Additionally, the three components within the design were placed relatively close to each other to reduce the distance that the printing nozzle had to travel, which decreased printing time. To further reduce printing time, the design of our hip implant was scaled down to 35%. With these slicing modifications, the printing time was narrowed down to an hour and twenty-two minutes.

Olivia's Summary:

There were many steps involved in successfully printing 3-D model of the hip implant design. Once the sub-modelling team created and explained their design, the group decided to move forward with the printing. To maximize efficiency regarding printing time and reducing potential for failure, the implant was printed sideways. This orientation would allow for extra support because more of the print is adhered to the printing bed. In addition, a lower percentage for filling was used to reduce printing time to an hour and twenty minutes. The model was also scaled down to 35%, and the components were printed closer together to reduce printing time. The first attempt at printing did fail; this was noticed as initially appearing flaky, then completely detaching from the printing bed. By drawing conclusions from these results, one could argue that the modifications made would enhance the overall printing experience, regardless of the failed print.

Ronav's Summary:

Before commencing the 3D printing process, it was crucial that all the parts to be printed were placed in an orientation that would ensure that they could be printed without any mistake. As a result, most of the hip implant components were placed sideways on PrusaSlicer. Using the 3D printer itself was a new endeavour for me but exporting the file into the SIM card and changing the settings of the 3D printer to whatever was desired became easy once it was done once. Unfortunately, the first print attempt resulted in failure as the product and framing appeared to be very flaky and as a result, the model was scaled down by 35% and the components were placed closed to each other. Once these adjustments were made, the printing process was both shortened and made more accurate. Overall, lowering the printing time to 1 hour and 22 minutes improved efficiency.

David's Summary:

This was my first time using a 3D printer, so the process was new to me. Once I uploaded the files to PrusaSlicer, I was informed that the best way to configure the objects to minimize print time was to put as much surface area as possible on the ground, to minimize the number of supports needed. Once I did this, the print time shrunk about 25 minutes, which is quite significant. The first time we printed, the 3D printer malfunctioned, and the print failed, which was quite frustrating. It shows the limitations of 3D printers because not only does it take a long time to get a print, but it can also fail at any moment, which restarts the whole process again. Overall, it was an informative first experience, and as I get more familiar with 3D printing the process of setting it up will be more efficient.

Marco's Summary:

I have used 3D printers before, so the process was not significantly new to me. However, the complex geometries involved in this project meant it was more of a challenge getting the parts printed this time. I had to mess around with the placement of the objects in the GCODE-generating software to reduce the print time as much as possible. This involved reorientating the objects to be as close as possible and have as much surface area on the print bed as possible, to reduce the amount of support that would be created. We also had to scale down the model significantly. The first print attempt failed as the model got stuck to the print head, which is a limitation of printing. Another limitation was the amount of detail it could provide, as the finer details like screw holes and ridges were not printed with complete accuracy.

Summary of Contributions:

Safana's Contributions:

As a coordinator, Safana took thorough notes following every meeting with the teaching assistants. As well, as a part of the sub-modelling team, she successfully designed and configured the femoral head and stem of the hip implant. Moreover, she was an active participant within the 3D printing stage. She booked time slots for 3D printing and diligently awaited the completion of the 3D print. Additionally, she attended meetings regarding poster layout and played a key role in the curation of the layout and content on the poster board. Furthermore, she dedicated time to completing the final report and ensuring all the criteria were met. Overall, she collaborated with her teammates to deliver a one of a kind prothesis.

Olivia's Contributions:

Olivia was responsible for keeping track of, and organizing the references used throughout the duration of the project. She was a part of the sub-coding team, and thus was responsible for completing the code for each subprogram, and the overall main function. More specifically, she worked mainly on subprogram 2, while still assisting other group members with their subprogram and the main functions. She participated in the printing of the 3-D models, monitoring one of the prints, and even detecting when it failed. She was involved in each design studio and other meetings outside the classroom, and she also helped pitch creative ideas for the prototype, materials selection, and the naming of the product.

Ronav's Contributions:

As an administrator, Ronav ensured that weekly and final deliverables were completed in a timely fashion and never submitted late. He was also a member of the computation sub-team and he specifically focused on completing subprogram 1. He also assisted the other computation sub-team members with their subprograms and heavily contributed towards the main function. Apart from coding, Ronav made valuable contributions towards the initial prototype, material for the acetabular cup/femoral stem, and poster presentation. Finally, Ronav aided the other members inside and outside of design studio with 3D printing and designing the poster.

David's Contributions:

David's administrative role was coordinator. He was tasked to take notes at weekly meetings as well as keeping team members informed on their future action items. He was on the programing sub team and was mainly responsible for the code of subprogram 3 but collaborated with team members if they needed any assistance. He used his computer for the programing team's 3D print. As well, he contributed to putting together the content and presentation of the poster board and contributed to the final report.

Marco's Contributions:

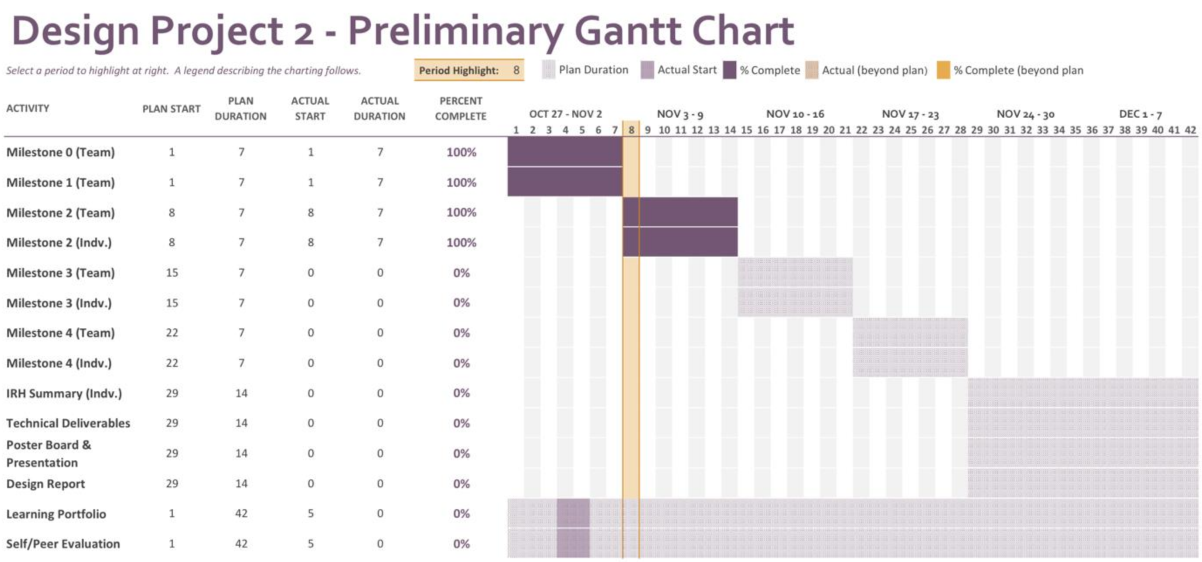
Marco was tasked with the overall management of the team as team manager. He was responsible for creating the agendas for each weekly meeting and facilitating the breakdown of the project into small sub-teams. He was on the modelling sub-team and was responsible for the design of the acetabular cup and liner. He was also responsible for ensuring all CAD-ed parts fit together in the final assembly. He facilitated

3D printing by generating efficient GCODE for the printing process. He was involved in every Design Studio session in and outside of the classroom and helped to design the final poster board for the presentation.

Appendices

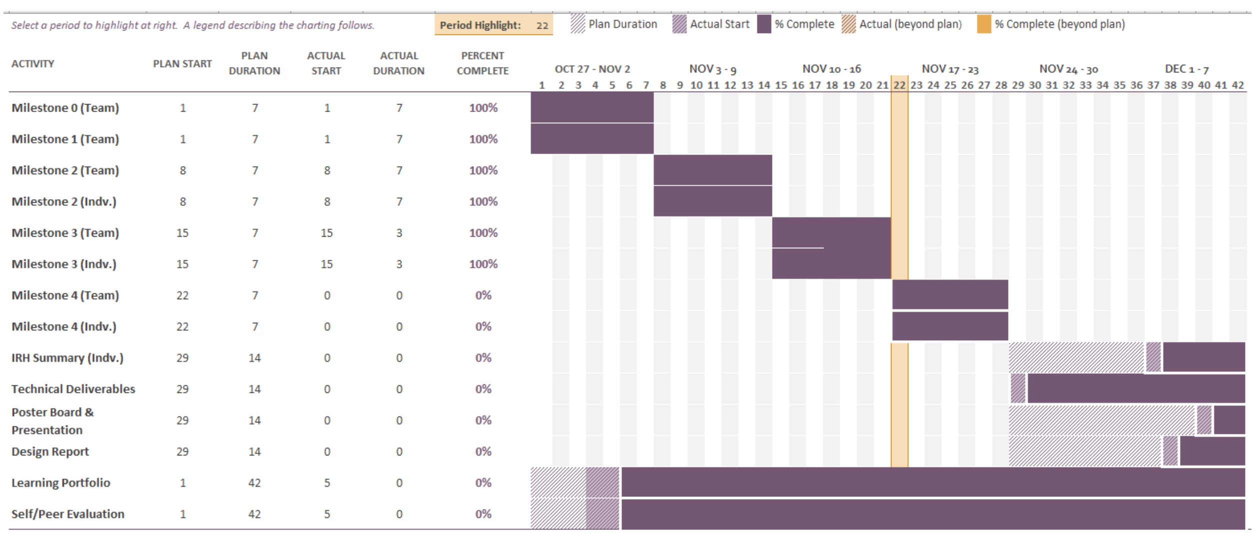
Appendix A: Project Schedule

Preliminary Gantt Chart:



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	7	1	7	100%
Milestone 1 (Team)	1	7	1	7	100%
Milestone 2 (Team)	8	7	8	7	100%
Milestone 2 (Indv.)	8	7	8	7	100%
Milestone 3 (Team)	15	7	0	0	0%
Milestone 3 (Indv.)	15	7	0	0	0%
Milestone 4 (Team)	22	7	0	0	0%
Milestone 4 (Indv.)	22	7	0	0	0%
IRH Summary (Indv.)	29	14	0	0	0%
Technical Deliverables	29	14	0	0	0%
Poster Board & Presentation	29	14	0	0	0%
Design Report	29	14	0	0	0%
Learning Portfolio	1	42	5	0	0%
Self/Peer Evaluation	1	42	5	0	0%

Final Gantt Chart:



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Milestone 0 (Team)	1	7	1	7	100%
Milestone 1 (Team)	1	7	1	7	100%
Milestone 2 (Team)	8	7	8	7	100%
Milestone 2 (Indv.)	8	7	8	7	100%
Milestone 3 (Team)	15	7	15	3	100%
Milestone 3 (Indv.)	15	7	15	3	100%
Milestone 4 (Team)	22	7	0	0	0%
Milestone 4 (Indv.)	22	7	0	0	0%
IRH Summary (Indv.)	29	14	0	0	0%
Technical Deliverables	29	14	0	0	0%
Poster Board & Presentation	29	14	0	0	0%
Design Report	29	14	0	0	0%
Learning Portfolio	1	42	5	0	0%
Self/Peer Evaluation	1	42	5	0	0%

Appendix B: Scheduled Weekly Meetings

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MEETING WITH TEAM 06 - 2022-11-03

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Marco Tan	tanm27	Y
Administrator	Ronav Roy Chowdhury	roychr2	Y
Coordinator 1	David Segal-Pillemer	segalpid	Y
Coordinator 2	Sefana Al-Emara	alemaras	Y
Subject Matter Expert	Olivia Dmitrovich	dmitrovo	Y
Guest	N/A	N/A	N/A

Agenda Items

1. Weekly check-in with everyone (stress levels, small talk).
2. Begin project work for the week.

Meeting Notes

1. The final design must align with the patient's need statement
2. Even though the guy is old we must take into consideration the normal lifespan of a male
    a. We must improve quality of life as final goal
3. Discussed two ideas that we have and then Aiden suggested that we combine both ideas into one

Post-Meeting Action Items

1. *Design ideas for the hip implant.*

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MEETING WITH TEAM 06 - 2022-11-10

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Marco Tan	tanm27	Y
Administrator	Ronav Roy Chowdhury	roychr2	Y
Coordinator 1	David Segal-Pillemer	segalpid	Y
Coordinator 2	Sefana Al-Emara	alemaras	Y
Subject Matter Expert	Olivia Dmitrovich	dmitrovo	Y
Guest	N/A	N/A	N/A

Agenda Items

1. Weekly check-in with everyone (stress levels, small talk).
2. Check-in with materials lab with everyone.
3. Begin project work for the week.

Meeting Notes

1. Do worksheet (Milestone 3)
2. Clarified who is on which sub team

Post-Meeting Action Items

2. Study chem and keep working on DP2!
3. Keep thinking about the best materials to use

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MEETING WITH TEAM 06 - 2022-11-17

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Marco Tan	tanm27	Y
Administrator	Ronav Roy Chowdhury	roychr2	Y
Coordinator 1	David Segal-Pillemer	Segalpid	Y
Coordinator 2	Sefana Al-Emara	Alemaras	Y
Subject Matter Expert	Olivia Dmitrovich	Dmitrovo	Y
Guest	N/A	N/A	N/A

Agenda Items

4. Weekly check-in with everyone (stress levels, small talk).
5. Plan out modified timeline for project deliverables.
6. Begin project work for the week.

MEETING NOTES

3. Figuring out timeline for project deliverables
4. Milestone 4 is up & available for us to do
5. Split up subprograms for programming team or possible to do it all together
6. Focus on cup that fits into the acetabulum (does not have to align perfectly with acetabulum because bone cement exists for that)
7. Cup shape cannot be altered, can only make it bigger (possible modifications)
8. Must decide on material before coding
9. Must have coding and modelling done before

Post-Meeting Action Items

- Regroup once we are done and completed Milestone 4
- Come up with a large list of possible materials
- Think of ways to make the design more unique

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MEETING WITH TEAM 06 - 2022-11-24

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Marco Tan	tanm27	Y
Administrator	Ronav Roy Chowdhury	roychr2	Y
Coordinator 1	David Segal-Pillemer	segalpid	Y
Coordinator 2	Sefana Al-Emara	alemaras	Y
Subject Matter Expert	Olivia Dmitrovich	dmitrovo	Y
Guest	N/A	N/A	N/A

Agenda Items

- Weekly check-in with everyone (stress levels, small talk).
- Subsection check-in with Programming and Modelling.
- Discussion about possible materials.
- Begin project work for the week.

Meeting Notes

- Spoke about the urgency of the upcoming deadlines
- Designated times for meet up to complete some subteam objectives
- Finalized materials
- Talked about iterations
- We asked if we could combine materials (told it is ok and that would be ill advised for liner bc it is thin)

Post-Meeting Action Items

- Attend subteam meetings
- Complete objectives
- Get poster

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MEETING WITH TEAM 06 - 2022-12-01

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Marco Tan	tanm27	Y
Administrator	Ronav Roy Chowdhury	roychr2	Y
Coordinator 1	David Segal-Pillemer	segalpid	Y
Coordinator 2	Sefana Al-Emara	alemaras	Y
Subject Matter Expert	Olivia Dmitrovich	dmitrovo	Y
Guest	N/A	N/A	N/A

Agenda Items

- Weekly check-in with everyone (stress levels, small talk).
- Subsection check-in with Programming and Modelling.
- Begin project work for the week.

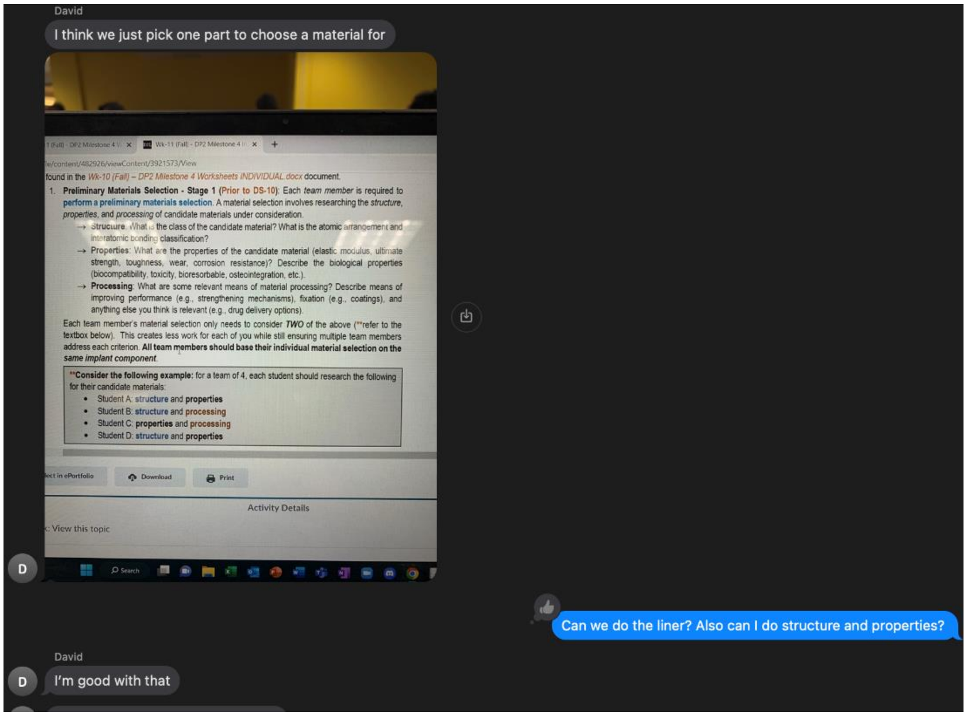
Meeting Notes

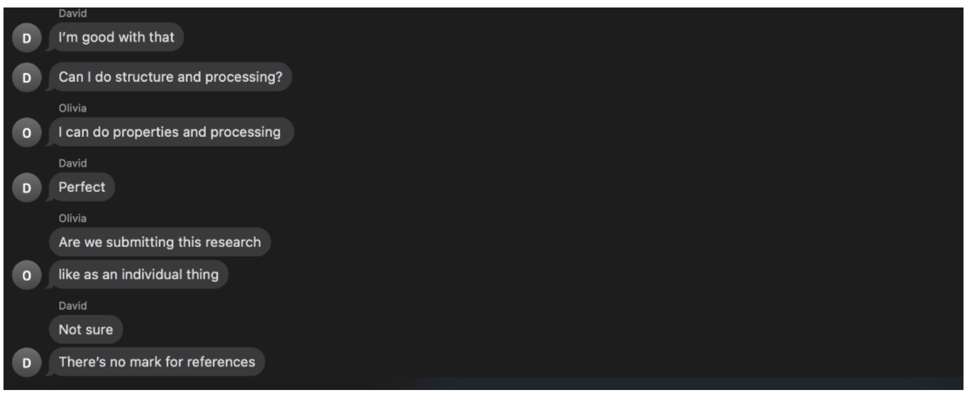
- Get stuff done.
- We're slightly behind in Subteam work
- Book a time to print
- We need to start thinking about poster presentation

Post-Meeting Action Items

- Finish subprograms and CAD models
- Start thinking about how poster is going to look
- Get poster board

Additional meet up time coordination:





Figures 1 & 2: Discussing who will do what for individual components of milestone 4 (Nov. 22, 2022)

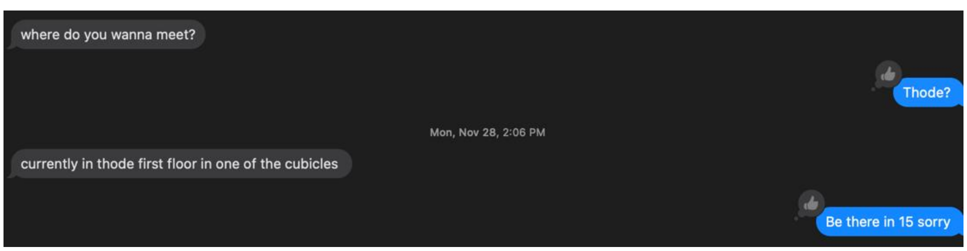
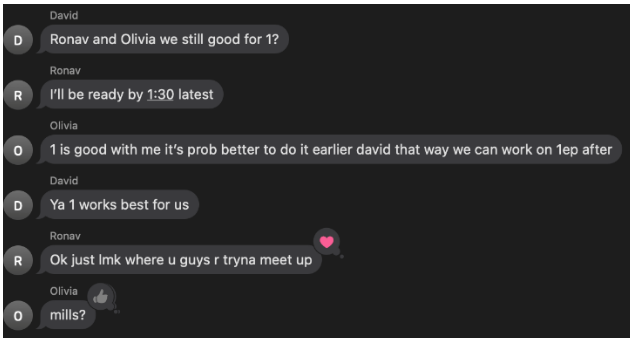
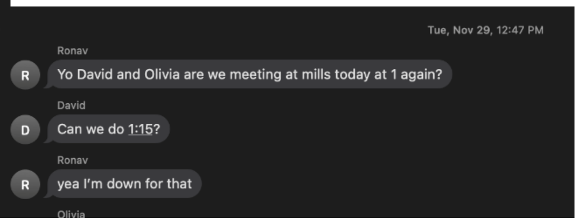
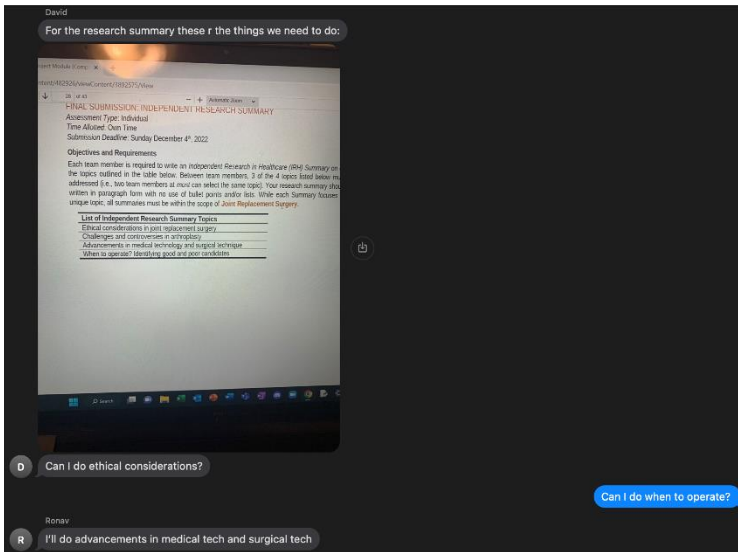


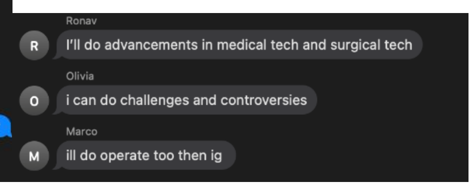
Figure 3: Modelling subteam discussing meetup times (Nov. 28, 2022)





Figures 4 & 5: Coding subteam discussing meetup times (Nov. 28 & 29, 2022)





Figures 6 & 7: Discussing IRH summary topics (Dec. 1, 2022)

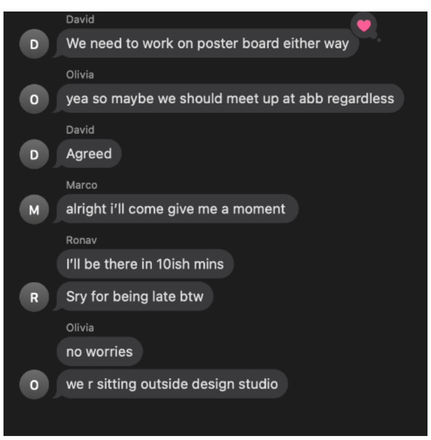


Figure 8: Discussing meet up times for completing poster (Dec. 7, 2022)

Appendix C: Comprehensive List of Sources

[1] Mayo Clinic, "Legg-Calve-Perthes disease - Symptoms and causes," *Mayo Clinic*, 2018. https://www.mayoclinic.org/diseases-conditions/legg-calve-perthes-disease/symptoms-causes/syc-20374343

[2] "Transient Synovitis In Kids," *Childrenscolorado.org*, 2019. https://www.childrenscolorado.org/conditions-and-advice/conditions-and-symptoms/conditions/transient-synovitis/

[3] B. A. Rogers, R. Kuchinad, S. Garbedian, D. Backstein, A. E. Gross, and O. A. Safir, "Cement Augmentation of the Acetabulum for Revision Total Hip Arthroplasty for Infection," *J Arthroplasty*, vol. 30, no. 2, pp. 270–271, Feb. 2015, doi: 10.1016/j.arth.2014.01.017.

[4] A. B. Bankston, H. Cates, M. A. Ritter, E. M. Keating, and P. M. Faris, "Polyethylene wear in total hip arthroplasty.," *Clin Orthop Relat Res*, no. 317, pp. 7–13, Aug. 1995.

[5] D. B. Bennett *et al.*, "Metal-Carbon Fiber Composite Femoral Stems in Hip Replacements," *The Journal of Bone and Joint Surgery-American Volume*, vol. 96, no. 24, pp. 2062–2069, Dec. 2014, doi: 10.2106/JBJS.M.01542.

[6] G. Tsikandylakis, M. Mohaddes, P. Cnudde, A. Eskelinen, J. Kärrholm, and O. Rolfson, "Head size in primary total hip arthroplasty.," *EFORT Open Rev*, vol. 3, no. 5, pp. 225–231, May 2018, doi: 10.1302/2058-5241.3.170061.

[7] Dr. J. M. Khan, Dr. M. I. Banday, and Dr. J. Muzaffar, "A study of measurement of acetabular diameter radiologically in northern Indian population of Jammu region," *International Journal of Orthopaedics Sciences*, vol. 4, no. 3.1, pp. 78–81, Jul. 2018, doi: 10.22271/ortho.2018.v4.i3b.16.

[8] "Mechanical Properties of Carbon Fibre Composite Materials," *Performance-composites.com*, 2009. http://www.performance-composites.com/carbonfibre/mechanicalproperties_2.asp

[9] "ACETABULUM LINER," *Hip & Knee Book*. https://hipandkneebook.com/new-blog/2017/3/13/tha-implants-acetabulum-liner

[10] "Joint Replacement Surgeon & Specialist - Bert Parcells, M.D.," *Seaview Orthopaedic & Medical Associates*. https://seaviewortho.com/dr-bert-parcells/ (accessed Dec. 01, 2022).

[11] Mayo Clinic, "Osteoarthritis - Symptoms and causes," *Mayo Clinic*, Jun. 16, 2021. https://www.mayoclinic.org/diseases-conditions/osteoarthritis/symptoms-causes/syc-20351925

[12] C. M. Yeung, A. R. Bhashyam, S. S. Patel, E. Ortiz-Cruz, and S. A. Lozano-Calderón, "Carbon Fiber Implants in Orthopaedic Oncology," *J Clin Med*, vol. 11, no. 17, p. 4959, Aug. 2022, doi: 10.3390/jcm11174959.

[13] E. M. Greber, C. E. Pelt, J. M. Gililland, M. B. Anderson, J. A. Erickson, and C. L. Peters, "Challenges in Total Hip Arthroplasty in the Setting of Developmental Dysplasia of the Hip," J Arthroplasty, vol. 32, no. 9, pp. S38–S44, Sep. 2017, doi: 10.1016/j.arth.2017.02.024.

[14] P. K. Edwards, S. C. Mears, J. B. Stambough, S. E. Foster, and C. L. Barnes, "Choices, Compromises, and Controversies in Total Knee and Total Hip Arthroplasty Modifiable Risk Factors: What You Need to Know," J Arthroplasty, vol. 33, no. 10, pp. 3101–3106, Oct. 2018, doi: 10.1016/j.arth.2018.02.066.

[15] D. Pincus, R. Jenkinson, M. Paterson, T. Leroux, and B. Ravi, "Association Between Surgical Approach and Major Surgical Complications in Patients Undergoing Total Hip Arthroplasty," JAMA, vol. 323, no. 11, p. 1070, Mar. 2020, doi: 10.1001/jama.2020.0785.

[16] M. A. Fernandez et al., "Cemented or Uncemented Hemiarthroplasty for Intracapsular Hip Fracture," New England Journal of Medicine, vol. 386, no. 6, pp. 521–530, Feb. 2022, doi: 10.1056/NEJMoa2108337.

[17] R. J. Ferguson, A. J. Palmer, A. Taylor, M. L. Porter, H. Malchau, and S. Glyn-Jones, "Hip replacement," The Lancet, vol. 392, no. 10158, pp. 1662–1671, Nov. 2018, doi: 10.1016/s0140-6736(18)31777-x.

[18] J. S. Siopack and H. E. Jergesen, "Total hip arthroplasty," The Western journal of medicine, vol. 162, no. 3, pp. 243–9, 1995, [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1022709/

[19] J. Starr, "Partial vs. total knee replacement - what's the difference and is either right for you?," Norton Healthcare, Apr. 04, 2018. https://nortonhealthcare.com/news/partial-knee-replacement-versus-total-knee-replacement/ (accessed Dec. 05, 2022).

[20] M. Marsh and S. Newman, "Trends and developments in hip and knee arthroplasty technology," Journal of Rehabilitation and Assistive Technologies Engineering, vol. 8, p. 205566832095204, Jan. 2021, doi: 10.1177/2055668320952043.

[21] L. Zagra, “Advances in hip arthroplasty surgery: what is justified?,” EFORT Open Reviews, vol. 2, no. 5, pp. 171–178, May 2017, doi: 10.1302/2058-5241.2.170008.

[22] “Total Hip Replacement (Direct Anterior Approach),” Yale Medicine. https://www.yalemedicine.org/conditions/total-hip-replacement-anterior-approach#:~:text=The%20direct%20anterior%20approach%20is

[23] “Advancements In Knee Replacement,” Orthopedic Associates of Hartford, Jan. 03, 2020. https://oahct.com/frequently-asked-questions-and-medical-advancements-for-knee-repleacements/#:~:text=Traditionally%2C%20the%20metal%20prosthetics%20were (accessed Dec. 05, 2022).

[24] C. Batailler, J. Swan, E. Sappey Marinier, E. Servien, and S. Lustig, “New Technologies in Knee Arthroplasty: Current Concepts,” Journal of Clinical Medicine, vol. 10, no. 1, Dec. 2020, doi: 10.3390/jcm10010047.

[25] S. Zanasi, “Innovations in total knee replacement: new trends in operative treatment and changes in peri-operative management,” European Orthopaedics and Traumatology, vol. 2, no. 1–2, pp. 21–31, Jul. 2011, doi: 10.1007/s12570-011-0066-6.

[26] P. A. Manner, M.D., Professor, U. W. Orthopaedics, S. M. I. you have any questions about T. K. Replacement, and O. S. an A. at 425.646.7777, “Minimally-Invasive Surgery (MIS) Quadriceps-Sparing Total Knee Replacement,” orthop.washington.edu. https://orthop.washington.edu/patient-care/articles/knee/minimally-invasive-surgery-mis-quadriceps-sparing-total-knee-replacement

[27] E. P.-R. Hansen, “Indications and eligibility for total hip replacement surgery,” *Arthritis*, 03-Sep-2020. [Online]. Available: https://www.arthritis-health.com/surgery/hip-surgery/indications-and-eligibility-total-hip-replacement-surgery#footnote2. [Accessed: 03-Dec-2022].

[28] H. Marks, “Are you a good candidate for hip replacement?,” *Healthgrades*, 29-Jul-2020. [Online]. Available: https://www.healthgrades.com/right-care/hip-replacement/are-you-a-good-candidate-for-hip-replacement. [Accessed: 03-Dec-2022].

[29] C. P. Surgery, “Bone Health: Can I have a joint replacement if I have osteoporosis?,” *City Place Surgery Center*, 13-Sep-2021. [Online]. Available: https://www.cityplacesurgery.com/orthopedics/bone-health-can-i-have-a-joint-replacement-if-i-have-osteoporosis/. [Accessed: 03-Dec-2022].

[30] G. S. Matharu, S. Mouchti, S. Twigg, A. Delmestri, D. W. Murray, A. Judge, and H. G. Pandit, “The effect of smoking on outcomes following primary total hip and knee arthroplasty: A population-based cohort study of 117,024 patients,” *Acta Orthopaedica*, vol. 90, no. 6, pp. 559–567, 2019.

[31] B. H. Kapadia, A. J. Johnson, Q. Naziri, M. A. Mont, R. E. Delanois, and P. M. Bonutti, “Increased revision rates after total knee arthroplasty in patients who smoke,” *The Journal of Arthroplasty*, vol. 27, no. 9, May 2012.

[32] J. R. Onggo, J. D. Onggo, R. de Steiger, and R. Hau, “Greater risks of complications, infections, and revisions in the obese versus non-obese total hip arthroplasty population of 2,190,824 patients: A meta-analysis and systematic review,” *Osteoarthritis and Cartilage*, vol. 28, no. 1, pp. 31–44, Nov. 2019.

[33] J. D. Capozzi and R. Rhodes, “Ethical challenges in orthopedic surgery,” *Curr Rev Musculoskelet Med*, vol. 8, no. 2, pp. 139–144, Jun. 2015, doi: 10.1007/s12178-015-9274-y.

[34] G. E. Parsons, H. Godfrey, and R. F. Jester, “Living with severe osteoarthritis while awaiting hip and knee joint replacement surgery,” *Musculoskeletal Care*, vol. 7, no. 2, pp. 121–135, Jun. 2009, doi: 10.1002/msc.145.

[35] W. H. Bronson *et al.*, “The Ethics of Patient Risk Modification Prior to Elective Joint Replacement Surgery,” *Journal of Bone and Joint Surgery*, vol. 96, no. 13, p. e113, Jul. 2014, doi: 10.2106/JBJS.N.00072.

[36] R. Cobos *et al.*, “Variability of indication criteria in knee and hip replacement: An observational study,” *BMC Musculoskelet Disord*, vol. 11, 2010, doi: 10.1186/1471-2474-11-249.

[37] G. A. Hawker *et al.*, “Determining the Need for Hip and Knee Arthroplasty: The Role of Clinical Severity and Patients’ Preferences.”

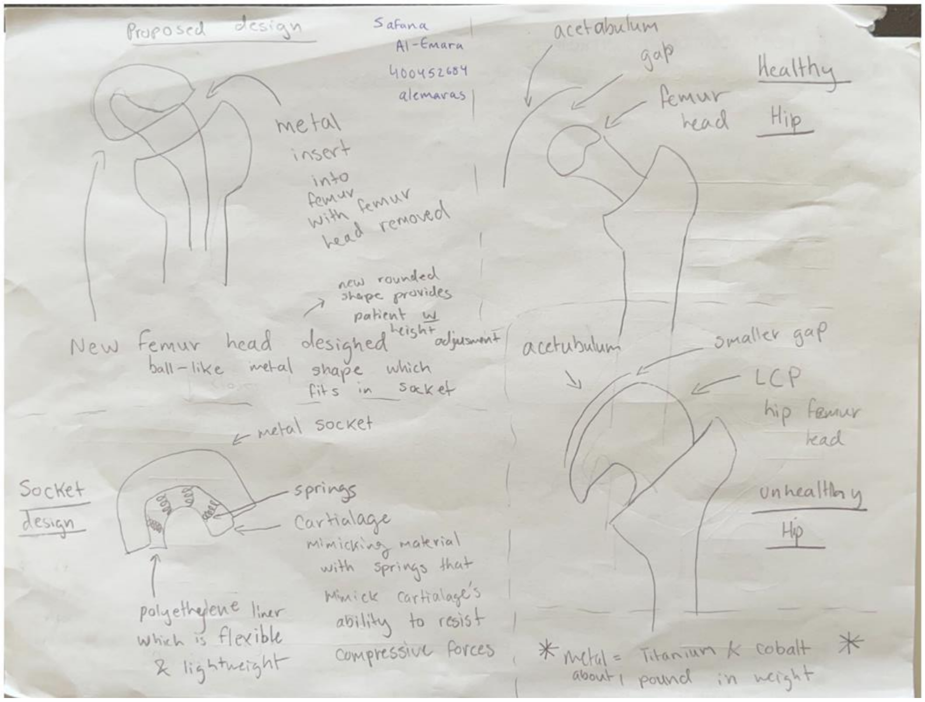
[38] M. M. Dowsey, J. Gunn, and P. F. M. Choong, “Selecting those to refer for joint replacement: Who will likely benefit and who will not?,” *Best Practice and Research: Clinical Rheumatology*, vol. 28, no. 1. Bailliere Tindall Ltd, pp. 157–171, 2014. doi: 10.1016/j.berh.2014.01.005.

[39] F. Atsma, O. Molenkamp, H. Bouma, S. B. Bolder, A. Stef Groenewoud, and G. P. Westert, “Uniform criteria for total hip replacement surgery in patients with hip osteoarthritis: A decision tool to guide treatment decisions,” *International Journal for Quality in Health Care*, vol. 33, no. 1, 2021, doi: 10.1093/intqhc/mzab030.

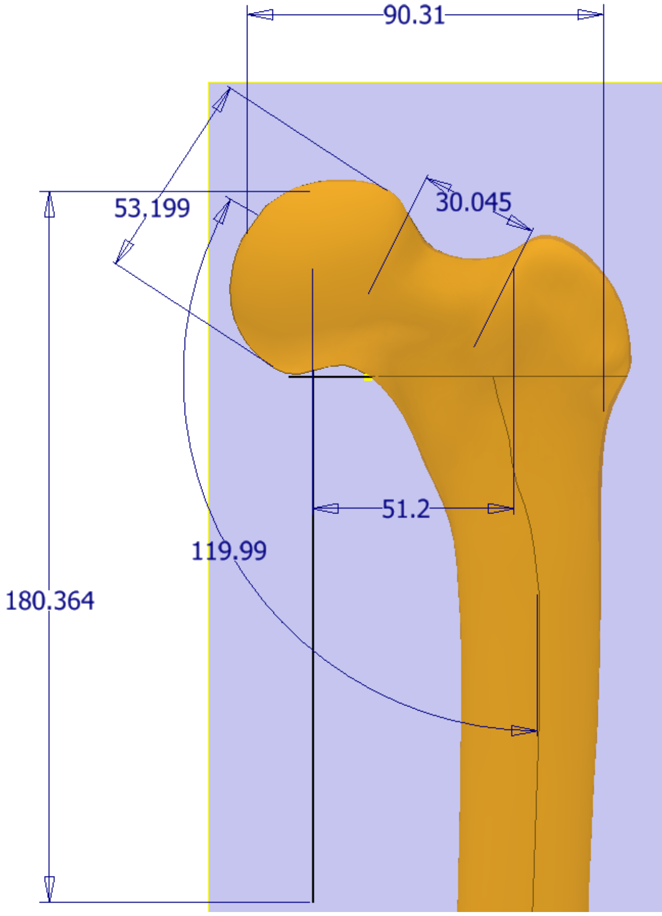
[40] R. B. Bourne, B. M. Chesworth, A. M. Davis, N. N. Mahomed, and K. D. J. Charron, “Patient satisfaction after total knee arthroplasty: Who is satisfied and who is not?,” in *Clinical Orthopaedics and Related Research*, 2010, vol. 468, no. 1, pp. 57–63. doi: 10.1007/s11999-009-1119-9.

Appendix D: Additional Documentation

Initial Design Ideas:



Iterations of Design:



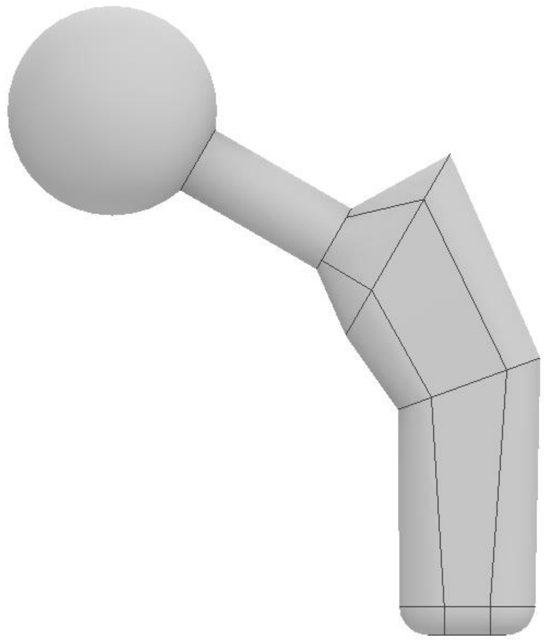
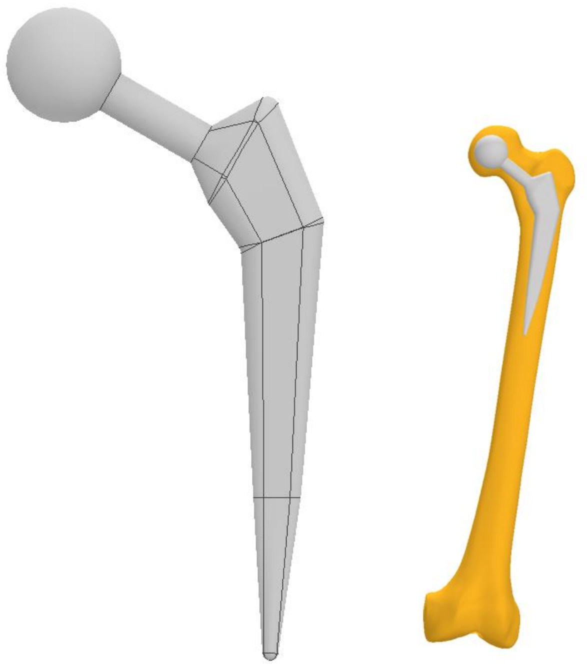


Figure 1: Dimensions of representative femur for Jackie Chiles

Figure 2: First iteration of design



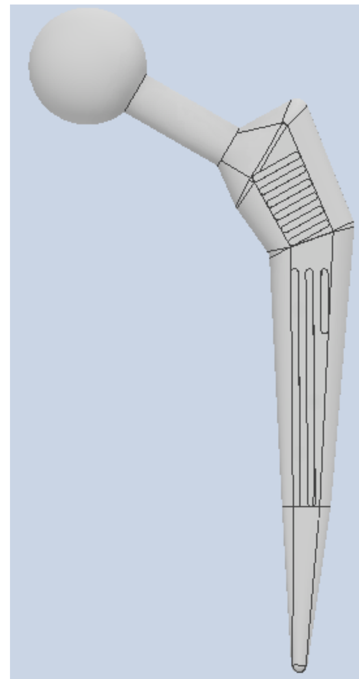
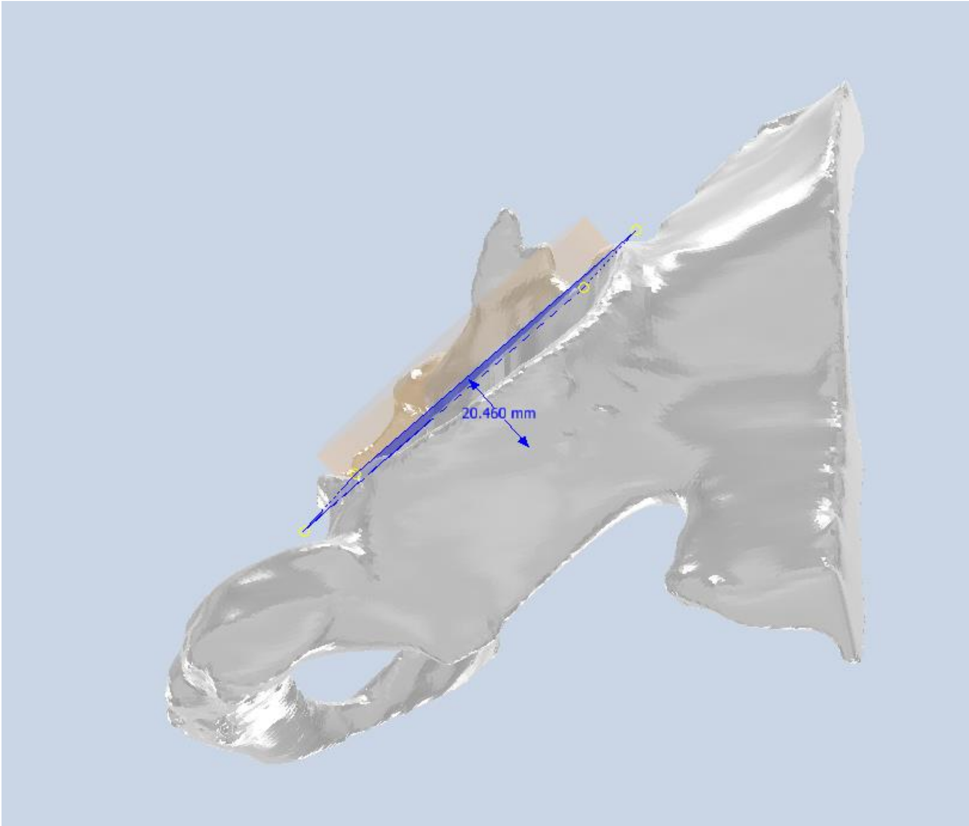


Figure 3: Testing of other iteration on Jackie's Femur Figure 4: Final design with grooves



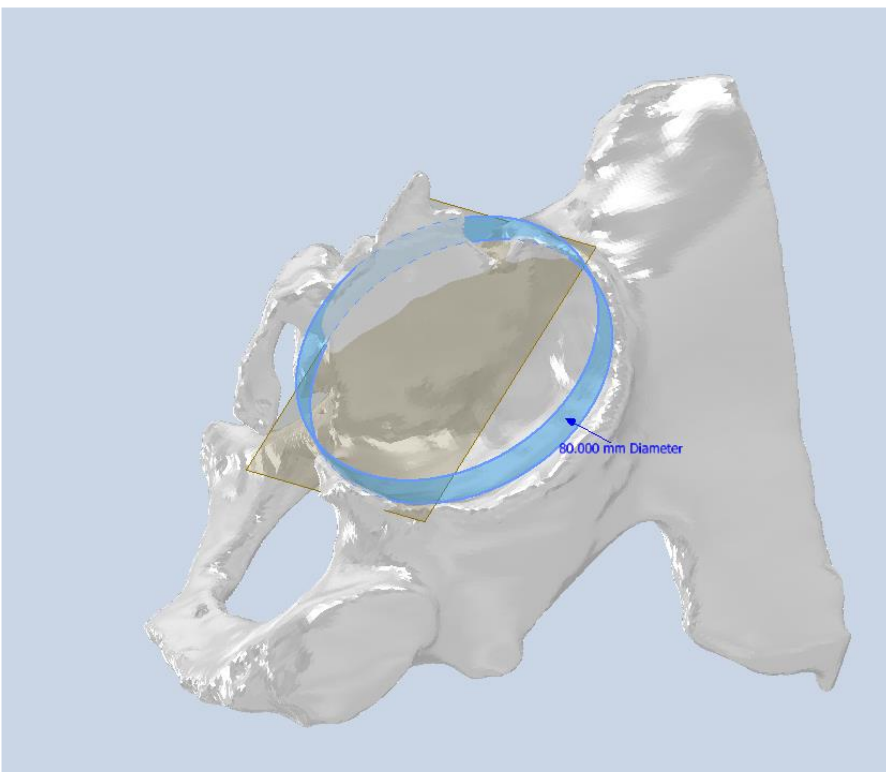


Figure 5: Dimensions of acetabulum of Jackie Chiles.

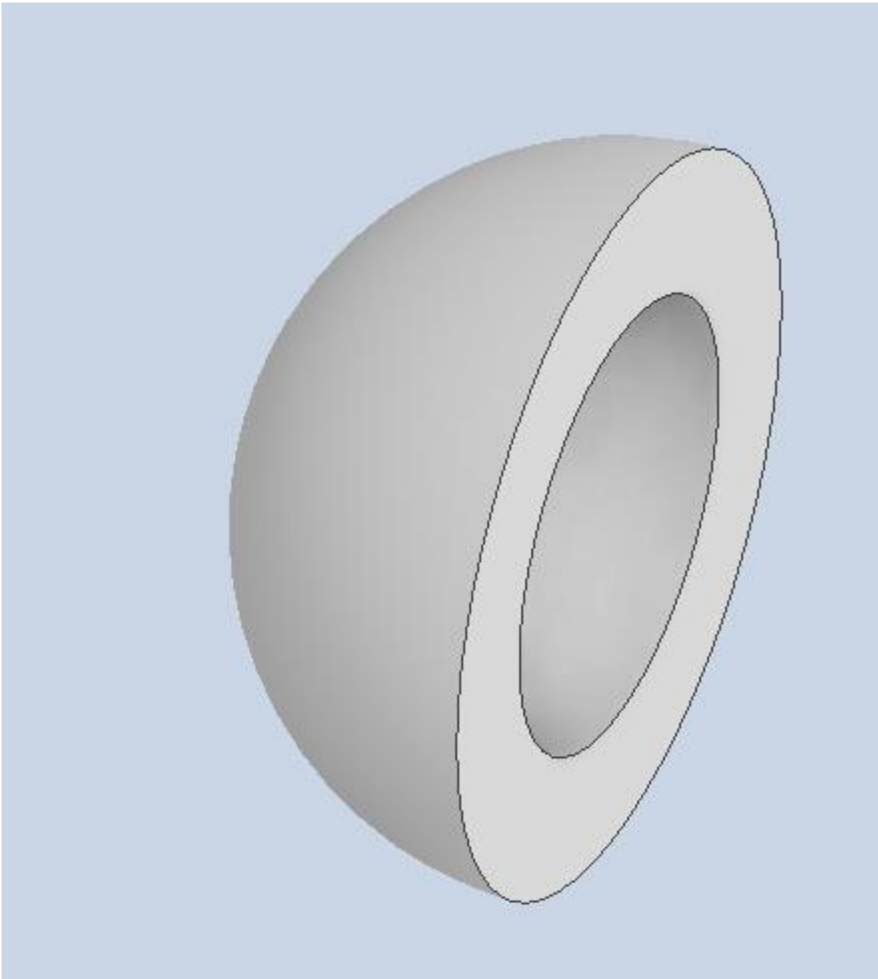
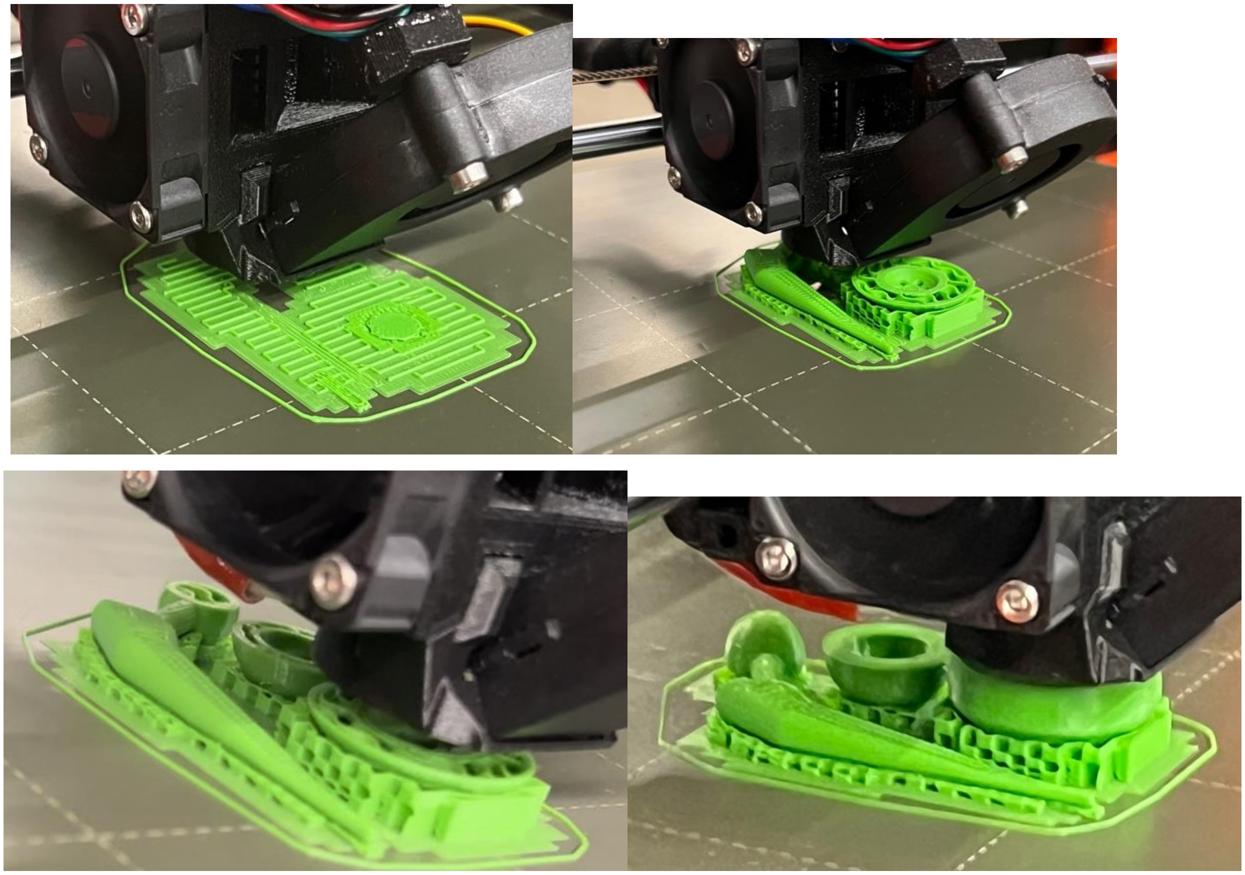


Figure 6: First iteration of acetabular cup.

Figure 7: Final iteration of acetabular cup and liner.

Figure 8: Whole assembly, including acetabular cup, liner, and femoral component.

3D Printing Process Images:



Figures 1-4: Images of the 3D printing at various stages

Appendix E: Design Studio Worksheets

Milestone 0 (Team) – Cover Page

Team Number: 6

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

Full Name:	MacID:
Safana Al-Emara	alemaras
David Segal-Pillemer	segalpid
Marco Tan	tanm27
Olivia Dmitrovich	dmitrovo

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: 6

***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.	Olvia Dmitrovich	☐ M ☐ A ☒ C ☐ S
2.	Marco Tan	☐ M ☐ A ☐ C ☒ S
3.	David Segal-Pillemer	☒ M ☐ A ☐ C ☐ S
4.	Safana	☒ M ☐ A ☐ C ☐ S
5.	Ronav	☐ 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	Marco Tan	tanm27 Marco Tan.
Administrator		
Coordinator	Safana Al-Emara	alemaras
Coordinator	David Segal-Pillemer	segalpid
Subject Matter Expert	Olivia Dmitrovich	Dmitrovo

MILESTONE 0 – TEAM CHARTER

Team Number: 6

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

Sub-Team:	Team Member Name:	MacID
Computing	David Segal-Pillemer	segalpid
	Olivia Dmitrovich	dmitrovo
Modelling	Safana Al-Emara	alemaras
	Marco Tan	tanm27

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

Milestone 1 (Team) – Cover Page

Team Number: 6

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

Full Name:	MacID:
Olivia Dmitrovich	dmitrovo
Marco Tan	tanm27
Safana Al-Emara	alemaras
David Segal-Pillemer	segalpid

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: 6

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

SYMPTOMS:	-Long history of hip pain -Can only walk 2 minutes using a cane
IMAGING INDICATORS:	-Lack of cartilage -Abnormally shaped femoral head -No gap between acetabulum and femoral head
PREVIOUS MEDICATIONS / DOCTOR VISITS:	Previous medication: -Tramadol (100mg per day. Ineffective) -Oxycodone (2.5mg per day)
MISCELLANEOUS NOTES:	Pain at a 7-9 range out of 10. BMI indicates patient overweight. Left leg 1cm shorter than right. Prior prostate cancer. Prostate removed. No chemo or radiation therapy used.

2. Record your final diagnosis in the space below.

FINAL DIAGNOSIS:	Osteoarthritis caused by undiagnosed Legg-Calvé-Perthes Disease (LCP Disease).

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

MILESTONE 1 – OBJECTIVES AND CONSTRAINTS

Team Number: 6

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	• Allow for range of motion equal to the other hip. • Able to bear weight with no pain. • Able to walk for an extended period without assistance. • Correct for the 1 cm difference between leg lengths.

CONSTRAINTS	• Must fit the anatomy of the patient. • Must be made of biocompatible materials. • Must be affordable • Must be Long-term • Must not exacerbate current condition.

MILESTONE 1 – NEED STATEMENT

Team Number: 6

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 replacement for Jackie Chiles' left hip to correct for his osteoarthritis caused by deformities associated with undiagnosed Legg-Calvé-Perthes disease. This should improve his quality of life by mitigating pain associated with his condition and increasing his mobility.

Milestone 2 (Team) – Cover Page

Team Number: 6

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

Full Name:	MacID:
David Segal-Pillemer	segalpid
Marco Tan	tanm27
Olivia Dmitrovich	dmitrovo
Ronav Roy Chowdhury	roychr2
Safana Al-Emara	alemaras

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MILESTONE 2 (STAGE 2) – DESIGN FEEDBACK

Team Number: 6

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:	Marco Tan	Colleague’s Name:	Everyone else
Your MacID:	tanm27	**Colleague’s MacID:**	Everyone else

Design Feedback:

Olivia

- Like the idea of an adjustable length to help correct the height difference

David

- Adjustable length with the screws is good because it will help make his legs the same length, but it does not help with the deformation of the bone

Safana

- Does not really address the acetabulum’s deformities but addresses the length issues for the left leg of the patient

Ronav

- An adjustable length for the hip implant is a great idea to ensure that the load placed on one leg for the patient is less (considering that the patient’s leg has a 1 cm height difference).

Design Feedback Entry

Your Name:	Olivia Dmitrovich	**Colleague's Name:**	Everyone else
Your MacID:	dmitrovo	**Colleague's MacID:**	Everyone else

Design Feedback:

Marco:

- Good idea since it would be less invasive for the patient.
- Some concerns about the strength of the acetabulum because of deformed shape of the back (maybe new material might be needed?)

Safana:

- Does not require the cutting of the acetabulum which makes it less invasive but must take into consideration how we would make a cup that aligns perfectly with the deformities.

David:

- Great idea because it will allow the implant to fit the patient's deformation. It will not overcompensate for the other hip. Since he is 65 and he is not in the greatest condition, a perfectly new hip may not be a good idea. However, it may be hard to replace if he needs another surgery in 10 years.

Ronav:

- Very effective solution as an altered hip implant tailored to the patient would be easier for them to manage.
- The deformation in the acetabulum is not addressed however which might become a problem later on.

Design Feedback Entry

Your Name:	David Segal-Pillemer	**Colleague's Name:**	Everyone else
Your MacID:	segalpid	**Colleague's MacID:**	Everyone else

Design Feedback:
Olivia • Very effective if patient requires multiple hip surgeries however, if the implant should last the rest of his life, it would be less invasive to stick to one implant rather than adding to the acetabulum and replacing the hip. Marco: • Very effective and less invasive than a regular hip implant, but worries about the material as it would have to be stronger than regular bone cement.   o Regular bone cement helps to fit metal components to bone (it's an adhesive), but here it would become a structural component. Ronav: • Very efficient solution in ensuring that the hip implant can be replaced easily but there might be concerns regarding the structural stability of the bone cement/acetabulum deformations. Safana: • Great for making the procedure less invasive, however we don't know if that would be a drastic change for the patient that their muscles won't be used to.

Design Feedback Entry

Your Name:	Safana	**Colleague's Name:**	Everyone else
Your MacID:	alemaras	**Colleague's MacID:**	Everyone else

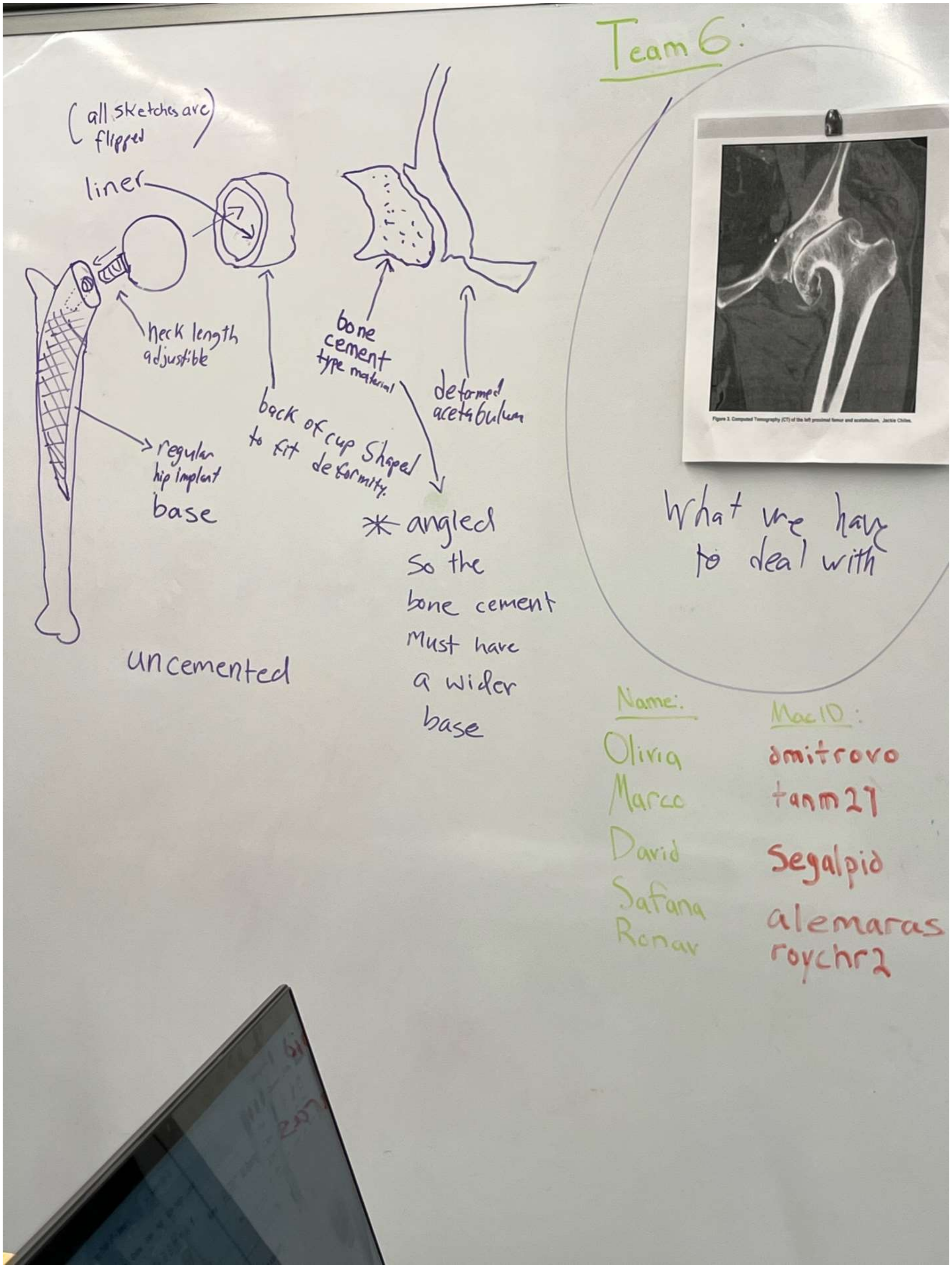
Design Feedback:
Olivia • The springs are a creative idea for cartilage; however, we should take into consideration the movement and how the leg would be impacted Marco: • Springs sound like a good idea for cushioning but I have worries about springs wearing down too quickly. Ronav: • Springs are good idea to mimic cartilage and to ensure the patient can move more naturally. David: • Good idea to make the cartilage with micro-springs inside to allow for more flexibility in the cartilage, but finding a bio-compatible material for this may be difficult

Design Feedback Entry

Your Name:	Ronav Roy Chowdhury	**Colleague's Name:**	Everyone else
Your MacID:	roychr2	**Colleague's MacID:**	Everyone else

Design Feedback:
Olivia • Like the combination of fixing both the acetabulum and the implant cup shape. Marco: • Like that it's a combination of both David and Olivia's ideas. • Have the same concerns as both of theirs (the material and strength of both the acetabular implant/bone cement since it's more load bearing now). Safana: • Great in combing the groups ideas but unsure what materials would be best in the additions for the bone and what would be the drawbacks of including bone cement. David: • Great idea with the combination, as it will allow for the best of all the designs, but we should keep in mind not over compensating since he is already 65 and not in the best condition.

MILESTONE 2 (STAGE 3) – REFINED CONCEPT SKETCH



Team Number: 6

MILESTONE 2 (STAGE 4) – GROUP DISCUSSION

Team Number: 6

Discuss the advantages and disadvantages of your refined concept solution

Advantages:

- Not too invasive altering only the femur head and cutting that off, not replace acetabulum
- Doesn't overcompensate for the right hip
- The muscles will not have to adapt to a completely different hip structure

Disadvantages:

- Difficult to have another replacement after this one
- Many points of weakness as a result of having many components combined
- Costs will probably be higher than a regular hip replacement since some components are patient specific.

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

Our refined concept solution will ensure that less load is placed on Jackie's one leg which will mitigate the amount of pain he feels from day to day. Since there is strong putty molded to fit the deformed acetabulum coupled with an altered cup, the fit will be less invasive and thus result in less pain for Jackie.

Milestone 3 (Team) – Cover Page

Team Number: 6

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

Full Name:	MacID:
Olivia Dmitrovich	dmitrovo
Marco Tan	tanm27
Ronav Roy Chowdhury	roychr2
David Segal-Pillemer	segalpid
Safana Al-Emara	alemaras

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: 6

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

$$A_{implant} = \frac{1}{4}\pi d^2 \Big|_{d=19mm/2}$$
$$= \frac{1}{4}\pi\left(\frac{19}{2}\right)^2$$
$$= \frac{361}{16}\pi \, mm^2$$

$$F = 3.5 \times 103.5kg \cdot 9.81 \, m/s^2$$
$$= 3{,}553.6725 \, N$$

$$\sigma_a = \frac{F}{A}$$
$$= \frac{3{,}553.6725 N}{\frac{361}{16}\pi \, mm^2}$$
$$= 50.135 \, N/mm^2$$

$$y = 0.5 \cdot d$$
$$= \frac{19}{4} mm$$

$$I = \frac{\pi}{64} \cdot d^4$$
$$= \frac{\pi}{64}\left(\frac{19}{2}\right)^4$$
$$= \frac{130321}{1024}\pi \, mm^4$$

$$M = F \cdot L$$
$$= 3{,}553.6725 N \cdot 51mm$$
$$= 181237.2975 \, Nmm$$

$$\sigma_B = \frac{M \cdot y}{I}$$
$$= 2153.162797$$

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

$$= \frac{\sigma_A + \sigma_B}{UTS_{implant}}$$

$$= \frac{50.135\,N/mm^2 + 2153.162747}{1010\ MPa}$$

$$= 2.1814\ldots$$

$$= 2.2 \quad (2\ s.f.)$$

MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS

FATIGUE LIFE

Team Number: 6

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

$$\sigma_{max} = \frac{30 \cdot BW}{A}$$

$$= \frac{30 \cdot (103.5 kg \cdot 9.81 m/s^2)}{\frac{361}{16} \pi \, mm^2}$$

from #1

$$= 429.7278692 \ N/mm^2$$

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

$$= -429.7278692 \ N/mm^2$$

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

$$= \frac{429.72... - (-429.72...)}{2}$$

$$= 429.72...$$

$$= 430 \ N/mm^2 \text{ (to 2 s.f.)}$$

$$\boxed{\therefore \text{ fatigue life would be } 7 \ 10^7 \text{ cycles}}$$

MILESTONE 3 (STAGE 2) – PRELIMINARY DESIGN ANALYSIS

BONE STRESS REDUCTION

Team Number: 6

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

$$F = BW \cdot 30 = 103.5kg \cdot 9.81m/s^2 \cdot 30 = 30460.05N$$

$$A = \frac{\pi}{4}(D_o^2 - D_i^2) = \frac{\pi}{4}((35mm)^2 - (19mm)^2) = 216\pi\ mm^2$$

$$\sigma_{comp} = \frac{F}{A} = \frac{30460.05N}{216\pi mm^2} = 44.88766226$$

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

$$= 16.49\ N/mm^2\ (2\ s.f.)$$

Milestone 4 (Team) – Cover Page

Team Number: 06

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

Full Name:	MacID:
Ronav Roy Chowdhury	roychr2
Safana Al-Emara	alemaras
David Segal-Pillemer	segalpid
Olivia Dmitrovich	dmitrovo
Marco Tan	tanm27

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:	06

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:	Acetabular Liner

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

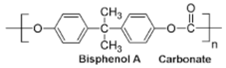
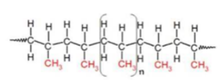
Team Number: 06

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	Polarity	Description	
Polyethylene	Polymer	Crystalline	Covalent	Non-polar	A chain of hydrocarbon (C_2H_4) monomers, that is saturated. Molecules packed tightly. Dense	
polycarbonate	polymer	amorphous	Mostly covalent bonding but also van Der	Polar (attractive & hydrophilic)	Bisphenol A (2 aromatic rings with carbon in between)	

			Waals and hydrogen bonds		Carbonate group All forming a chain of n repetitions 	
Silicone	Polymer	Crystalline	Covalent		Made up of siloxane bonds (-Si-O-Si-) with organic groups attached to the silicon. Big molecule once small monomers are packed tightly	
polypropylene	polymer	Semi-crystalline	Mostly covalent bonding but also van Der Waals and hydrogen bonds	Non-polar (neutral & hydrophobic)	Backbone of single bond carbons with hydrogens branching off and a single carbon branching in each monomer 	

Zirconia Toughened Alumina	Zirconium oxide and aluminum oxide – composite ceramics called AZ composites	Zr-Al2O3 grains of this material are sintered together.	2 aluminum atoms bonded to 3 oxygen atoms and 1 zirconium atom bonded to 2 oxygen atoms. It is a giant covalent bond.			
Polyether ether ketone	Polymer – specifically semi-crystalline thermoplastic	Poly (oxy-1, 4-phenyleneoxy-1, 4-phenylenecarbonyl-1, 4-phenylene) -$C_{19}H_{14}O_3$	3 6 carbon rings where 2 of the carbon atoms are bonded to oxygen and 2 other carbon atoms are bonded to another carbon atom which is subsequently bonded to an oxygen atom.			

Cobalt-Chromium (CoCr)	Metal	Crystalline	Metalic			Chromium and cobalt single bonded to oxygen.
Yttria stabilized zirconia	Ceramic	$ZrO_2 + Y_2O_3$	Covalent in a monoclinic crystal structure	Non-polar	A crystal lattice of ZrO_2 in cubic form made stable using Y_2O_3 to maintain the cubic structure.	

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

PROPERTIES

Team Number: 06

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	Biocompatibility
Polyethylene	1.07 - 1.09 GPa	22.1 – 31.0 MPa	1.52 - 1.82 $MPam^{1/2}$	Very resistant to wear, low coefficient of friction	Very corrosion resistant	High biocompatible because they do not contain toxins. Chemically inert and are not soluble in water, so no ions to enter the bloodstream
polycarbonate	2.4 GPa stiff material will not bend or stretch easily	65 MPa stronger than polyethylene (common material for	3.0 MPa*sqrt(m)	Unavailable information but studies using material indicated no changes in material following 5 years so	This material is resistant to acids, oxidizing/reducing agents & alcohols (excluding methyl alcohol)	Approved & used for many medical devices due to its biocompatibility

		liners) by >200 times		greater than 5 years.		No toxicity associated with material
polypropylene	1.68 GPa Less stiff material will bend or stretch more easily	29.2 MPa	1.4 kJ/m^2	Unavailable	This material is resistant to non-oxidizing acids & bases, fats & most organic solvents	Used for treatment in pelvic floor conditions, biocompatible and does not trigger inflammatory response
Silicone	0.0793	7.24 MPa	0.7 MPa/m$^{1/2}$	Poor wear resistance, but when coupled with other materials can be much improved	Except for sulphuric acid, hydrofluoric acid, silicone is corrosion resistant	High biocompatibility, non-toxic, insoluble in body fluids. Used in cardiovascular system
Yttria stabilized zirconia	200 – 210 GPa	0.55 GPa	0.01 Gpa/m^0.5	Very high wear resistance	Strong corrosion resistance, especially at excessively high temperatures.	Strong biocompatibility, supports strong adhesions of cells on surfaces and promotes cell proliferation (used in dental already).
Cobalt-Chromium (CoCr)	220 MPa	145-270 MPa	-low ductility, can potentially cause component fracture	- does not wear easily, also has great resistance to fatigue	-shows a high degree of corrosion resistance even in chloride surroundings.	448-1606 MPa

Zirconia Toughened Alumina	360 GPa	2750 MPa	7.2 MPa/m^1/2	Very high wear resistance	Very corrosion resistant	High biocompatibility as there are no grains formed over time.
Polyether ether ketone	3.7-4.0 GPa	170 MPa	2.733 - 4.296 MPa/m^1/2	Very high wear resistance.	Very corrosion resistant	It has a high biocompatibility as the elastic modulus is similar to that of bone.

MILESTONE 4 (STAGE 2) – MATERIALS SELECTION GROUP DISCUSSION

PROCESSING

Team Number: 06

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	Cost	Additive Manufacturing	
Zirconia Toughened Alumina	A bioactive coating to improve bone integration and bonding with the implant could be implemented (e.g. a layer of covalently bonded	The material is sintered meaning that it is one solid mass making it more reliable.	Has a high corrosion and wear resistance as a result of sintering.	Relatively Inexpensive		

	phosphonate molecules (CM))					
Polyether ether ketone	This implant can be coated with hydroxyapatite (HA) to allow for the deposition of new bone from adjacent living bone.	PEEK plastic is processed through an injection molding machine and unique molds to form raw plastic materials into the parts you need. The plastic is melted into the injection molding machine and then into your customized mold.	Has a high corrosion resistance as very concentrated nitric and sulfuric acids are the only acids that can attack PEEK.	Quite expensive		
Yttria-stabilized zirconia	N/A	N/A	Strong corrosion resistance, especially at excessively	Pricy.	A silicon carbide interlayer may be used to increase strength and	

			high temperatures.		corrosion resistance (but SiC has health effects)	
Polyethylene	N/A	N/A	-fairly resistant to corrosion to most mineral acids including sulfuric up to 70% concentrations	Usually inexpensive but it depends on the type of polyethylene employed.	-for high density polyethylene, it contains undesirable thermal properties which cause the material to shirk and not adhere to printing bed	
Cobalt-chromium (CoCr)	Electrodeposition has versatility relating to large variety of component shapes which can be precision-coated.	N/A	-also relatively resistant to corrosion	more expensive compared to polyethylene, however still less expensive than		
Silicone	silicon can be coupled with a nitrogen compound to create silicon nitride. Increases	N/A	Except for sulphuric acid, hydrofluoric acid, silicone is corrosion resistant	Expensive		

	strength and wear.					
Polycarbonate	N/A	N/A	This material is resistant to acids, oxidizing/reducing agents & alcohols (excluding methyl alcohol)	$5,469.60 per 6 kg Expensive but doable	N/A	
polypropylene	N/A	N/A	This material is resistant to non-oxidizing acids & bases, fats & most organic solvents	$1,714.25 per 6 kg Less expensive	N/A	

MILESTONE 4 (STAGE 3) – PROPOSED MATERIAL

Team Number:	06

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

Proposed Material:	Polycarbonate

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

Structure: It is amorphous and a polymer, which means it will be flexible and comfortable for Jackie Chiles.

Properties: It has a relatively high UTS for polymers which means it will be strong and not break down with movement, which still being flexible. Processing: Not very expensive for the amount of material needed for the liner.

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

- Material is very biocompatible as there is no toxicity or graining associated with it. - Polycarbonate is also a very flexible material as opposed to being very stiff making it comfortable for Jackie Chiles. - Adds a little bit of height to balance out the height difference between his two legs. - Addresses the issue involving lack of cartilage - Does not make it too strong or overcompensate the other hip that does not require a hip replacement but isn't perfect.