Deliverable D: Detailed Design and BOM

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Introduction

This deliverable focuses on taking the next steps in our design stage. We summarize the client feedback received during our second client meeting to better understand areas for improvement. Based on this information, we will create an updated, detailed design of our concept using CAD software. In our CAD design, we will explain why and how we plan to connect each subsystem. We will then identify the skills and resources needed to produce our prototypes and the final product. This will allow us to determine if we are lacking any skills and formulate a plan to acquire them. Subsequently, we will assess the time required to implement our design and see if it aligns with the team members' availability. We will also examine any product assumptions that might pose challenges as we approach design day. Finally, we will compile a bill of materials to estimate the cost of materials for our design.

Summary of Client Meet 2: Initial Concept Feedback

During our second client meeting, we presented two conceptual designs: the "Punch Box" and the "Wedge" design, using a CAD file for the former and a sketch for the latter. The Punch Box, akin in size to a Rubik's Cube, is designed to reduce the force needed to close renal clips, facilitating easy and efficient sequential clipping. This concept was favored by the client, followed by suggestions like increasing the interior space, modifying the spring mechanism, and further thinking about the attachments and manufacturing of the product. The Wedge design, contoured for a natural handgrip, utilizes full arm action for clip application. Feedback indicated it might not be as efficient for consecutive clip applications.

The client enlightened us about the real-world setting, emphasizing the clip application speed and cleaning efficiency. They aim for a 3-second or less clip application and rapid cleaning between patients. Further insights include an intended price point below $50, factoring in production costs. Our TA also contributed valuable input regarding the device's functional features. Our approach to the meeting was centered on gathering reactions, understanding suggestions, and clarifying previously discussed requirements from our first meeting and questions gathered during the ideation process.

Presented Concepts:

1. **Punch Box Design**
   - Description: This device reduces the force required to close renal clips. It is approximately the size of a Rubik's Cube and is designed to fit comfortably in one's hand. The C-shape with supporting walls aids in preventing clip movement during the closure. Textured sides offer a better grip. The device features a spring-loaded plunger mechanism for clip closure. This is where the punch box name comes from. Notably, the design permits efficient sequential clipping. There's a hole for attaching it to keychains or bracelets. It seems like the client favored this design more than the rest.
   - Feedback:
     - Initial confusion about its operation by the client. This needs to be noted as it needs to be clear initially how it should be used when first “approaching” the product.
     - Interior space could be larger to accommodate varying clip sizes. There is room to make the space inside as big as the maximum clip size. Room to make this one size fits all.
     - Spring's primary purpose is for resetting, not clip application. To push the mechanism back up to be able to punch it down again.
     - Consideration for gating systems to prevent multiple clip insertions. To not end up with 2 clips in the box at a time.
     - Pondering on the tube-switching capability; moving between tubes might be a challenge with the current feeding system.
     - Consideration for a half-box design for transitioning between clips on different lines.
     - Usually, a second hand stabilizes the tubing; this device should accommodate dual-hand use. Being able to be used with hand is not a priority according to the client. Can use a second hand to stabilize the blood tube as it is loose.
     - Cleaning and hygiene were brought up. Should be able to be cleaned within a few seconds, without being a biohazard for the next patient.
     - Using the palm is more ergonomic therefore making this the better option of the two to reduce thumb strain.
2. **Wedge Design**
   - Description: The wedge has a natural hand grip curve, changes the pinching motion into a full arm action for clip application, and offers clip support. However, it lacks support behind the clip.
   - Feedback:
     - The size allows for keychain attachment.
     - Not as efficient when applying many on one line.
     - Emphasis on compression force using two fingers beyond the clip.

        - Using the shoulder/ arm would be less stable.

Additional Information and Considerations Client Mentions:

- The client provided insights into the typical application setting:
    - Up to 40 clips per tubing line, depending on patient and line requirements.
    - Clips are single-use and discarded after application.
    - Clips are pre-aligned on the tubing, awaiting application.
- Answers to our questions to further clarify some facts we had from our last meeting:
    - Force required to close clips (plans to test with actual clips).
    - Clip application speed; targeting 3 seconds or less per clip. 4-5 seconds for clip application would be too long.
    - There was an emphasis on efficient cleaning, thus knowing the typical speed in which nurses clean things between patients. Quick wipes should be enough on the go with nurses according to the client. Aim for a few seconds of cleaning time.
    - A clearer understanding of the actual clipping process; possibly a video demonstration will be sent for further analysis of the process.
- On Pricing:
    - Aims to keep the device affordable, targeting a price under $50, but considering factors like labor, materials, and manufacturing costs. This has to be something that nurses can purchase privately initially.

TA Insights post meeting:

- Recommendations on the device's operational features, including not sliding when open.
- Suggestions to consider spring placements, particularly hidden ones, and attachment methods for the slab press plate onto the plunger.

Changes to Design Based on Feedback

Changes & Considerations for the Punch Box Design based on Client Meeting 2 Feedback:

1. **Operational Clarity:**
    - Address the initial confusion about the device's operation. The design should be intuitive and should communicate its usage without requiring extensive instructions.
2. **Interior Space Expansion:**
    - Enlarge the interior to be as big as the maximum clip size. This adaptation would make it a universal solution accommodating various clip sizes.
3. **Spring Mechanism Adjustment:**
    - The spring's function should be clearly identified and optimized for resetting.
4. **Possible Gating System Implementation Will be Explored:**
    - Incorporate mechanisms that prevent the insertion of multiple clips simultaneously to avoid any operational hiccups.
5. **Tube-Switching Capability:**
    - Reevaluate the current feeding system to ensure efficient transitioning between tubes.

- Half-Box Design Consideration:
  - Explore the potential for a half-box design to allow smoother transitions between clips on different lines.

6. **Single-Hand Usage:**
   - While single-hand use isn't a priority, the design should still consider a scenario where there is no need for the second hand to be required to stabilize the tubing. If 2 hands are required it is fine as it is in their routine already to stabilize the tube with their second hand anyways.
7. **Cleaning and Hygiene:**
   - The design must prioritize easy cleaning. Given the feedback, the device should be cleanable within seconds, minimizing any biohazard risks.
   - Spring will not be exposed, to reduce crevices where bacteria can build up.
8. **Ergonomics:**
   - Ensure the design promotes the use of the palm for operation, as it's more ergonomic and minimizes thumb strain.
9. **Design & Operational Enhancements:**

- Incorporate recommendations about the device's operational features, especially ensuring it doesn't slide when open.
- Consider different spring placements, especially hidden ones. Additionally, identify optimal attachment methods for the slab press plate onto the plunger, to minimize crevices for cleaning purposes.

11. **Affordability:**

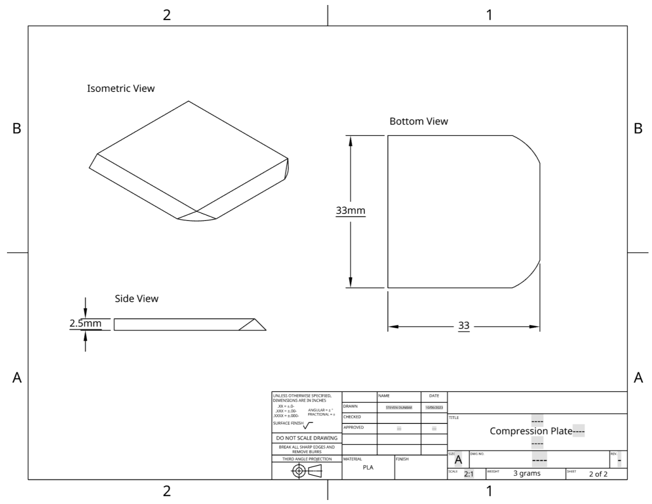
- Keeping the manufacturing, material, and labor costs in mind, strive to keep the end price under $50, catering to individual nurses' purchasing capabilities.

By addressing these suggestions and insights, we can ensure that the Punch Box Design aligns closely with the client's requirements and real-world usage scenarios. It's essential to keep these factors given during our feedback session at the forefront during the following redesign and prototyping phases.

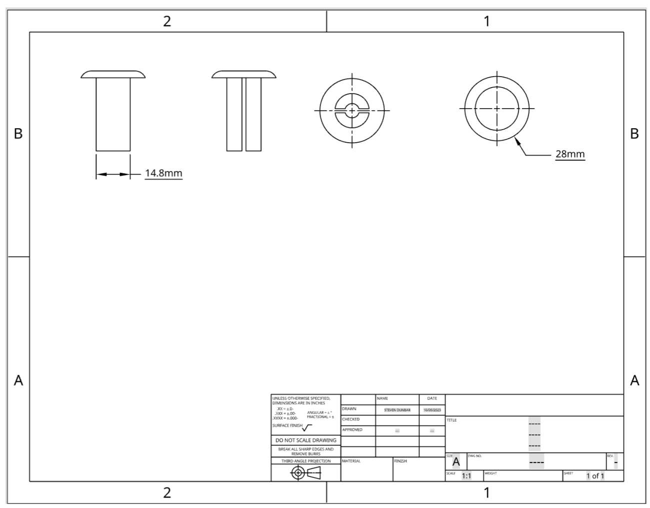
Detailed Design of Chosen Concept

Are overall design concept is a C shaped device with a plunger and compression plate to apply force to the renal clip. The C-shaped opening allows for the tube to be slid into the tool so that the compression plate can push down on the clip. The C shape also allows for the tool to fit comfortably in the user's hand. The small and compact design allows for easy transportability while the nurses are performing other tasks. The plunger is fitted with a smooth top which allows the device to be pressed by the user's palm eliminating any thumb joint movement.

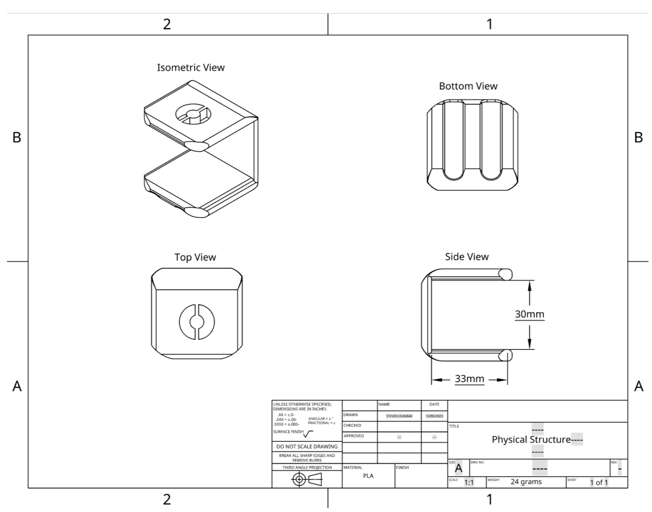
CAD Drawings of Subsystems of Concept



The plate of the punch box concept

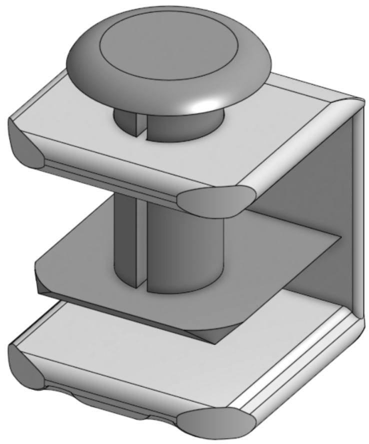


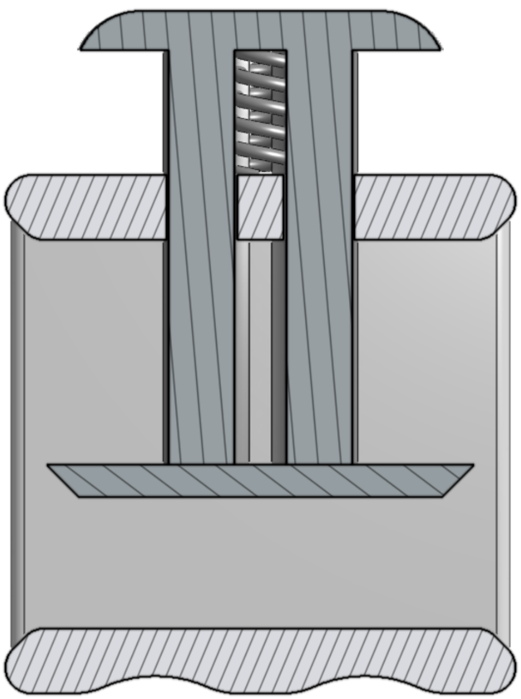
The plunge of the punch box concept

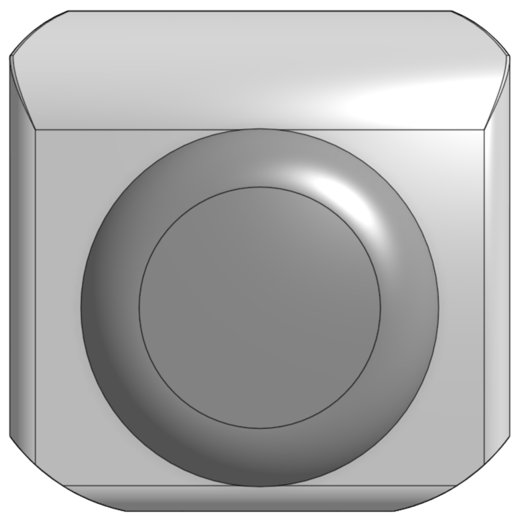


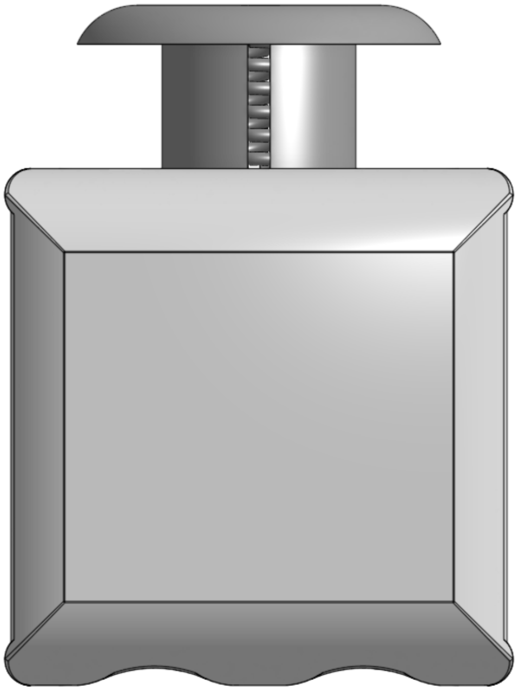
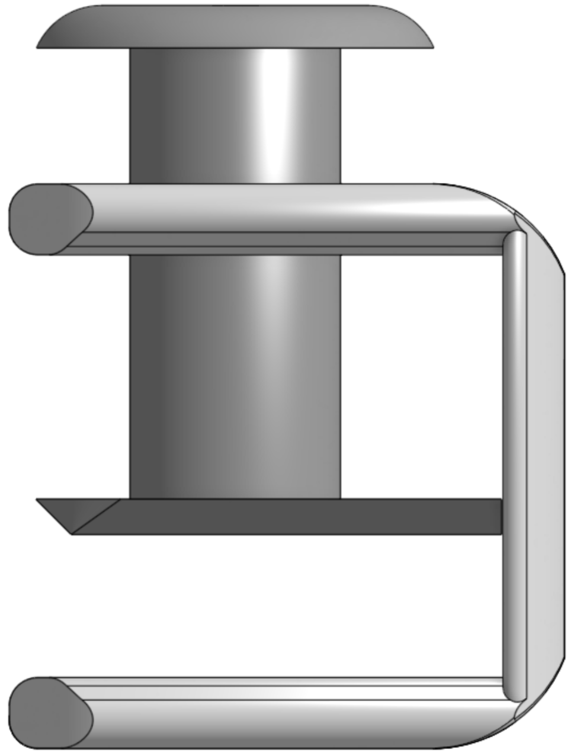
The body of the punch box concept

Visual Representation of Concept







OnShape CAD File Link to View

The current design uses preliminary concepts from our global design as well as feedback from our client meeting. Based on these 2 ideas as well as natural improvements to our design, we compiled a master prototype to test. Using the benchmarking criteria, the following details about the subsystems were selected

Subsystems Of Concept Linked Together

The subsystems are linked together by printing the part as a whole piece on a 3D printer. The subsystems of the design are as follows.

Physical Structure

The physical structure has changed from our global design concept. The design is a softly rounded C-shape cube. This choice was made to ensure the design remains compact and ergonomic, taking into consideration both its shape and the material used. The C-shaped box structure offers several advantages for our project. Firstly, its compact design facilitates efficient storage and transport, making it an ideal choice for our intended purpose. Additionally, the C-shaped structure contributes to the overall strength and stability of the system, ensuring it can effectively fulfill its function. However, it's important to note a potential drawback, which is that depending on the size of the box, the square design might lead to discomfort during use if it's either too small or too large for comfortable handling. To address this, careful consideration of the box size based on clip size is crucial to guarantee user comfort and usability.

In terms of how we make it in 3D, we utilize a one-piece + insert approach. The file can be printed in one single piece for easy manufacturing. An internal spring used to reset the device can be inserted halfway through the print, allowing for no disassembly required to use. This method allows for a seamless and streamlined construction, contributing to the overall simplicity and integrity of the design.

If our 3D printing + insert manufacturing method is not successful due to the strength of plastic, we can employ milling and lathe processes to shape and craft the components of the device in metal. Once the individual pieces are ready, they are connected through a combination of welding and screwing, ensuring a robust and secure assembly. This approach not only enhances the structural integrity of the system but also facilitates ease of maintenance and potential modifications.

Regarding the connection of our physical structure to other systems, the C-shaped box serves as the central element that links various subsystems within our design. Its efficient design and sturdy construction make it an ideal hub for connecting and integrating other components and systems, ensuring a seamless and cohesive operation of the entire system. This interconnectedness is vital for the overall functionality and effectiveness of our project.

Hand Grip

The Hand Grip subsystem of our design plays a critical role in ensuring user comfort and effective handling of the device. It is carefully designed to minimize stress on the user's hand and provide ergonomic support, as well as distribute forces evenly and reduce discomfort during operation. This choice offers numerous advantages, starting with its intuitive and natural design that comfortably fits into the curve of a user's palm, enhancing overall usability. It also incorporates helpful grip aids, such as a finger ledge and a rubberized / grooved exterior, which further improve handling and control. Notably, the ambidextrous design ensures that both left and right-handed individuals can use it comfortably. Additionally, its compact and straightforward design makes it easy to handle and operate. It successfully eliminates pressure on the thumb joint, reducing strain and discomfort during prolonged use. However, there are some potential drawbacks to consider, such as its suitability for individuals with Irregular hands, which might lead to discomfort. In summary, the hand grip subsystem provides a promising solution with an emphasis on natural design, control, and comfort, although it may require some adjustments to accommodate users with different hand sizes and address potential slippage and finger pressure issues. In terms of how we make this hand grip, it is as simple as adding CAD inserts and indents to the main body of the device

Regarding the connection of the hand grip to other systems, it serves as a pivotal interface between the user and the device, connecting the ergonomic design with the overall functionality. Its intuitive and user-friendly nature ensures a seamless interaction between the user and the technology. This integration is crucial for the effective operation of the entire system, as it directly impacts user experience and device control.

Compression Device

The Compression Device subsystem of our design is crucial for the mechanical action of closing or compressing the clip efficiently and with minimal force. The primary objective is to create a design that minimizes the effort required to close the clip while maintaining a compact form. To achieve this, we've employed a plunger and spring design, allowing for the compression stroke to be the only stroke required to enable the use of this device. The design boasts a high level of friction, ensuring a secure grip during use. The surface area of the flat jaw plane allows for direct force transmission to the target, reducing the effort required. Moreover, it is a cost-effective and easily producible solution, which is essential for practicality. The device is also easy to sanitize, meeting hygiene standards, and has the potential for quick application, which can improve with user experience. Notably, its universal clip size makes it versatile for various applications. However, there are potential drawbacks to consider, such as the speed of application, which may be slower, especially for less experienced users. Material choice and size reduction should be carefully considered to avoid fragility and bending or snapping of the spring mechanism. Additionally, the design lacks support for the clip until it is clamped down, which may require precise handling.

When considering how to make this Compression Device, we have opted for a one-piece 3D printing approach using plastic. This method streamlines production, as the entire device can be created as a single unit, minimizing the need for assembly or additional testing. Plastic is a suitable material choice, given its ease of 3D printing, cost-effectiveness, and flexibility. This ensures a straightforward and efficient manufacturing process that aligns with the designs objectives. In the event that plastic proves insufficient or less durable, the design can be adapted for metal production using milling and lathe processes. This offers a robust alternative and maintains the option to weld or screw together assemblies, enhancing durability and extending the device's lifespan.

In terms of connecting the Compression Device to other systems, it plays a pivotal role in the overall functionality of the design, as it is responsible for the essential mechanical action of closing and compressing the clip. It is integral to the device's operation and must be seamlessly integrated into the overall system. This integration is essential for ensuring a user-friendly, efficient, and versatile product, and it directly influences the ease of use and the quality of the device's results.

Clip Support

The Clip Support subsystem is an essential element in our design, tasked with securely holding clips in place as the compression device operates. Our chosen approach involves sliding the clip into a C jaw for practical and efficient clip management, especially since our tool must be operated with just one hand. This C jaw design offers noteworthy benefits, such as one-handed operation for user convenience and flat jaws with rubbery material, providing excellent friction for a secure grip on the clip, minimizing the risk of slippage and ensuring precise control. It's worth noting, however, that achieving precise adjustments with this system may prove challenging in certain situations, and the complex hand motions required for precise clip adjustments could potentially pose some challenges for users.

When it comes to the manufacturing of the Clip Support system through 3D printing, our strategy involves creating it as a single, one-piece component, simplifying the production process and ensuring a cohesive unit. Plastic is the chosen material for this subsystem due to its compatibility with 3D printing technology, offering cost-effectiveness and design flexibility. What's notable is that the Clip Support is designed to be pre-attached to the structure, eliminating the need for additional testing. This seamless integration not only saves time and resources but also aligns with our design's focus on efficiency and practicality. In cases where plastic might prove inadequate or less durable, the design can be adapted for metal production using milling and lathe processes. This allows for the option of welding or screwing together assemblies, enhancing durability and extending the system's lifespan.

As for how the Clip Support connects with other components, it plays a central role in ensuring the compression device operates effectively, serving as the critical interface for handling the clips. It facilitates a seamless interaction between the user and the mechanical action, making it an indispensable component of the entire system. This seamless integration ensures that clip handling is not only reliable but also user-friendly, enabling efficient use of the device. The secure grip and one-handed operation it provides are essential for the product's success, enhancing its practicality and overall usability.

Skills and Resources Utilized to Create Design

Skills Used

1. **Computer-Aided Design (CAD):** Leveraged by team members Steven to design and visualize the product in 3D space. CAD software used for this project will be Onshape.

2. **3D Printing:** A prominent skill, especially for Aaditya and Zach, who are also certified in 3D printing. It enabled us to transform our CAD designs into tangible prototypes. Steven has used his 3D printing skills to print our first prototype.
3. **Material Knowledge:** An understanding of suitable materials for our design was pivotal to ensure durability, hygiene, and ease of use. Farah has taken many materials classes, and with discussions and research and information given by the client, we are choosing to use ABS plastic.
4. **User Research:** Farah’s experience with client interviews ensured we gathered precise feedback from our stakeholders, aligning our design closely with the user's needs.

Resources Used

1. **CAD Programs:** Used for designing parts of the prototype. Notable software includes Solidworks (Can be used by most team members), Onshape (Steven), will be starting with Onshape.
2. **3D Printer:** Critical in producing tangible prototypes from our CAD designs. Aaditya and Zach are certified in its use.

For this prototype, we were short on some skills including how to modify the code to be able to add some tools to the printer while midway printing and skills for finishing like polishing and smoothing. One way to obtain those skills would be to directly go to the TA or CEED staff and ask them to teach us the necessary skills or obtain them from learning through YouTube. Some of the product assumptions could potentially limit the implementation of our design and these are the assumption that the clip size is under 35 mm tall, small PLA in the compression system, and that the PLA will withstand the multiple repetitions of the device. Resources to build prototype 1 are the CAD program to design prototype parts, 3D printer, PLA for printing material of the prototype parts and more proficiency in coding language used for the 3D printer. Although we are starting out prototypes using PLA we will be using ABS for our final prototype.

We possess a broad range of skills, a potential missing skill could be our in-depth expertise in medical ergonomics specific to nursing requirements. Which is why to bridge this gap, our client provides us with feedback and resources to help us understand this field better to have a better product designed at the end.

Assessment of Time Required to Implement Design

Time Assessment for Design Implementation:

Given the combined skills of the team, we have estimated a week's timeframe to complete the design and implementation of the 1st prototype. The time allocation is broken down as follows:

1. **CAD Design:** This took roughly a day, and another day to implement feedback from our client, and controlled group (asking stakeholders for feedback)
    - Any changes to the CAD would be in dimensions once we get the actual clips to test on. The client seemed to be happy with the first set of feedback, which means there will be minor changes going forward, which can be quick to change.
2. **3D Printing:** 2-4 days. Given the complexity of the device of putting together the device, and test out different ways to put the device together.
3. **Assembly and Testing:** 2 days. This will involve the collective effort of all team members, depending on availability.

Due to the current midterm season, our group's available time for Deliverables is comparatively limited. However, by leveraging platforms like Wrike (Valentin) and Notion (Farah) for project management, along with the dedication of the team members, we are confident in our ability to stay on track. Furthermore, Steven's proficiency with the 3D printer can expedite prototype development, saving crucial hours, and we can print after hours from Makerspace due to one of our team members having a 3D printer at home.

It's worth noting that while our time estimate is based on the assumption that the project progresses without hiccups, we have allocated buffer time within the week-long duration to accommodate unforeseen challenges. Should we face setbacks, members have expressed their willingness to learn and adapt, further bolstering our ability to stay on schedule.

Critical Product Assumptions

Define any other critical product assumptions that could affect your ability to implement your design. For example: the acceptable values for a specification, availability of material/component, or a critical functionality.

Critical product assumptions

The main assumption made is that nurses are willing to buy (or hospitals to buy the product in bulk) and use the product. If nurses, being the only possible clients, are not entertained by the device, because the device slows them down, hurts their hand, is too large etc… it would be impossible to implement the design.

The acceptable values for a specification:

Metric #	Needs #s	Metric	Units	Weight
Functional Requirement				
1	3	Number of clips the device can close before failure	# of clips	0.6
2	4,5	Reduction in thumb joint stress (compared to manual operation)	%	1
3	7	Time taken to apply a clip using the device (should not exceed manual operation time)	seconds (s)	0.8
4	11	Time taken to adjust the device for different tubing and clip sizes	s	0.8
Non-Functional Requirement				
5	2	Ability to be used with both left and right hand (binary: yes or no)	binary	0.4
6	8	Ability to maneuver in space of X cm width (binary: yes or no)	binary	0.8
7	10	Resistance to alcohol-based cleaning agents (no degradation after X wipes)	# of wipes	0.8
8	12	Compatibility with different hand sizes (e.g., can be used with X% of adult hand sizes)	%	0.6
Constraints				
9	1	Total volume of the device	cm^3	0.6
10	1	Total weight of the device	g	0.6

Metric #	Needs #s	Metric	Units	Weight
11	5	Number of operations using thumb (should be 0)	#	1
12	6	Manufacturing cost of the device	CAD $	0.2
13	9	The lifespan of the device under normal daily use	days	0.6
14	13	Adjusts to a number of different renal clip sizes.	cm	0.4

As determined in deliverable C, the device must respect all these metrics. The ideal specifications were assumed, so despite our final design meeting all the ideal values, they may still be insufficient.

Availability of material/component

The current design for the device is comprised of a plastic shell and plunger which can be 3-D printed, and a metal spring which will require a small amount of steel. We assume that these materials will be highly available, as they are all common materials. Paired with the fact that the device is meant to last for several years, and will not be replaced often, acquiring the materials should never be an issue. However, the process of 3-D printing is slow, so if there were a large amount requested a holdup might occur.

Critical functionality

The product must close at least 500,000 clips before failure. The final design is assumed to meet this requirement, however, without physical testing, it is impossible to be certain. If the product does not meet this requirement, it could become more of a nuisance than a useful tool. If the thumb joint has more stress than the minimal amount, the device would be insignificant as it wouldn’t succeed at its primary purpose of removing all thumb joint stress. In addition, if the device creates additional stress in other parts of the hand, the device could cause even more damage. The only way to determine if this is the case would be to do rigorous physical testing. The device must also close each clip within a certain amount of time. We assumed a time of 3 seconds would be an ideal amount of time to close each clip. If our assumptions are incorrect and it is too slow, our device could become redundant as it would impede the nurses’ ability to close the clips rapidly. The final critical assumption is the amount of time required for the device to adjust to each clip size. The nurses currently do not need to make this adjustment as they are currently using their hands. The device must obey an ideal value, that being 20 seconds to adjust, however, this value was never tested and as such may be too high, which would prove difficult to use.

Preliminary Bill of Materials (BOM) of Final Prototype

The Bill of Materials (BOM) was meticulously crafted after a comprehensive analysis of the prototype's design requirements and specifications. Essential components were identified through collaborative brainstorming sessions with team members and then sourced from the most cost-effective and reliable suppliers online. The BOM represents not only the material costs but also the strategic planning undertaken to ensure the prototype's feasibility within the budget constraints.

Item #	Part Name	Quantity	Material	Description	Unit Cost	Link to Purchase Part
1	Physical Structure - Frame	1	ABS Plastic Filament (1.75mm)	40 mm x 40mm x 40mm	$28	link
2	Spring	1	Stainless Steel	0.44’’ x 0.18’’ stainless steel spring	$2.95/ unit (comes in a pack of 6)	link
3	Plunger	1	ABS Plastic Filament	25mm in height and diameter of	Same as #1	—

Item #	Part Name	Quantity	Material	Description	Unit Cost	Link to Purchase Part
				hole plunged is ~11 mm.		
4	Compression Plate	1	ABS Plastic Filament	33mmx33mmx 2.5mm plate.	Same as #1	—
				Total Cost =	**$45.97**	

Potential Additional Costs:

- **3D Printing Costs**: Considering it is mentioned that the plastic shell and the plunger are 3D printed, there may be costs associated with the 3D printing service.
- **Testing & Validation**: Costs associated with physical testing and validation of the device. Before our final prototype, we will need to print, analyze, and test the product. We need to test different assembly techniques, and maybe different sizes and dimensions of our design. Also, making alterations depends on the feedback from the client and the results of testing.

While the BOM costs total up to ~$46.00, these additional costs need to be factored in to ensure the project remains under the budget.

For this BOM, we're making some assumptions regarding material costs and supplier availability. It is crucial to verify these costs with actual suppliers before proceeding with purchases. It's also important to consider bulk purchases if production scales up in the future, which could further reduce the unit costs for our customers.

Project Plan Update: Wrike SnapShot

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=RNPGljiGtuwDKEjMK6bA5ShpKGtW3o98%7CIE2DSNZVHA2DELSTGIYA

Conclusion

In conclusion, this deliverable has been instrumental in advancing our design stage by incorporating valuable client feedback and addressing areas of improvement. By summarizing the feedback received during our second client meeting, we learned that we need to prioritize the ergonomics, speed, and portability of our tool. Using CAD software, we have created an updated and detailed design of our concept, deciding to connect each subsystem by printing the part as a single piece.

This approach allows us to visualize the integration of various components effectively and to evaluate any discrepancies between the subsystems. Through the identification of required skills and resources for prototyping and final product development, we realized the need to learn how to modify g-code and polish 3D prints. By formulating a plan to obtain any missing skills, we ensure that we have the necessary expertise to bring our design to completion.

Furthermore, the assessment of the time required to build a prototype in relation to team members' availability ensures a realistic timeline for the project. By proactively examining product assumptions, we can anticipate and address any potential challenges that may arise as we approach the design day. Lastly, the creation of a bill of materials indicates that we will be under budget for our project.

Overall, this deliverable has been helpful in refining our design process, ensuring a well-informed and strategic approach towards the development of our final product.