Deliverable C - Problem Definition, Concept Development, and Project Plan

Group 2.3

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Introduction

This deliverable is divided into two main parts: Problem Definition and Concept Development. In the problem definition phase, we will list and prioritize client needs/problems, create a problem statement, provide need-inspired metrics and conduct benchmarking, and develop target specifications. In the concept development phase, we will develop design concepts and evaluate them against target specifications. After this we will select the most promising solutions to develop a global design concept and then visually represent it using CAD. We will finish by explain the relationship of the global design to target specifications. The purpose of this document it to prepare design ideas to show to the client at the next meeting.

C1: Problem Definition

To define the problem definition, we summarized the initial client meeting to ensure a clear understanding of the project requirements. This includes identifying any specific needs or challenges mentioned by the client. The next step will be to carefully analyze the gathered information, aiming to identify any areas that require further clarification. This step is crucial in guaranteeing that the problem statement accurately reflects the true problem that needs to be solved. Finally, we will compile this information into a problem statement.

Client Meet 1 Insights

The meeting with the client focused on the challenges nurses face when clipping and unclipping the clips on the blood tubing for renal care. Nurses use plastic renal clips for dialysis, a process that involves 30-40 multiple plastic clips on one piece of tubing. The force required to snap the clips into place depends on the size of the clip and the diameter of the tubing, which differ by a maximum of 2 cm in size. Given the repetitiveness of this task combined with the poor ergonomic side of the pinching motion (using the thumb to close the clip), nurses have developed osteoarthritis in their thumbs, from the repetitive stress/ strain on their thumb joints.

The main objective that the client emphasizes throughout the meeting, is to design a device that assists nurses in clipping rigid plastic clips on blood tubing for renal care and reduces stress on the thumb joints while clipping.

The following encompasses what was stated by our client about the problem and what we are designing for:

1. **Ergonomics & Safety**

- As mentioned before, the repetitive nature of the clipping process poses ergonomic challenges for nurses, leading to thumb injuries (mainly osteoarthritis) due to repetitive stress.
- The current side pinch motion of the thumb is poor ergonomically and increases the risk of osteoarthritis.
- The device should aim to avoid using the thumb as the primary mechanism, potentially utilizing the entire hand or a different motion which is considered safer.

2. **Ambidextrous & Maneuverability**

- The device should be ambidextrous, allowing for use with either hand.
- It needs to be easily maneuverable in tight spaces, such as around IVs, other tubing, and bed spaces.
- Quick operation is essential to maintain or even enhance the current speed of the clipping process when attaching clips to the tubing. Essential to lower the barrier of initial mass use of product and adaptation in the market.

3. **Durability**

- The device should withstand repetitive use, with an average nurse handling between 250-500 clips daily, with a minimum of 100 clips per day/ nurse.
- It should ideally last a long time without requiring frequent replacements, but easily manufacturable, for bulk orders by clinics/hospitals once adopted in the market, as stated by the client.

4. **Sanitization**

- The device needs to be easily cleaned and sanitized.
- Compatibility with cleaning agents like alcohol wipes and heavy-duty Lysol is crucial.
- Sterilization capability is essential, and the device should withstand consistent wiping with alcohol multiple times a day.

5. **Portability**

- The ideal device would be small enough to be carried from room to room, potentially fitting on a keychain or inside a pocket, as stated by the client.
- Ideal to be small in dimension and lightweight.

6. **Adaptability**

- The device should accommodate various sizes of tubing and clips, ideally without requiring time-consuming adjustments between sizes.

7. **Client Recommendations & Desired Example**

- The client suggests the possibility of a squeezing mechanism for the hand. A mechanism similar to looped scissors for children with motor difficulties is suggested as an inspiration.

8. **Target Market Mentioned, Awareness of Different Brands & Sizes**

- Although the initial focus is on the standards in British Columbia (BC), there is potential for expansion to other regions.

- The design needs to consider variations in clip brands (material inconsistency) and sizes, but they all meet a standard in our initial market (BC), though the motion and function remain consistent across them.

9. Possible Waste Reduction

- Currently, used clips are discarded. If the device can facilitate unclipping, there might be potential for reducing waste by reusing clips. However, unclipping is not a primary focus, and should not be prioritized at all over the clipping functionality and ergonomics.

10. No Existing Solutions

- Presently, there are no dedicated tools or devices that the client is aware of for this purpose. Some nurses might use braces or splints, but these are not ideal or formal solutions.

11. Business Perspective

- The design should consider factors like pricing, feasibility, and potential for broad adoption.
- The initial rollout could target a specific group of nurses or a clinic, starting with the arthritis clinic in BC, with a vision for more extensive implementation later on.

We concluded the meeting by requesting access to a few of the renal clips and tubing that the nurses use to aid with the design process. It was agreed that further communication via email could be used to address any additional thoughts or insights that may arise.

Overall, the meeting provided valuable information regarding the challenges that nurses face when using renal clips. This information will help us define our needs and problem statement to address so that our product will meet the client's needs. These insights will be critical in developing design ideas and prototypes with efficiency and ergonomics in mind.

Information to be Clarified Later

The following list explains what information we were unable to obtain during the client meeting:

1. During the client meeting one, the client was unable to give us a metric for: how much force is required to close the clips. This information will be critical for designing certain components of the final design. We will obtain this information once we have the renal clips, then we will use a pressure gauge and measure the resistance of the clip ourselves, to calculate the minimum force required.

2. How fast the nurses apply the clips in a workplace setting. We need to ensure that our design does not slow down the workplace of the nurses. Hence, we need a set a target specification of how fast our device must operate, to either speed up the process or keep it

at the same pace nurses already operate at. Ideally, we need our clients to time a few nurses doing this task so we can get an average value.

3. The design and clipping process. We need to know a bit more information on the actual application of the clips. We are under the impression that the clips are looped onto the blood tubing and then clipped on, as described by the client during the meeting. However, to make the device fit the nurses' needs we need to be sure that we know the clipping process. For this we will ask the client to provide a short video of a nurse performing the task, to analyze slowly at our own pace.

Identified Need Statements

To define client needs, we summarized the meeting with the client and highlighted any needs that the client communicated with the team. Then, we started by finding a target user group of people who would specifically be interacting with the product who are mainly nurses and a few doctors/ medical students. Through an interview with our client (client meet 1) we asked open-ended questions to understand the points, challenges, and requirements for the project. This allowed us to get a broader picture of the problem and insights into the purpose of our tool. Next, we researched information about how the clips are used on a dialysis machine to better understand the clipping process. During the meeting, the client shared valuable information on how the tool should interact with the hand to prevent injury. This information underlined specific needs that we may have overlooked. Once this was done, we compiled all our information and organized the list of needs into common themes and patterns removing or combining needs to reduce repetitiveness. We then ranked the needs based on the information from the client, what the client emphasized, discussing it among the team, and our design for X criteria.

Given the deadline for this deliverable we were unable to observe user interactions with a dialysis machine nor were we able to talk with any stakeholders, as stated earlier. We did however explore the possibility of observing renal nurses by contacting the Jindal Kidney Care Center in Riverside Campus. We will keep this option in mind for future research for the project.

Table 1: Need Statements

#	Needs	Weight
1	Lightweight/small enough to be able to clip onto clothing/ fit in the pocket.	0.6
2	Designed for ambidextrous use.	0.4
3	Can withstand the repetitive task of closing clips.	0.6
4	Reduce stress on thumb joints with the motion to clip	1
5	Eliminate the use of the thumb as the primary mechanism to operate the device.	1
6	Needs to be affordable.	0.2

7	The speed of the clip application stays the same/ increases.	0.8
8	Easy maneuverability in confined spaces around medical equipment.	0.8
9	Robust to withstand rigorous daily use. Lasts a long time	0.6
10	Doesn't degrade/ rust when consistently cleaned daily with cleaning agents containing alcohol.	0.8
11	Not time-consuming to accommodate different sizes of tubing and clips.	0.8
12	Fits well and can be used with all different types of hands.	0.6
13	Adjustable to different renal clip sizes	0.4

**The weight column evaluates from a scale of 0 - 1 how important this feature is to implement, with step sizes of 0.2. The higher the weight the more important it is. **

Problem Statement

A good problem statement articulates the problem clearly and concisely. We used the needs statements to contract a problem statement that focus on the impact and significance of the problem while emphasizing the needs and desires of the target audience or users. Additionally, we tried to avoid biases and assumptions in our problem statement to avoid preventing design creativity. The final product statement will be used in our design project as a precise definition of the problem we are solving. Hence, based on the needs and client meeting summary we defined the following problem statement:

"Nurses are facing thumb osteoarthritis from repetitively attaching renal clips on blood tubing, highlighting a need for a portable, adaptable, durable device that alleviates thumb strain, and ensures ambidexterity and quick operation, while withstanding frequent sanitization."

Metrics Based on Client Needs

From the defined needs of the client, we converted these needs into project objectives. These objectives are specific and measurable metrics. We then categorized these metrics into functional, non-functional, and constraint categories. After that, we ranked the importance of each metric based on the importance ranking of the corresponding need from earlier.

Table 2: Metrics with measurable units.

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	seconds (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	grams (g)	0.6
11	5	Number of operations using thumb	#	1
12	6	Manufacturing cost of the device	CAD $	0.2
13	9	The lifespan of the device under normal daily use	year	0.6
14	13	Adjusts to several different renal clip sizes.	cm	0.4

Functional Requirements

Functional requirements describe what the systems must do specifically. Outlining the intended behavior of the product, detailing what it must do to effectively fulfill its purpose and meet user needs. In this context, these set of requirements ensure that the device adequately assists nurses in applying clips to tubing, contributing to task efficiency and reduction in physical strain.

Non-Functional Requirements

Non-functional Requirements ensure the system's effectiveness and define how a system performs its function; they are known as quality attributes. They are requirements that cover usability, reliability, performance, and supportability. In this context, these requirements ensure that the device is convenient and practical to all users, irrespective of their hand dominance, and can withstand thorough/ regular cleaning.

Constraints

Constraints are restrictions/ limitations to the design, which can come from things like the budget, resources, technology, and time. They define the boundaries within which the design must operate. In this context, the constraints defined in the table ensure that the device is economically and practically feasible to produce and use without exceeding budgetary size, and resource limits placed by the client.

Benchmarking

User Benchmarking

The focus of user benchmarking is to examine a product/solution to a problem from the user's perspective, considering usability, user satisfaction, and the overall user experience. This helps to improve the end product design and functionality to better meet user needs and expectations. Our approach to user benchmarking is through the client interview (learned that there is little to no knowledge on existing products), observations, and online research/ forums on direct/indirect products competing with our product. The main point is to collect information on preferences, needs, and challenges with existing products.

Direct:

We looked into direct competitors, who are businesses that offer the same or similar products to the same market; products that fulfill the same needs for customers. From our initial client meeting we discovered that our client is familiar with any products on the market that fulfill the needs that our client is looking for. We were not able to find direct competitors, which are devices that are specifically designed to help with the ergonomics of clipping renal clips for dialysis tubing. This confirms the statement made by our client, where they stated that there is no formal product/ device marketed towards this problem.

Indirect:

Also, we looked into indirect competitors that offered different/ unrelated products but satisfied the same needs for the same/similar problem in different ways. Through our research we found other solutions that nurses might be able to use to make this task easier, even if not specifically designed for this purpose. For example, general-purpose gripping, clamping tools, or existing arthritis aid devices on the market.

The following tools are indirect competitors with a summary of the user benchmarking data obtained through our research online through product reviews on Reddit, amazon reviews, YouTube videos, and blogs from those who have used each product. Each product is evaluated based on 4 usability metrics and focuses more on usability and experience using the product, so no technical aspects. Photos and descriptions of each product under the technical specifications section of report.

Pliers Padget 7-3/4:

- Ease of Use:
  - Comfortable grip handles that fit most hand sizes.
  - Intuitive squeezing mechanism for operation.
- Durability:
  - Made from stainless steel, ensuring a long lifespan.
  - Resists rust and common stains from extended use.
- Portability:
  - A bit on the larger side, may not be pocketable.
  - Lightweight, making it easy for transport in a toolkit.
- Safety & Ergonomics:
  - Rounded edges to prevent accidental injury.
  - Requires manual force; might be strenuous on prolonged use.

LIGACLIP® Endoscopic Rotating Multiple Clip Applier:

- Ease of Use:
  - Designed for medical applications which ensures precision with application.
  - The rotating mechanism allows for flexible positioning, which is useful in tight spaces.
- Durability:
  - Primarily made for single-patient use; thus, not extremely durable for repetitive tasks.
- Portability:
  - Compact design suitable for medical settings.
  - Not intended for pocket ability.
- Safety & Ergonomics:
  - Specifically designed for minimal tissue trauma.
  - Comfortable hand-feel and low effort (force) required to operate with squeezing mechanism.

WECK - Auto Endo5 - Automatic Clip Applier:

- Ease of Use:
  - Automatic mechanism reduces manual effort.
  - Precise with clip application.
- Durability:
  - Durable materials suitable for medical environments. (Stainless steel, titanium, and medical-grade plastics)
  - Resistant to common disinfectants. Does not easily degrade.
- Portability:
  - Compact, designed for endoscopic use.
- Safety & Ergonomics:
  - Ergonomic design (squeeze mechanism) to reduce user fatigue.
  - Safety mechanisms in place to prevent unintended release of clips.

Hydraulic Crimping Tool:

- Ease of Use:
  - Heavier and typically designed for industrial use, not medical.
  - Hydraulic mechanism greatly reduces manual force required to squeeze down.
- Durability:
  - Extremely durable given the industrial applications.
  - Resistant to wear and tear from heavy usage.
- Portability:
  - Heavy and not easily portable; typically used in fixed locations. Not good for the application for a hospital setting or the application of renal clips on blood tubing.
- Safety & Ergonomics:
  - Safety precautions are needed given the high force.
  - Comfortable grips but might require two hands for operation.

Technical Benchmarking Products

The focus of technical benchmarking is to evaluate the technical aspects, features, and specifications of products in the same market as the problem we are trying to solve. This is done to understand technical characteristics that make a product successful and to either adopt or adapt certain technical features to improve our design. Our approach is to analyze technical specifications, construction, materials, and other technical attributes of competing (direct) or similar products (indirect). When researching products to benchmark it became apparent that there were no direct products solving this problem directly. As a result, we had to benchmark products could perform a similar task (indirect).

For our technical benchmarking we continued with the following products, looking into their product specifications, which are laid with our metrics table:

1. Pliers Padgett 7-3/4

The Padgett pliers are a medical grade pair of pliers. The pliers use a pivot joint to increase the pressure of the user on the jaws of the tool. The pliers could be used to close the renal clips while reducing stress to the thumb joint. The jaw on this pair of pliers has the capability of adjusting to accommodate different sized clips. The stainless-steel material of the pliers allows for easy sanitization without corrosion. Finally, the pliers have a formed handle with finger groves to increase hand comfort.

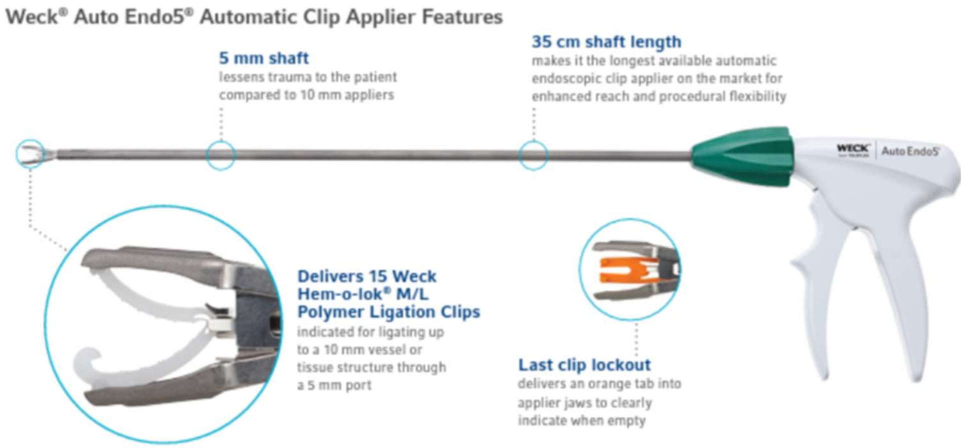
2. LIGACLIP Endoscopic Rotating Multiple Clip Applier

This tool is used to apply stable sized clips to patents during surgery. While the clips are significantly smaller than renal clip the device has the capability of applying multiple clips. The device has a replaceable cartridge of clips to allow for fast and uninterrupted application of clips. The long arm of the device allows it to access hard to reach places. While does not reduce the pressure need to close the clip it allows the user to use their entire hand to apply the force to close the clip. This device is also a medical grad tool and allows for easy sterilization.

3. Hydraulic Crimping Tool

This tool is an industrial tool meant for construction work and clamping rivets. The tool is force capabilities are highly exceeding the required force to close a clip. However, the design significantly increases the applied pressure at the jaw of the tool. This means that the user would only half to apply less than half the force regularly required to close the renal clip. Furthermore, the design of the tool is compact and could be maneuvered into tight spaces.

4. WECK – Auto Endo5 – Automatic Clip Applier



The WECK device is utilized to affix consistently sized clips to patients during surgical procedures. Although the clips are notably smaller than renal clips, the instrument possesses the ability to deploy multiple clips consecutively. It is equipped with a replaceable cartridge, ensuring swift and continuous clip application. The elongated armature of the tool grants it accessibility to more challenging and remote surgical sites. While the WECK device doesn't mitigate the force required to secure the clip, it is ergonomically designed to allow the practitioner to engage their entire hand when exerting the necessary pressure. As a medical-grade instrument, it is tailored for easy and effective sterilization.

Technical Benchmark on Metrics

Based on the information available about the design of the chosen products we filled in the following table to benchmark. The products are rank with respect to the importance of the metric weight. The underlined values are the best values of all the products.

Table 3: Technical Benchmarking

Metric#	Needs#	Metrics	Weight	Units	Products			
					Pliers Padgett 7-3/4	Ligaclip	Hydraulic Crimping Tool	WECK – Auto Endo5
1	3	Number of clips the device can close before failure	0.6	# of clips	<u>1,000,000</u>	100,000	800,000	500,00
2	4,5	Reduction in thumb joint stress (compared to manual operation)	1	%	64	40	<u>80</u>	60

3	7	Time taken to apply a clip using the device (should not exceed manual operation time)	0.8	sec (s)	4	2	3	2.5
4	11	Time taken to adjust the device for different tubing and clip sizes	0.8	sec (s)	4	N/A	0	1
5	2	Ability to be used with both left and right hand (binary: yes or no)	0.4	binary	yes	yes	yes	yes
6	8	Ability to maneuver in space of X cm width (binary: yes or no)	0.8	cm	17.5	5	20	6
7	10	Resistance to alcohol-based cleaning agents (no degradation after X wipes)	0.8	# of wipes	Unlimited	Unlimited	Unlimited	Unlimite d
8	12	Compatibility with different hand sizes (e.g., can be used with X% of adult hand sizes)	0.6	%	99	99	99	99
9	1	Total volume of the device	0.6	cm^3	UTO	UTO	UTO	UTO
10	1	Total weight of the device	0.6	g	250	350	2720	300
11	5	Number of operations using thumb only (should be 0)	1	#	0	0	0	0
12	6	Manufacturing cost of the device (markup estimated to be 50%)	0.2	CAD $	84	325	31	140
13	9	The lifespan of the device under normal daily use	0.6	years	10+	2+	7+	UTO
14	13	Adjusts to a number of different renal clip sizes.	0.4	1 to 5 cm	1 to 4	N/A	1 to 4	4.9mm to 9.2mm
				Rank	5	4	4.8	4.6

The technical benchmarking highlighted several tools tailored for diverse applications. The Padgett pliers' adjustable jaw accommodates various clip sizes; the LIGACLIP ® offers rapid, multiple clip application in hard-to-reach areas; the Hydraulic Crimping Tool emphasizes force amplification while being compact; and the WECK device's ergonomic design aids in minimizing user strain. While no direct competitors surfaced, these insights reveal an opportunity to integrate these optimal features into a dedicated renal clip applicator, filling a distinct market gap.

Target Specifications

To set the target specifications of the product we will use the benchmark data along with analyzing and performing basic calculations to determine ideal values for the product. Both sets of marginal value and ideal value will be used to define the final design specifications.

Marginal and Ideal Target Values

Using the best specifications from benchmark data we obtain the marginal values. The ideal values are acquired from determining the specs required to meet the standard for product design. For example, the "number of clips the device can close before failure" was decided by finding the product of the life expectancy times the average number of clips used per day. The max weight was determined by consulting Canadian Center for Occupational Health Safety (CCOHS) page on Hand Tool Ergonomics. Then, the max volume was determined based on the average volume of plastic/metal material that does not exceed the required weight.

Table 4: Marginal and Ideal Target Values

#	Metric	Units	Marginal Value	Ideal Value	Weight
1	Number of clips the device can close before failure	# of clips	1,000,000	500,000	0.6
2	Reduction in thumb joint stress (compared to manual operation)	%	80	70 - 80	1
3	Time taken to apply a clip using the device (should not exceed manual operation time)	seconds (s)	2	3-4	0.8
4	Time taken to adjust the device for different tubing and clip sizes	seconds (s)	0	20	0.8
5	Ability to be used with both left and right hand (binary: yes or no)	binary	yes	yes	0.4
6	Ability to maneuver in space of X cm width (binary: yes or no)	cm	5	5	0.8
7	Resistance to alcohol-based cleaning agents (no degradation after X wipes)	# of wipes	Unlimited	30,000	0.8

8	Compatibility with different hand sizes (e.g., can be used with X% of adult hand sizes)	%	99	95	0.6
9	Total volume of the device	cm^3	UTO	282	0.6
10	Total weight of the device	g	250	350	0.6
11	Number of operations using thumb (should be 0)	#	0	0	1
12	Manufacturing cost of the device	CAD $	31	50	0.2
13	The lifespan of the device under normal daily use	years	10+	7+	0.6
14	Adjusts to a number of different renal clip sizes.	1 to 5 cm	1 to 4	1 to 5	0.4

**Note: The acronym (UTO) stands for unable to obtain. **

Final Specifications Table

Looking at the marginal values and ideal values we now can formulate our final values. For most of the values, we tried to take an average of the values to ensure reasonable specifications and to ensure that our product would be competitive in the market. For some of the specifications, we decided to keep them closer to the ideal values as the client specifically requested those features. Some examples would be the client wanted the tool to be universal for all clips, so we kept the ideal values. We added greater and less then signs on most values to indicate that the product will be more effective if we are able to beat the specification value.

Table 4: Final Specifications

#	Metric	Units	Value
1	Number of clips the device can close before failure	# of clips	>700,000
2	Reduction in thumb joint stress (compared to manual operation)	%	>75
3	Time taken to apply a clip using the device (should not exceed manual operation time)	seconds (s)	<3
4	Time taken to adjust the device for different tubing and clip sizes	seconds (s)	<10
5	Ability to be used with both left and right hand (binary: yes or no)	binary	Yes
6	Ability to maneuver in space of X cm width (binary: yes or no)	cm	5

7	Resistance to alcohol-based cleaning agents (no degradation after X wipes)	# of wipes	500,000
8	Compatibility with different hand sizes (e.g., can be used with X% of adult hand sizes)	%	>95
9	Total volume of the device	cm^3	<200
10	Total weight of the device	g	<300
11	Number of operations using thumb (should be 0)	#	0
12	Manufacturing cost of the device	CAD $	<50
13	The lifespan of the device under normal daily use	years	>8
14	Adjusts to a number of different renal clip sizes.	1 to 5 cm	1 to 5

The established needs statements, problem statements, and target specifications will serve as foundational pillars for our brainstorming and ideation sessions, that we had. These well-defined criteria not only offer clear direction but will also be instrumental in evaluating and refining the concepts we came up with as we navigate through the design process. Our goal is to ensure that every idea aligns with the core requirements, driving us toward a solution that addresses the defined problem well.

C2: Concept Development

We decided to break project into four subsystems based on our list of needs. These four subsystems are meant to be a broad overview of the design to allow for creative brainstorming.

Physical Structure

The physical structure subsystem has to do with anything related to the structure and general shape of the design. If your design requires a special material this can also be included in this subsystem. It is important that the shape of this subsystem will not result in the device being bulky or hard to maneuver.

Hand Grip

This subsystem has to do with any part of the device that the users will use to hold or handle the device. The subsystem must be ergonomic and designed to have the minimal amounts of stress to the user's hand. The subsystem will consider how the user will hold the device when in operation and how the user will store the device for transport.

Compression Device

The compression subsystem is for the mechanical action of closing/compressing the clip. This subsystem design goal is to create a design that requires the minimal amount of force possible to close the clip. The compression device should be as compact as possible to oved the product from being bulky. Also, the device must be relatively fast to be an efficient device.

Clip Support

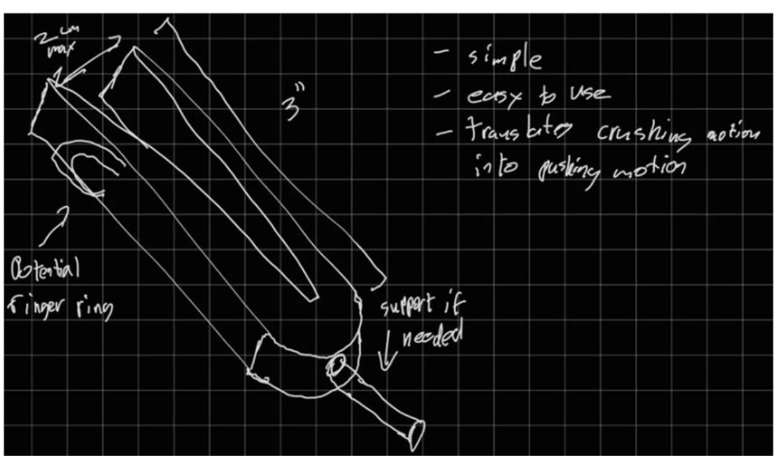
This subsystem deals with how the product will hold the clip in place while the compression device closes the clip. It will focus on the parts of the device that come in direct contact with the clip.

Proposed Prototype Concepts

To come up with the prototype concepts, our team did a brainstorming session to generate innovative and diverse ideas. To ensure a productive session, we had an overseer whose primary jobs was to keep the group focused on the task at hand. In addition, the overseer's job was to ensure that the other team members didn't judge the proposed ideas during the brainstorming session. Having someone immediately judge another team members idea would harm the uniqueness of the design ideas. Alongside the overseer, having we had note taker to record all the ideas made during the meeting. The notes were used as a reference for further analyzing the proposed ideas. This assisted in identifying potential design directions for the product. We swapped roles during the brainstorming meeting to allow everyone in the group to share an idea. environment that fosters creativity and innovation. The following ideas were the taken from the notes of the proposed design during the brainstorming meeting. Not all ideas from the brainstorming session are presented as there was a very large quantity of ideas presented during the session. Those presented below are those that through group discussion have gravitated more towards.

Before the session started, we segregated, and individually, came up with ideas under a timed manner, then came together to present our ideas to one another. Through out the session we sketched many ideas to help visualize our concepts digitally, using pen and paper, a white board, etc. We dove deeper into some ideas as we thought laterally, and evolved on existing products, ideas presented, and even combined some ideas together, as seen at the very end of this report.

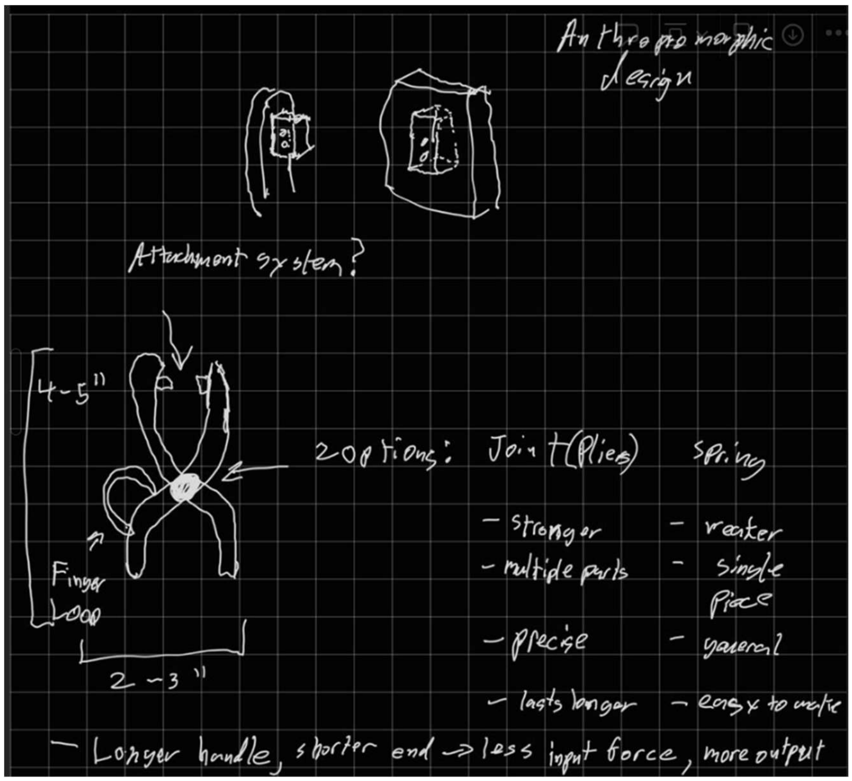
Aaditya Proposed Concepts:



Hand Grip: The device is curved to naturally fit into your hand.

Compression Device: The device slides forward and uses a smooth ramp to naturally compress the clip over time, changing a pinching motion into a whole arm exercise.

Clip Support: the tool will be made to stick well into the hand, however, has an issue with support behind the clip. This concept can definitely be implemented into other designs.



Physical Structure: This is a small device designed to convert a pinching motion into a fist-closing motion. It is designed based on needle nose pliers. It has a joint in the center and an attachment system at the ends. Ideally, it has longer handles and shorter front ends to maximize mechanical advantage

Hand Grip: The device has two handles which will be covered in rubber or grooved to increase grip. There will be a finger hole on the side to provide stability and a small hole to attach it to a keychain

Compression Device: The device is operated by squeezing the two handles together. This will cause the jaws for the tool to close around the clip.

Clip Support: The jaws of the tool are flat surface of ½ inch with a rubbery material to increase the easy of holding the clip between the jaws. In addition, the jaws can be partially closed to firmly hold the clip while positioning the clip.

Farah's Proposed Concepts:

Physical Structure: Handle with a long tube with a jaw at the end, that has a squeezing mechanism. Similar to the image above. One of three materials:

1. Polycarbonate (PC):
    - High impact resistance.
    - Transparent.
    - Used in eyewear lenses, optical disks, and bulletproof glass.
2. Polyether ether ketone (PEEK):
    - Excellent thermal and chemical resistance.
    - Used in aerospace, automotive, and medical implants.
3. Acrylonitrile Butadiene Styrene (ABS):
    - Good impact resistance and toughness.
    - Used in automotive components, protective headgear, and toys (e.g., LEGO bricks).

Hand Grip: The handle is ergonomic and allows the user to have a good grip on the device while using their whole hand, instead of just the thumb.

Compression Device: The compression is done by large handles which close a small jaw. The jaw is positioned on the clip allowing it to secure the clip on the tubing. The jaw size is adjustable.

Clip Support: The only way to support the clip is to hold the clip in the jaws of the device.

Zach's Proposed Concepts:

Designing a device similar to pliers that would shut the clip using the force of one's entire palm directed at two small points on the clip, quickly and easily shutting them, thereby eliminating the risk of arthritis in the thumb joint.

Physical structure: The following image is a proposed handle for the device.

As our client mentioned, an idea currently circulating among nurses is to create a device with a handle similar to children's scissors. Because of the ability to make precise movements with relative comfort and speed, as well as relieving the pressure from the thumb joint, which would be a good design feature.

Compression device: The following image is a proposed design for the tongs.

Compression device idea 1: This image is of beaker tongs. The tongs are comprised of two small, yet sturdy rods of metal covered with rubber sleeves which greatly increases friction between the tongs and the object. The proposed idea would be to slightly decrease the size to fit the child's scissors handle, as well as to reshape the tongs to fit the clip instead of a beaker.

Compression device idea 2: The second proposed tongs would be similar in shape to the previous one but will have a rectangular box at the end of the tongs which splits down the center to open and close with the tongs. This box will fit the clamp and directly position the tongs where the pressure needs to be applied.

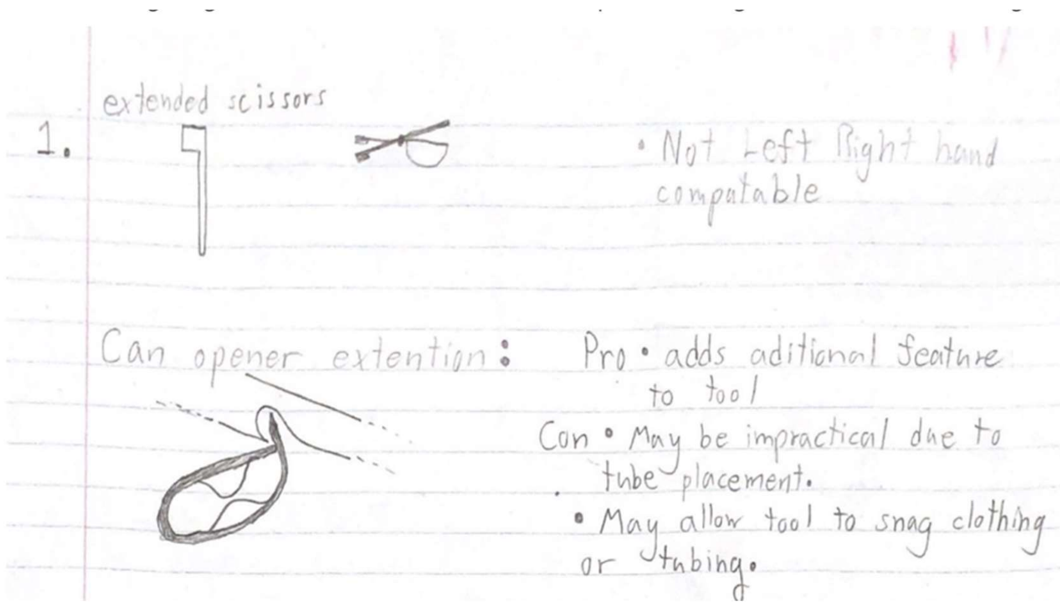
Clip Support:

Device idea 1: The only way to support the clip is to hold the clip in the jaws of the device.

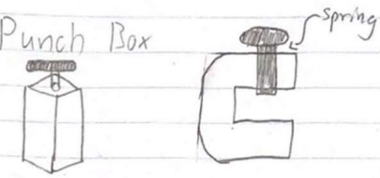
Device idea 2: The clip will rest in the jaws of the tongs allowing the user to guide the clip up and down the tube and maintain control while shutting it.

Steven's Proposed Concepts:

The following diagrams were the ideas that were come up with during the initial brainstorming session. There are two designs, that were decided to focus on for this deliverable.



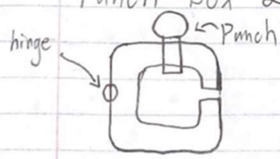
Punch Box



Pro: • Small compact
• easy to maneuver

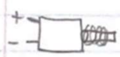
Con: • may not fit all sizes
• usure of ergonomic

Punch Box 2



Pro: Can be wrapped aroud a tube so the user simpley slides the device along the tube to clamp all of the clips

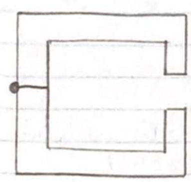
Could be automated with a actuator.



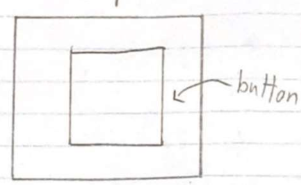
Con: • hinge could weaken clamping ability

← not likely strong enough

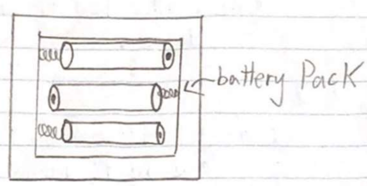
Punch Box 3:



Top veiw



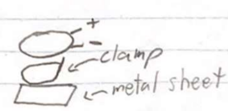
Bottom View



Need to supply 6 to 8 pounds of force or 35.5N.

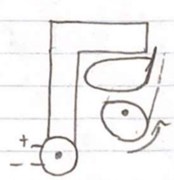
Electrical Components:

electric magnet:



Pro: Fast

DC motor



Con: Slow
• Overheating

Based on the brainstorming session, the following design ideas for the categorized sub-systems, were produced:

Physical Structure: The structure of this design is a C shaped box. The idea is that the tube can be slipped through the opening of the box allowing for easy transfer between clips. The box structure will provide stability of the device.

Hand Grip: The boxes dimensions will be small enough to fit in the palm of the hand. This will allow for the user to support the box with their entire hand. Then, the design includes a large, rounded surface button to activate the clipping function. The large surface will reduce injury from the repetitive motion of closing the clips.

Compression Device: The device works by a plunger system. If pressure is applied to the top of the plunger, it will apply pressure to the top of the clip. A spring could be utilized to return the piston back to its initial position improving clipping speed. This device could be replaced with electronic components to reduce stress to the hand.

Clip Support: The C shape of the design will support the clip on all 3 sides to prevent sidewards and downward movement. The entrance hole for the clip is chamfered to allow the clip to be easily fed through the device.

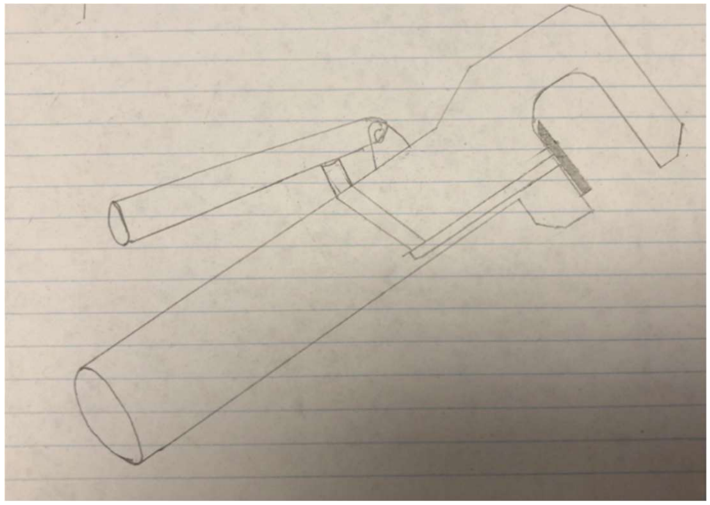
Valentine's Proposed Concepts:

Physical Structure: The structure of the design is a cylinder shape with square jaw. The shape will allow for easy storage in a pocket and will allow for access to small spaces.

Hand Grip: The device has two handles which will have groves to increase the ergonomic of the grip and to avoid the device from slipping out of your hand.

Compression Device: The device is operated by squeezing the two handles together. This will cause the jaws for the tool to close around the clip.

Clip Support: The jaws of the tool are flat surface of ½ inch with a rubbery material to increase the easy of holding the clip between the jaws. In addition, the jaws can be partially closed to firmly hold the clip while positioning the clip.



Analysis of Design Ideas

To analyze our brainstorming design ideas, we started by examining how well they met our target specifications. We then can determine which subsystem design best fits the needs of the client. We did this in a group setting where after the brainstorming session we talked through the design ideas while getting input from all members. Similar to the brainstorming session, we had a note taker and an overseer to ensure that the team stayed on track. The team then talked about how they though each design would meet the design specifications. This method provides a structured framework for analysis and helps identify the strengths and weaknesses of each idea. We also evaluated the ideas to our DFX considerations functionality, usability, cost, and ergonomics. By clearly defining the criteria before the analyzing the designs we were able to reduce the bias and subjectivity. We found that by using this method we were able to efficiently determine as a group if a design idea would be a good solution to our problem.

Analysis of Zach's Design Ideas

Physical Structure: The physical structure of the proposed idea is a set of pliers with the handle of children's scissors. The scissor portion offers a greater force distribution form the nurse's hand, and the plier portion concentrates the force directly to the part of the clip which needs to be clipped.

Pros:

- Slim, small volume
- Easily maneuverable
- Cheap to manufacture

Cons:

- Prone to breaking
- The long shape could cause issues, such as getting tangled, or lack of space if the area is narrow

Hand Grip: The proposed hand grip is similar to that of children's scissors. All fingers lie on some portion of the handle and apply pressure. This completely alleviates the pressure from the thumb joint, effectively eliminating the cause of arthritis in nurses thumb joints. In addition, while only requiring one hand, the device would have great maneuverability.

Pros:

- Ambidextrous
- Maneuverable
- Reduction in thumb joint stress
- Resistant to alcohol and easy to sanitize.
- Universal clip size
- Easy to manufacture, low cost

Cons:

- Difficult to use with much larger hands
- Might have short lifespan (needs to be tested)

Compression Device Idea 1: The tongs are comprised of two small, yet sturdy rods of metal covered with rubber sleeves which greatly increases friction between the tongs and the object. The proposed idea would be to slightly decrease the size to fit the child's scissors handle, as well as to reshape the tongs to fit the clip instead of a beaker.

Pros:

- High friction so no slipping
- A small surface area means force will be transmitted directly to where the pressure needs to be applied.
- Cheap and easy to produce
- Easy to sanitize
- Could be very quick, however, depends on how skilled the nurse is (ideally, they would become more adept with use)
- Universal clip size

Cons:

- Could be very slow, however, depends on how skilled the nurse is (ideally, they would become more adept with use)

- Depending on the material, and because of size reduction, could be fragile (bend out of place, snap at the middle)
- No support for the clip until it is clamped down

Compression Device Idea 2: The second proposed tongs would be similar in shape to the previous one but will have a rectangular box at the end of the tongs which splits down the center to open and close with the tongs. This box will fit the clamp and directly position the tongs where the pressure needs to be applied.

Pros:

- With every movement, a clip will be secured (reliable)
- No practice is required to achieve maximum efficiency
- Supports clip

Cons:

- More complex to produce
- More difficult to sanitize
- Slower
- Could be prone to breaking
- Might not fit all clip sizes

Clip Support Idea 1:

Pros:

- Universal clip size

Cons:

- Only supports clip once pressure is being applied

Clip Support Idea 2:

Pros:

- Easy to support clips (slides right in)

Cons:

- Could be slow and bulky
- Not universal clip sizes

Analysis of Steven's Design Idea

Physical Structure: The structure of the design is in the C shaped box. The box will go around the tube, allowing it a sliding motion to swiftly ascend and descend the tube, quickly securing the clips. In addition, the box structure will provide stability and to the device.

Pros:

- Compact
- Strong
- Quickly able to maneuver the tube

Cons:

- Depending on the size of the box the square design might cause discomfort to the hand

Hand Grip: The boxes dimensions will be small enough to fit in the palm of the hand. This will allow for the user to support the box with their entire hand. Then, the design includes a large, rounded surface button to activate the clipping function. The large surface will reduce injury from the repetitive motion of closing the clips.

Pros:

- Small fits in hand
- Very easily maneuverable
- Easy to sanitize
- Lightweight

Cons:

- Stresses will be located on one part of the hand
- Could cause discomfort after long use

Compression Device: The device works by a plunger system. If pressure is applied to the top of the plunger, it will apply pressure to the top of the clip. A spring could be utilized to return the piston back to its initial position improving clipping speed. This device could be replaced with electronic components to reduce stress to the hand.

Pros:

- Able to withstand multiple uses
- Quick

Cons:

- Clip has to be directly centered under the piston

Clip Support: The C shape of the design will support the clip on all 3 sides to prevent sideward and downward movement. The entrance hole for the clip is chamfered to allow the clip to be easily fed through the device.

Pro:

- Easy to secure clip in device while only using one hand.

Con:

- Deferent sized clips could affect the devices effectiveness in holding the clip.
- Nothing to hold the clip from sliding forward and backwards.

Analysis of Farah's Design Idea

Physical Structure: The physical structure would resemble a handle with a long neck running 90 degrees with an adjustable jaw. The material chosen would be Acrylonitrile Butadiene Styrene for its strength and its duration.

Pros:

- Very durable
- Able to be sanitized unlimited times

Cons:

- Very big in size
- Difficult to maneuver
- Requires two hands to hold
- Very difficult to sanitize every small piece of the device.

Hand Grip: The handle is ergonomic and allows the user to have a good grip on the device while using their whole hand, instead of just the thumb. The handle is designed as two bars that run perpendicular to the neck.

Pros:

- Comfortable
- A good grip allows for little slip

Cons:

- Because of the length of the object, an additional grip would need to be added to the neck, requiring two hands.

Compression Device: Small jaws clamp down on the clip which secures it in place. The jaw size is adjustable which allows for the closing of multiple clip sizes. The jaws are compressed by squeezing the handle.

Pros:

- Quick action to clamp
- Able to secure multiple clip sizes
- Easy to position on a clip

Cons:

- With such a small jaw, repeated stresses could cause the jaws to break over a short amount of time
- Poor friction could cause the jaws to slip easily

Clip Support: The clip is held in place by the user squeezing the handle halfway.

Pros:

- Simple to hold onto clip

Cons:

- Difficult to move in Z direction due to long neck
- Requires holding the jaws shut to maneuver

Analysis of Aaditya's Design Idea 1 - Compression Wedge

Physical Structure: The structure is small and simple, can be made cheaply, and is very hard to damage as it has no moving parts. A wedge that starts off as a single bar and diverts into two long prongs. The prongs would have space in the middle so they can be slid around the clips.

Pros:

- Cheap
- Small
- No moving parts
- Simple structure
- Sturdy
- Easy to manufacture
- Easy to sanitize

Cons:

- Could be difficult to maneuver in space
- Might be too long to carry in pockets

Hand Grip: The shape will fit naturally into the curve of a user's palm. It will include some sort of grip aid with possible examples being a finger holder and rubberized or grooved exterior. The user would hold the wedge in their hand. A ring near the top of the device allows the user to rest their finger on it and have additional support and control. The device must be held with one hand and the clip in another.

Pros:

- intuitive and natural
- small and simple
- Ambidextrous
- Fits comfortably in the hand
- No pressure on the thumb joint

Cons:

- This can be an issue for larger hands
- There could be slippage
- Pressure on the finger in the ring could be uncomfortable

Compression Device: The compression of this device is great because it is gradual and linear and reduces stress on smaller muscles. The motion goes from pinching to pushing, using the entire arm. The wedge is slid around a clip and effectively clips with ease

Pros:

- Little stress
- linear motion
- Very quick if adjusted to tube diameter
- Very simple maneuver to attach the clip

Cons:

- Could be slow to adjust for different size
- It could be easy for the user to hurt themselves if the wedge slips

Clip Support: No clip support, the device must be held with the other hand.

Cons:

- User needs to hold the clip with their other hand to attach it to the tube

Analysis of Valentin Mugabo Design Idea

Physical Structure: The structure of the design is a cylinder shape with a square jaw. The shape will allow for easy storage in a pocket and will allow for access to small spaces. A mechanism runs down the center of the device and transfers the force from the handle to the jaw, which will shut.

Pros:

- Maneuverable in a small space
- Small size

Cons:

- Difficult to sanitize
- Many small parts would include a lengthy assembly process
- The device is prone to breaking as there are many small moving parts in the interior of the device

Hand Grip: The device has two handles which will have groves to increase the ergonomics of the grip and to prevent the device from slipping out of your hand. The hand grip is comprised of a handle that lies supported against the main body, which when squeezed shuts the jaw.

Pros:

- Pressure does not come from the thumb joint
- Allows a good grip (good friction)
- Comfortable for long periods of time
- Ambidextrous

Cons:

- The connection to the main body may get damaged over time
- If a finger slips, the user could crush their finger between the handles

Compression Device: The device is operated by squeezing the two handles together. This will cause the jaws of the tool to close around the clip.

Pros:

- Simple maneuver to secure clip

Cons:

- Slow because the clip has to be in a perfect position
- If the material isn't strong, the jaw could deform and become useless
- No mention of different clip sizes

Clip Support: The jaws of the tool are a flat surface of ½ inch with a rubbery material to increase the ease of holding the clip between the jaws. In addition, the jaws can be partially closed to firmly hold the clip while positioning the clip.

Pros:

- Only requires one hand
- Good friction

Cons:

- Difficult to adjust clip with great precision
- Would require difficult hand motion to adjust clips with the device

Subsystems Designs Compared to Target Specifications Tables

#	Metric	Units	Physical Sub Systems Analysis				
			Steven	Farah	Zach	Aaditya	Valentin
6	Ability to maneuver in space of X cm width (binary: yes or no)	binary	Yes	No	Yes	Yes	Yes
7	Resistance to alcohol-based cleaning agents (no degradation after X wipes)	# of wipes	Unlimited	Unlimited	Unlimited	Unlimited	15,000
9	Total volume of the device	cm^3	5x5x3=75	25x2x7=350	4x7x1 = 28	15x2x2=60	3x5x15=25
10	Total weight of the device	g	200	400	250	400	400
12	Manufacturing cost of the device	CAD $	15	30	15	25	40
13	The lifespan of the device under normal daily use	days	2,492	1,000	1,495	2,000	700

#	Metric	Units	Hand Sub Systems Analysis				
			Steven	Farah	Zach	Aaditya	Valentin
2	Reduction in thumb joint stress (compared to	%	0	0	1/65=1.5	100	1/5

	manual operation)						
5	Ability to be used with both left and right hand (binary: yes or no)	binary	Yes	Yes	Yes	Yes	Yes
8	Compatibility with different hand sizes (e.g., can be used with X% of adult hand sizes)	%	80	100	95	95	100
11	Number of operations using thumb (should be 0)	#	0	0	1/5	1/5	0

#	Metric	Units	Compression Sub Systems Analysis				
			Steven	Farah	Zach	Aaditya	Valentin
1	Number of clips the device can close before failure	# of clips	500,000	100,000	300,000	1,000,000	100,000
3	Time taken to apply a clip using the device (should not exceed manual operation time)	seconds (s)	3	2	3	1.5	4
4	Time taken to adjust the device for different tubing and clip sizes	s	5	5	0	10	N/A

#	Metric	Units	Support Sub Systems Analysis				
			Steven	Farah	Zach	Aaditya	Valentin
14	Adjusts to a number of different renal clip sizes.	#	All	All	All	All	All

Explanation to the Data Presented in Subsystem Analysis Tables

Physical Structure (6,7,9,10,12,13)

Steven:

- 6, Yes, 0.8/0.8: The compact structure allows the device to flow quickly along the tubing. In addition, since it fits in the palm of the user's hand, it can maneuver in whatever space the user can.
- 7, Unlimited, 0.8/0.8: The material used will resist ethanol and therefore not degrade by alcohol wiping.
- 9, 75<282, 0.6/0.6: The total volume of the device is less than the maximum size, therefore making it ideal.
- 10 200<250, 0.6/0.6: The weight of the device would not exceed the maximum weight, making it ideal.
- 12 15<20, 0.2/0.2: Since the device is simple in shape, small in size, and made of affordable materials, its price will be well within the proposed range.
- 13 2,492=2,492, 0.6/0.6: The lifespan of the device is expected to meet the proposed length, making it an idea subsystem.

<u>3.6/3.6</u>

Every target specification of Steven's physical structure is met or exceeded.

Farah:

- 6, No, 0/0.8: The incredible length of the device gives it major maneuverability issues making it very difficult to use in tight spots.
- 7, Unlimited, 0.8/0.8: The material used will resist ethanol and therefore not degrade by alcohol wiping.

- 9, 350>282, 0.48/0.6: The object is on significant length, but it is not too wide or too tall, making its volume bigger than ideal, but not excessively so.
- 10, 400>282, 0.42/0.6: The weight of the device is larger than wanted, however, does not exceed the maximum.
- 12, 30>20, 0.13/0.2: Since the device is comprised of many small parts and would require a difficult assembly, and taking into account the price of the material, the price exceeds the ideal value but does not exceed the maximum.
- 13, 1000<2492, 0.24/0.6: The fragility of the jaws in addition with the overengineering of the shaft would result in the device being more prone to breaking, rendering the device incapable of reaching our ideal amount of time before it breaks.

  2.07/3.6

Zach:

- 6, Yes, 0.8/0.8: The small length of the device, in addition with its slender frame allows it great maneuverability in small spaces.
- 7, Unlimited, 0.8/0.8: The material used will resist ethanol and therefore not degrade by alcohol wiping.
- 9, 28<282, 0.6/0.6: The compact design results in it having a volume much smaller than required.
- 10, 250=250, 0.6/0.6: The mass of the device matches that of the ideal weight.
- 12, 15<20, 0.2/0.2: Due to its simplicity and use of inexpensive materials, the price of the device falls well within the ideal price range.
- 13, 1495<2492, 0.36/0.6: Due to the simplicity of the jaws, they are prone to deformation, making them weak and eventually bend over time, making their lifetime shorter than the idea value.

  3.36/3.6

Aaditya:

- 6, 0.5, 0.4/0.8: The length and width of the device make it hard to maneuver in the ideal range, however, it does fall within the acceptable range.
- 7, Unlimited, 0.8/0.8:The material used will resist ethanol and therefore not degrade by alcohol wiping.

- 9, 60<282, 0.6/0.6: The design of this device has a compact volume which falls well within the ideal values.
- 10, 250=250, 0.6/0.6: The weight of the device matches the ideal value.
- 12, 25>20, 0.16/0.2: The price of the device, as it would require metals, which are more expensive, produces a price higher than the ideal value.
- 13, 2,000<2,492, 0.48/0.6: The metal will deform before the ideal length of time has passed; however, it will be nearly as long.

3.04/3.6

Valentin:

- 6, Yes, 0.8/0.8: The small length of the device, in addition with its slender frame allows it great maneuverability in small spaces.
- 7, Unlimited, 0.8/0.8: The material used will resist ethanol and therefore not degrade by alcohol wiping.
- 9, 225<282, 0.6/0.6: The compact design results in it having a volume much smaller than required.
- 10, 400>250, 0.42/0.6: The weight of the device is larger than wanted, however, does not exceed the maximum.
- 12, 40>20, 0.1/0.2: The price of the device, as it would require metals, which are more expensive, produces a price higher than the ideal value. In addition, the device requires a lengthy assembly.
- 13, 700<2,492, 0.17/0.6: The device would suffer from deformities rendering it useless, as well as a high chance of internal damage due to the high stress. This results in the device having a much shorter lifespan than ideal.

2.89/3.6

Steven's physical structure is the best performing out of all the subsystems, with a perfect 3.6/3.6.

Hand Support (2,5,8,11)

Steven:

- 2, 0%, 100>80, 1/1: Since the device uses force from the palm, it eliminates all thumb joint stress, which surpasses the ideal value.

- 5, Yes, 0.4/0.4: The product is ambidextrous and therefore meets the requirements.
- 8, 80%, 80<95, 0.5/0.6: Due to the c-shape of the device, it will not fit people with different hand sizes, approximately 80%. This is less than the ideal 95%, however, it is not a major discrepancy.
- 11, 0, 0=0, 1/1: Since the amount of thumb movements is zero, the device meets the requirements.

<u>2.9/3</u>

Farah:

- 2, 0%, 100>80, 1/1: Since the device uses force from the palm and all fingers, it eliminates the majority of thumb joint stress, which surpasses the ideal value.
- 5, Yes, 0.4/0.4: The product is ambidextrous and therefore meets the requirements.
- 8, 100%, 100>95, 0.6/0.6: Due to the ergonomic grip, everyone is able to hold the device, which meets the ideal value.
- 11, 0, 0=0, 1/1: Since the amount of thumb movements is zero, the device meets the requirements.

<u>3/3</u>

Zach:

- 2, 1.5%, 98.5>80, 1/1: Since the device uses force from the palm and all fingers, it eliminates the majority of thumb joint stress, which surpasses the ideal value.
- 5, Yes, 0.4/0.4: The product is ambidextrous and therefore meets the requirements.
- 8, 95%, 95=95, 0.6/0.6; Due to the ergonomic grip, nearly everyone is able to hold the device, which meets the ideal value.
- 11, 20%, 20%>0%, 0.8/1: Since the product uses force from all fingers, 20$ comes from the thumb, however, this is a very small amount which doesn't create detract from its value.

<u>2.8/3</u>

Aaditya:

- 2, 0%, 100>80, 1/1: Since the device uses force from the palm and all fingers, as well as a pulling force for the other hand, it eliminates the majority of thumb joint stress, which surpasses the ideal value.
- 5, Yes, 0.4/0.4: The product is ambidextrous and therefore meets the requirements.
- 8, 95%, 95=95, 0.6/0.6: Due to the ergonomic grip, everyone is able to hold the device, which meets the ideal value.
- 11, 0, 0=0, 1/1: Since the amount of thumb movements is zero, the device meets the requirements.

  3/3

Valentin:

- 2, 20%, 80=80, 1/1: Since the device uses force from the palm and all fingers, it eliminates the majority of thumb joint stress, which surpasses the ideal value.
- 5, Yes, 0.4/0.4: The product is ambidextrous and therefore meets the requirements.
- 8, 100%, 100>95, 0.6/0.6: Due to the ergonomic grip, everyone is able to hold the device, which meets the ideal value.
- 11, 0, 0=0, 1/1

  3/3

Farah, Aaditya and Valentin's subsystems perform perfectly, and Steven's comes very closely behind, all offering exceptional hand support.

Compression Device (1,3,4)

Steven:

- 1, 500,000, 500,000=500,000, 0.6/0.6: The rigidness of the device would allow it to close roughly 500,000 clips before failure, meeting the ideal value.
- 3, 3, 3=3, 0.8/0.8: Given it takes roughly 3 seconds to approach the clip, position it, and complete the clipping motion, the device meets the ideal value.

- 4, 5, 5<20, 0.8/0.8: It takes 5 seconds for the device to switch between clip sizes, which is much more efficient than the ideal 20.

  <u>2.2/2.2</u>

Farah:

- 1, 100,000, 100,000<500,000, 0.12/0.6: Due the fragility of the jaws, the device would only be able to close one fifth of the ideal number of clips before failure.
- 3, 2, 2<3, 0.8<0.8: Given it takes roughly 2 seconds to approach the clip, position it, and complete the clipping motion, the device surpasses the ideal value.
- 4, 5, 5<20, 0.8/0.8: It takes 5 seconds for the device to switch between clip sizes, which is much more efficient than the ideal 20.

  <u>1.72/2.2</u>

Zach:

- 1, 300,000, 300,000<500,000, 0.36/0.6: Due to the likeliness to deform, the device would only be able to close three fifths of the ideal number of clips before failure.
- 3, 3, 3=3, 0.8/0.8: Given it takes roughly 3 seconds to approach the clip, position it, and complete the clipping motion, the device meets the ideal value.
- 4, 0, 0<20, 0.8/0.8: The device works with every clip size and does not require any adjustment, making it surpass the ideal value.

  <u>1.96/2.2</u>

Aaditya:

- 1, 1,000,000, 1,000,000>500,000, 0.6/0.6
- 3, 1.5, 1.5<3, 0.8/0.8: Given it takes roughly 1.5 seconds to approach the clip, position it, and complete the clipping motion, the device surpasses the ideal value.
- 4, 10, 10<20, 0.8/0.8: It takes 10 seconds for the device to switch between clip sizes, which is much more efficient than the ideal 20.

2.2/2.2

Valentin:

- 1, 100,000, 100,000<500,000, 0.12/0.6: Due the fragility of the jaws, the device would only be able to close one fifth of the ideal number of clips before failure.
- 3, 4, 4>3, 0.6/0.8: Given it takes roughly 4 seconds to approach the clip, position it, and complete the clipping motion, the device nearly meets the ideal value.
- 4, N/A, 0/0.8: The device does not adjust to different clip sizes.

0.72/2.2

Steven and Aaditya's systems perform equally well, both fulfilling every need for this subsystem.

Clip Support (14)

Steven:

- 14, All, 0.4/0.4
- The clip is able to adjust to every clip size, meeting the requirements.

Farah:

- 14, All, 0.4/0.4
- The clip is able to adjust to every clip size, meeting the requirements.

Zach:

- 14, All, 0.4/0.4
- The clip is able to adjust to every clip size, meeting the requirements.

Aaditya:

- 14, All, 0.4/0.4
- The clip is able to adjust to every clip size, meeting the requirements.

Valentin:

- 14, N/A, 0/0.4
- The clip does not adjust to every clip size, which does not meet the requirements.

All subsystems perform equally, except for Valentin's which does not fulfill the requirements.

Final Design and Plan for Development

Based on the analysis of the systems we chose the following sub-systems, defined the global design, made a CAD model based off of it, and analysed the global design to the design metrics.

Selected Sub-Systems

Using the analysis of the systems above, we chose the following sub-systems.

Physical Structure:

For the physical structure of the design, we chose Stevens C shaped box. The main advantages of the box were that it allows for a compact design while considering ergonomics and physical strength.

Pros:

- Compact design allows for efficient storage and transport of the device.
- The C-shaped box structure provides strength and stability to support its intended function effectively.

Cons:

- Depending on the size of the box, the square design might cause discomfort to the hand during use, particularly if it's too small or too large for comfortable handling.

In summary, the C-shaped box design for the Physical Structure of the system is advantageous due to its compactness and strength. However, careful consideration of the box size is necessary to ensure user comfort and usability.

Hand Grip

For the hand grip we went with Steven's subsystem because the system was most likely to reduce stress to the hand since large surface area of the plunge would spread out the forces on the hand.

Pros:

- Intuitive and natural design that fits naturally into the curve of a user's palm, enhancing comfort and usability.
- Incorporates grip aids such as a finger holder and a rubberized or grooved exterior, improving handling and control.
- Ambidextrous design ensures it can be comfortably used by both left and right-handed individuals.
- Compact and straightforward, making it easy to handle and operate.
- Ensures comfort during use by eliminating pressure on the thumb joint, reducing strain and discomfort.

Cons:

- May not be suitable for individuals with larger hands, potentially leading to discomfort or reduced effectiveness.
- Possibility of slippage, which could impact stability during use.
- Pressure on the finger resting in the ring could become uncomfortable during prolonged use.

In summary, the proposed grip support system offers a natural, user-friendly design with features to enhance control and comfort. While it may not be suitable for larger hands and could have issues with slippage and finger pressure, it presents a promising solution for a wide range of users.

Compression

The proposed idea for the compression subsystem involves Zach's idea of modifying beaker tongs by slightly decreasing their size and reshaping them to fit a child's scissors handle, rather than a beaker. This idea offers several advantages:

Pros:

- High friction ensures no slipping during use.
- The small surface area of the tongs allows for direct transmission of force to where it's needed.
- The design is cost-effective and easy to produce.
- Easy to sanitize, ensuring hygiene standards are met.
- Potential for quick application, depending on the nurse's skill level, which could improve with use.
- Universal clip size, making it versatile for various applications.

Cons:

- The speed of application may be slow, especially for less experienced users.
- Depending on the chosen material and size reduction, the tongs could be fragile and prone to bending or snapping.

- There is no support for the clip until it is clamped down, which might require precise handling.

In summary, the proposed modification of beaker tongs for the compression subsystem offers advantages such as improved friction, cost-effectiveness, and ease of sanitization, but it may require careful consideration of material choice and user training to mitigate potential drawbacks.

Clip Support

The proposed clip support system that we chose was Steven's and Valentines system. The idea of supporting the clip by sliding the clip into a C jaw was more practical than using compression to hold the clips in place. Since the tool needs to be operated with one hand only the C jaw far outweighed the other subsystems.

Pros:

- It only requires one hand for operation, enhancing ease of use and practicality.
- The flat jaws, equipped with a rubbery material, provide good friction, ensuring a secure grip on the clip.

Cons:

- It might be challenging to adjust the clip with great precision, which could be a limitation in certain situations.
- The device may require complicated hand motions for precise clip adjustments, which could be cumbersome for some users.

In summary, the Clip Support system offers one-handed operation and good friction for secure clip handling. However, precision adjustments may be challenging, and the required hand motions could be complex for some users.

Global Design Concept

Taking the selected subsystems into consideration we made a global design concept. Our global design concept reduces the force needed to close renal clips. The device takes the form of a box with a C shape, featuring a small groove on the side to assist with opening clips. Its size is slightly smaller than a Rubik's Cube, allowing for comfortable handling in the palm of the hand.

The three supporting walls of the C shape supporting the clip during the closing process to prevent movement. In addition, the sides of the box are textured to improve grip and prevent accidental dropping.

One notable advantage of this device is its ability to increase the speed of clipping. By allowing the device to slide up and down the tube without interruption, users can efficiently close clips with minimal effort. This feature is particularly useful when dealing with multiple clips in quick succession.

To increase the tools portability, the device will have a small hole on one of the corners. This hole enables users to attach the tool to a keychain or bracelet.

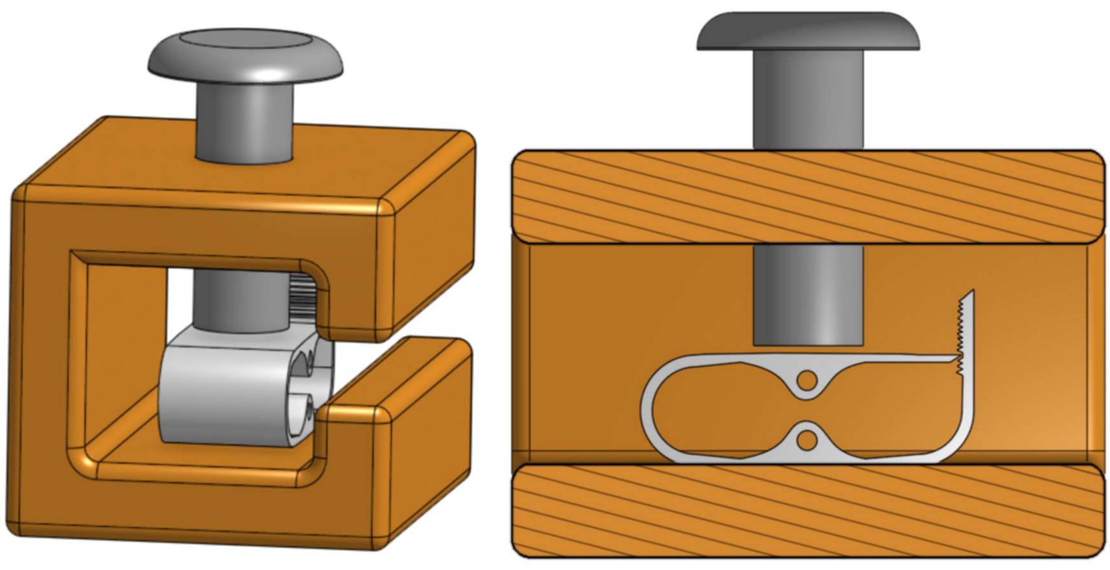
The mechanism for closing the clips involves a spring-loaded plunger that applies pressure from the top. When the plunger is pushed down, it activates the pressure on the clip, securely closing it. The plunger is designed with a large mushrooming top to increase hand comfort during the clipping process by spreading out the force of the plunge on the hand.

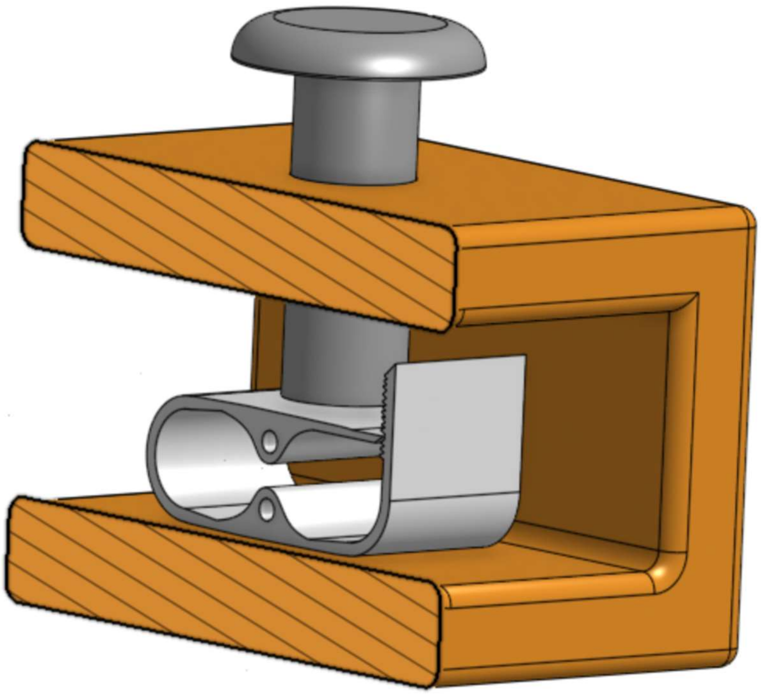
Overall, this device offers an ergonomic and efficient solution for closing clips. Its compact size, textured surface, attachment options make it a convenient tool for various applications. By increase the speed of the clipping process and prioritizing user comfort, this design idea presents a promising solution to the client's problem.

CAD Design

The following images were snipped from our CAD design made on Onshape. Below is the link to the file.

https://cad.onshape.com/documents/a12d1a89247a1cc364d2b98e/w/d13f9863388db75b930d6485/e/4fbbf768c0954bdbd57909eb





Global Design's Relationship to Target Specifications

Given the creative designs given above, it is truly difficult to choose the final version of each subsystem. However, using simple calculations and simulations we can find that one design stands above the rest. Our Global Design is the clear winner, ranking at the top of all our metrics. When comparing it physical structure to other ideas, it surpasses all other designs; earning a clean 3.6/3.6 based on our weighted decision matrix. It is light, compact, and can be sanitized easily. In terms of hand grip, our Global Design is on par with all the others. In our weighted decision matrix, it receives a 2.9/3. It is small and easy to hold in your hand, making it great as a simple tool. Our device also ranks as the highest in our Compression subsystem category. Its punching power is ideal, its speed is ideal, and its ability to reposition quickly is superb. Finally, our Global design solution can easily adjust to multiple clip sizes, earning it a 0.4/0.4 and putting it as one of our top ideas. According to our analysis using simple calculations, benchmarks, test specifications, and a weighted decision matrix; our global design clearly outshines all others. That is not to say it is perfect, but that this is a great base design to plan our final prototype around.

C3: Project Plan: Wrike

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=KB6DI1scjMP1MtCPjPHlbNVXHWpC5EmO%7CIE2DSNZVHA2DELSTGIYA

Conclusion

In conclusion, our journey began with the creation of a comprehensive list of need statements, allowing us to crystallize and clearly define the problem at hand. Through benchmarking and the acquisition of marginal specifications, we laid the foundation for our design process. By juxtaposing these values with the ideal specifications, we meticulously crafted our final design specifications.

A pivotal moment in our creative process was the productive brainstorming session that led to ingenious design solutions. These innovative concepts then underwent rigorous evaluation against the design specifications, resulting in the selection of the most optimal subsystems. The choices were not easy, given the wealth of creative designs we had generated, but through thoughtful analysis, we ultimately identified the best-performing subsystems.

With these chosen subsystems in hand, we forged our global design, synthesizing them into a cohesive whole. This vision was further brought to life through the creation of a detailed CAD model, serving as a tangible representation of our ideas. Finally, we rigorously compared our global design to the initial design specifications, assessing the overall efficiency and alignment with our initial goals.

This comprehensive process allowed us to home in on the key specifications we sought to address and develop a robust global design that serves as a solid foundation for future improvements. Our journey has been marked by meticulous planning, creative ingenuity, and a commitment to delivering a well-defined and efficient solution to our identified needs.

Resources

LCA-Of Laparoscopic Tool

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9085686/

CCOHS- Hand Tool Ergonomics

https://www.ccohs.ca/oshanswers/ergonomics/handtools/tooldesign.html

Pliers Padgett® 7-3/4

https://mms.mckesson.com/product/633497/Integra-Lifesciences-PM-3875

LIGACLIP® Endoscopic Rotating Multiple Clip Applier

https://www.jnjmedtech.com/en-US/product/ligaclip-ethicon-endoscopic-rotating-multiple-clip-applier

Hydraulic Crimping Tool

https://www.amazon.ca/Range4-70-mm2Pressure-YQ-70Hydraulic-Crimping-Terminal/dp/B07QVBD6VM/ref=sr_1_2_sspa?keywords=Hydraulic+Crimping+Tool&qid=1696134649&sr=8-2-spons&ufe=app_do%3Aamzn1.fos.b06bdbbe-20fd-4ebc-88cf-fa04f1ca0da8&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1

WECK- AutoEndo 5

https://weck360.com/usa/ae05-productlaunch.html