Japanese Finger Sleeves

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ABSTRACT

Hand traction is a critical component of many orthopedic and surgical procedures, allowing clinicians to maintain wrist alignment and joint stability during fracture reduction and casting. Idrissa Poye Hospital in Senegal previously relied on a traction device that they no longer have, leaving physicians without a reliable method to stabilize the hand during surgery. The absence of this tool has created a significant barrier, as clinicians are forced to depend on manual assistance or improvised setups that can compromise both accuracy and patient safety. These shortcomings limit precision and increase clinician workload during demanding operations. This project aims to design a digital traction device that addresses the evident gap in our client hospital's practice by developing a digital traction device that provides consistent, comfortable, and easily adjustable traction while reducing the physical strain placed on both patients and medical staff. The device will enable secure hand positioning with minimal manual intervention and will be designed for reusability, safety, and compatibility with standard clinical environments. The goal is to create a system that not only replaces the hospital's lost device but also improves upon it through enhanced control and ergonomics. Prototype evaluation will focus on verifying traction consistency and minimizing slippage during simulated procedures. The results will determine its potential to provide dependable performance across repeated uses as well as its suitability for low-resource clinical settings such as the one the team is targeting for the client.

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1 INTRODUCTION

1.1 Motivation

Fractures of the upper extremity are common in the orthopedic world, accounting for around 17.5% of all fractures [1]. In procedures done to repair these, it is essential to maintain patient comfort in order to promote rehabilitation. When using a digital traction system, it is also important to keep a steady static load on the finger and forearm. An effective traction device would position a load on the upper extremity and accurately measure it throughout the entire operation, properly aligning the bones and relaxing the surrounding muscles. Traction has long been used in the medical industry, but its use has decreased over time and the quality of traction devices has declined as a result [2] . With less adequate systems, surgeries that utilize traction devices can lead to stiffness, surgical complications, and even loss of motor function in certain regions of the body [3].

In many low and middle income healthcare settings such as Idrissa Pouye Hospital, the client's hospital in Senegal, traction often needs to be performed manually. A traction system that is commonly used is the manual variation, which requires hospital workers to physically maintain the tension of the patient's arm for the entire surgery. This can often lead to physician fatigue and flawed outcomes. Although commercial traction systems exist, they are mostly designed for high-resource environments due to their intricate designs and high price, making it difficult for hospitals like the client's to resupply and manage the devices. This emphasizes a common problem for resource-constrained regions. Many times they run short on equipment because of issues with accessibility and sustainability within the hospital. The client stated that "[they] are fully redundant with foreign suppliers" [4]. Overall, the goal of this project is to create a versatile and locally manufacturable system that can work in a sterile and non-sterile environment. This will address the clients initial needs while also functioning as a path towards more equitable access to healthcare.

1.2 Existing Devices & Current Methods

Through a combination of the client's prior experience and the team's independent research, multiple existing hand traction devices were examined. The field of orthopedic traction systems includes both simple gravity-based finger traps and more complex mechanical stabilization frames. These devices vary in their level of precision, comfort, and adjustability, and while they perform well in certain contexts, none fully meets the client's current needs for a lightweight, sleeve-based digital traction system.

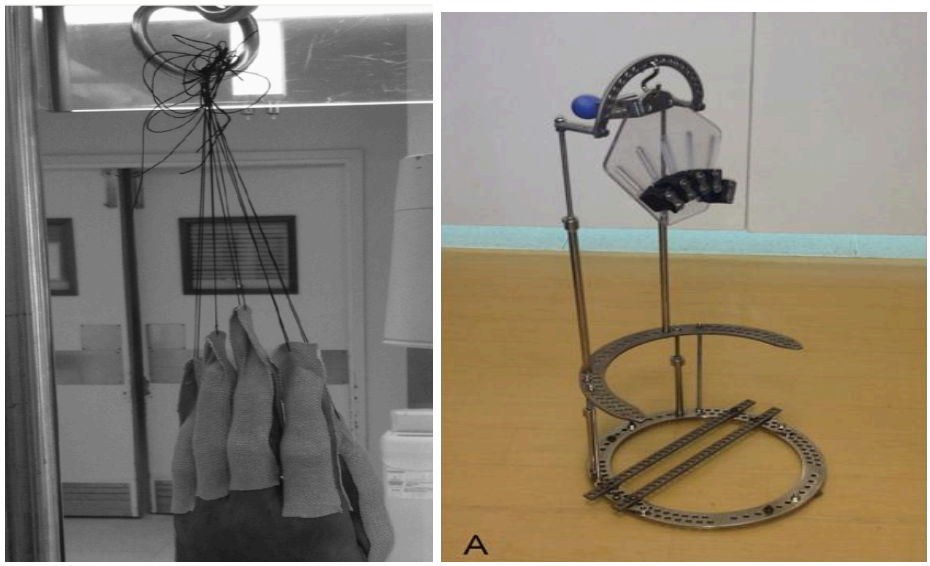
The Reison Hand Fixation Device (Reison Medical, Part No. 10-394) provides rigid stabilization of the hand and forearm during surgery using stainless steel and polycarbonate components. The device is adjustable to accommodate different hand sizes and offers strong

positional stability during fracture repair or fixation procedures, as shown in Figure 1 [5]. Despite its stability, it is heavy and static, lacking individual finger mobility and ergonomic flexibility. These limitations make it less ideal for longer procedures where patient comfort and clinician control are critical.

Figure 1: Reison Hand traction [5]

The Chinese Finger Trap System is a traditional device for wrist and forearm traction. It suspends the patient's hand using woven finger sleeves, allowing gravity to apply continuous traction. A readily available alternative described by Akhtar et al. (2013) demonstrates how clinicians sometimes substitute tape for the woven traps when the original device is unavailable [6]. Although effective in generating traction, this system depends entirely on gravity, offers limited adjustability, and lacks built-in feedback or sensing capabilities. Moreover, availability can be inconsistent, particularly in resource-limited or after-hours clinical settings, making it an unreliable option for the client's needs. Figure 2 illustrates a standard finger trap setup [6].

The third device analyzed was the Handmade Traction Wrist Tower, also referred to as the Hook and Trumpf Hand Holder [7]. This system consists of a metal base with an S-shaped hook and adjustable rods designed to create controlled traction across the fingers and wrist. Foam padding is used to protect soft tissue at points of contact, but the overall design is large and metal-based. While it provides adjustability, its weight and bulk limit ergonomic efficiency and portability. The device is shown in Figure 2 [7].



Figures 2: Chinese finger traps (left) and Hook-and-Trumpf (right) [6, 7]

The designs presented above are all functional and commercially available but lack critical features needed for the client's environment. They offer neither lightweight, non-metallic materials nor individualized traction control to reduce the need for manual traction. Section 3.1 (Design 1) further discusses how these limitations guided the team's development of an improved, sleeve-based digital traction device capable of improving upon the weaker functionality of the client's current device.

1.3 Problem Statement

At Idrissa Pouye Hospital, manual traction is used to stabilize the wrist and forearm during procedures like casting, wrist arthroscopies, and more. Digital traction, when handled manually, is imprecise for the doctor and often uncomfortable or painful for the patients. That leads to less successful surgeries and longer recovery time for the patient. When done correctly, digital traction aligns fractures to preserve joint mobility and allows the surgeon to see and work inside the small joints [8]. Commercial traction tractions outlined further do work and are effective, but are costly to maintain and are not suitable for local reproduction. Furthermore, most models on the market are unadaptable for clinicians and hospitals. Most are unable to be used in both the non-sterile plaster casting room, as well as the sterile operating room. Reasons include lack of mobility and reusability of the device. This forces doctors to use makeshift manual traction systems that are less effective. The client's hospital formally made use of Japanese Finger Traps for digital traction but the system deteriorated over time or was lost. At this specific hospital, upkeep of such devices is tough on the budget and supply is a major problem in the region.

The objective is to create a digital traction device using Japanese finger traps that precisely pulls the patient's hand, wrist, and forearm into a comfortable, neutral position while holding a stable static load. The device must be adaptable to the client's practice. This means it must have the mobility to move from room to room, and the ability to be reused and sterilized. Lastly, the device needs a cost effective method for management by the staff, and needs to be able to be reproduced locally.

2 BACKGROUND

2.1 Biology and Physiology

Together, the wrist and forearm are a very intricate system within the human body. To understand why digital traction systems are important and impactful, it is essential to know the anatomy and physiology of the treatment area. As a whole, the wrist and forearm provide mobility and structural support for the upper limb, allowing for successful use of the hand. The forearm itself consists of two long bones, the radius and the ulna. These bones provide support and flexibility of the forearm during pronation and supination. The distal end of the radius connects to the carpal bones through the radiocarpal joint. This joint allows for flexion and extension of the wrist, critical for a multitude of human activities [4]. The carpus is the collection of 8 small bones held together by stabilizing ligaments. Due to their small size, they are often susceptible to fractures when subjected to heavy loads and rotational movements. With that, the carpal tunnel encloses many tendons and the median nerve. The compact and intricate compilation of these bones, ligaments, nerves, and tendons make it necessary to be precise and exact during the operation of these body parts. This means that the digital traction device must maintain the hand in a neutral position and provide proper traction. This allows for the minimization of discomfort and effective realignment by reducing internal stresses and protecting soft tissue [9].

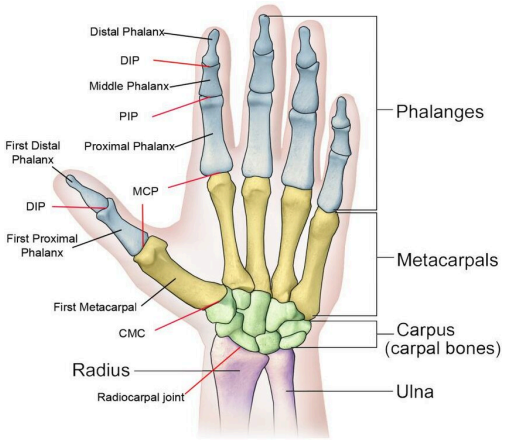


Figure 3: Anatomical figure of the hand, wrist, and forearm [1]

As stated earlier, distal radius fractures are very common in the orthopedic setting [1]. In these types of procedures, commonly wrist arthroscopies, digital traction can serve as a diagnostic and therapeutic tool. It aligns small bone fragments, and can prevent neurovascular compromise, leading to better results afterwards [2]. Therefore, maintaining consistent traction with a neutral wrist and forearm position is critical to achieving a successful surgery and preventing further harm down the line in the recovery process.

2.2 Relevant Research

Developing a digital traction device that needs to be locally reproducible and adaptable enough to be used both in surgery and casting requires knowledge in many areas. These include logistical, regulatory, and biological areas. Biomechanical research regarding the type of forces being put on the wrist during use of the device is an area of important note. This research allows for knowledge of safe thresholds, and methodologies of keeping the wrist in a neutral position for long periods of time. Articles that outline the process of traction devices often range on the scale of the whole body and across numerous hospitals and regions of the world. Further, it is also necessary to complete anatomical and biological research, to recognize what parts of the body are being acted on, and their specific physiology. This will inform proper alignment in regards to positioning of the wrist and forearm.

On the more logistical side of things, research must be done on the materials. This device comes into contact with the human, so materials must be medical grade, non-allergenic, and sterilizable [10]. Further, both aspects of the design need to endure sterilization without degrading. Lastly, an extensive amount of research needs to be done on the regulatory standards regarding medical devices. The team studied relevant standards such as ISO 13485:2016 for quality management systems, ISO 10993-1:2018 for biocompatibility testing, ISO 14971:2019 for risk management, and more. On top of that, research was conducted to learn more about medical device quality system regulation in the U.S. such as FDA 21 CFR Part 820, even if this project is for Senegal. All of this is to make sure the device aligns with the recognized rules for a medical device such as this one.

2.3 Client Information

Mr. Pape Samb is the founder and executive director of Jamerek, a non-profit organization based in Sun Prairie. He also serves on the board of the Sun Prairie Media Center and is a community TV and radio producer [11]. Dr. Mohamed Soumah is a doctor at a hospital in Senegal that has many hand and wrist surgeries.

2.4 Product Design Specification

The product design specification defines the functional, safety, and performance requirements of the digital traction device using Japanese finger sleeves. The goal of the design is to provide a stable and controlled method for hand positioning during orthopedic and surgical procedures, while maintaining patient comfort and clinical efficiency.

The device functions as a digital traction system that uses Japanese finger sleeves to achieve precise stabilization of the hand and wrist. It must be capable of supporting the patient's hand for approximately fifty minutes during fracture casting or surgery without slippage or loss of tension. To meet these requirements, each sleeve must support a consistent traction force in the range of 22 to 44 newtons per finger, ensuring even load distribution and stability throughout the procedure.

In terms of safety and materials, the design must use latex-free materials to prevent allergic reactions, preferably non-metallic components, and allow for use in imaging environments. The sleeve system must also minimize compression to avoid interference with circulation or nerves, while maintaining a sufficient grip to hold each finger securely. The materials must be biocompatible and sterilizable, capable of withstanding repeated autoclave or chemical sterilization without degradation or loss of elasticity.

To accommodate a variety of hand sizes, the traction sleeves should feature adjustable or multiple size options that can comfortably fit various finger diameters. The device must provide a high-friction grip for stability and dexterity, while allowing natural finger flexion and extension to ensure tendons glide smoothly during minor patient movements. Regarding service life, the finger sleeves must reliably perform at least 500 full uses over their service lifetime, with each use lasting 50 minutes under load. The sleeves should maintain full function for at least two years, with a stock of 36 sets accounting for daily use. Elastic and sensor components should endure up to 100,000 loading cycles. Device components must retain functionality for at least three years when stored at 10–30 °C, below 70% relative humidity, and protected from direct UV light. The operating environment includes standard surgical conditions (20–24 °C, 20–60% relative humidity), with surfaces resistant to blood, saline, antiseptics, and disinfectants.

Together, these specifications establish the quantitative and qualitative standards for prototype development and evaluation. The full PDS, including supporting references and regulatory standards, is provided in Appendix A.

3 PRELIMINARY DESIGNS

The design was divided into two components, the mechanical structure and hand attachment method, because this allowed the team to develop three designs for each separately and have a more focused evaluation of each component's function without limiting potential combinations.

3.1 Mechanical Design 1 - Standing Platform

The first mechanical design features a free standing traction platform intended for use during rehabilitation or preoperative preparation, seen in figure 4. The device consists of a vertical base pole with wide set locking wheels for stability and mobility. The base accepts a removable extender pole that allows for height adjustment and a curved arm on top of the extender pole that rotates 360° to accommodate patient positioning. The curved upper arm also supports individualized tension cables that connect to finger loops, which are attachment points for the finger sleeves that provide controlled traction for each finger. A force control box, located along the main support pole, would regulate and display finger specific traction forces. The arm assembly can also be detached and inserted into a clamp down platform different from the wheeled base shown. This enhances its versatility and cost effectiveness by allowing both stationary and mobile configurations.

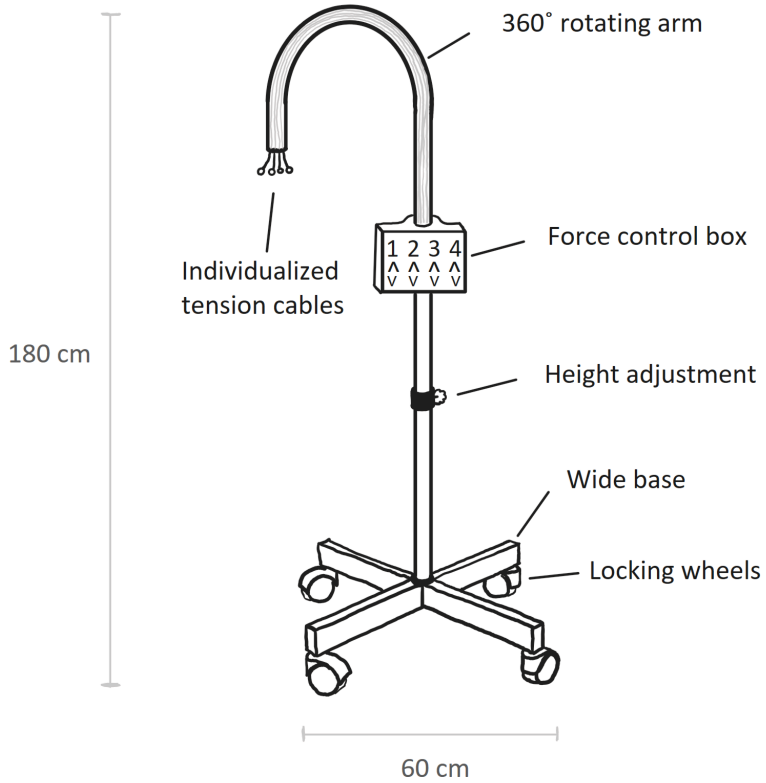


Figure 4: Stranding structure on wheeled base design

3.2 Mechanical Design 2 - Bed Clamp & Restraint

The second mechanical design features a sleek structure that mounts directly to the frame of a hospital bed, as seen in figure 5. The base of the device is secured using a heavy-duty clamp that mechanically interacts with the shape of the bed frame, which locks the entire system in place, preventing movement during use. A circular, vertical mounting post extends upward, along the side of the bed, serving as an attachment point for other components. All attachments connect to the post with an adjustable stand clamp that uses a hand tightened set screw, allowing each component to be moved freely up and down and rotated 360° around the post to accommodate different arm lengths and sizes. One component is a bicep restraint arm, positioned lower on the post. This arm features a curved, ergonomic plate that presses down on the top of the bicep, stabilizing the arm by blocking upward movement under tension. An adjustable upper arm is attached higher on the post, which secures the device that applies the tension force to the lower arm. This arm has a plate with five holes in it, for finger sleeve attachment, to apply an even amount of force to each finger.

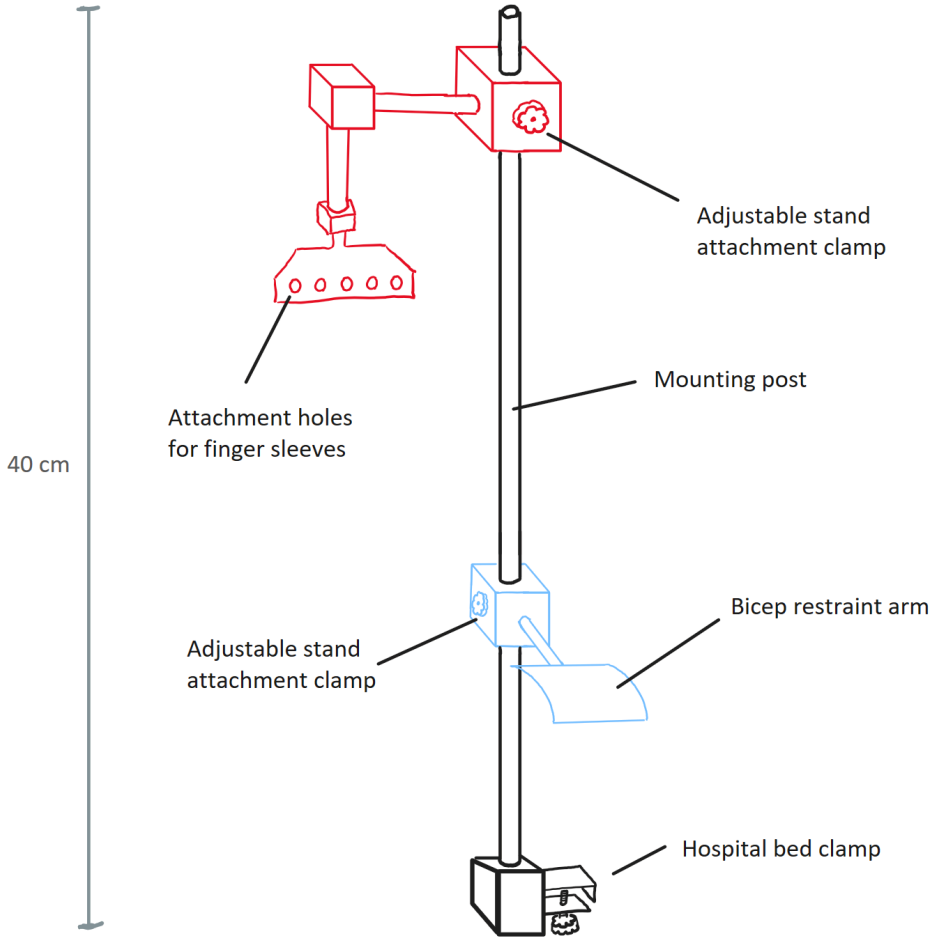


Figure 5: Bed clamp with restrain arm design

3.3 Mechanical Design 3 - Extension Brace

The third mechanical design is an arm and hand orthosis, used to support and position a patient's whole arm below the shoulder, seen in figure 6. The upper arm and proximal forearm are secured by multiple Velcro straps over contoured arm padding, ensuring a secure and comfortable fit. A locking elbow hinge connects the upper arm and forearm components, allowing for adjustment and fixation of the elbow angle. Extending distally from the hinge is a rigid extension bar, which leads to the hand portion of the orthosis. The elbow hinge contains a mechanism which allows for the extension bar to slide and be fixed at precise points. This movement adjusts the distance between the elbow and hand, applying tension to the lower arm. The hand is stabilized by a hand strap positioned across the palm and individual fingers are secured by several finger straps, however this is subject to change depending on the determined finger sleeve design.

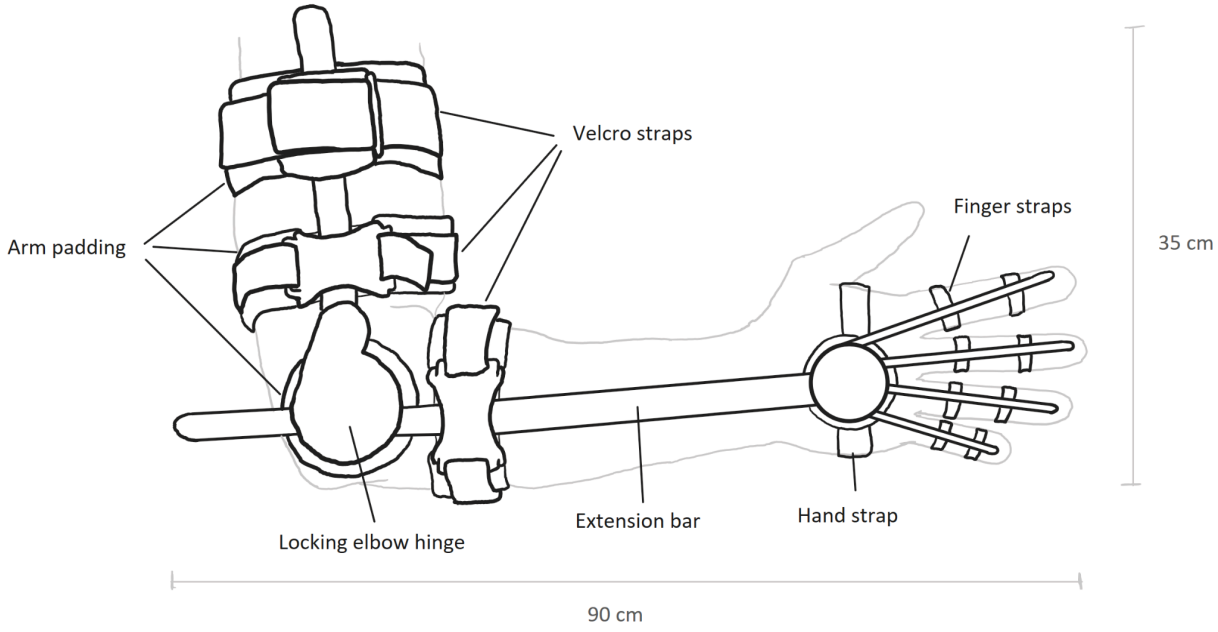


Figure 6: Extension brace design

3.4 Finger Sleeve Design 1 - Nylon Sleeve

The first finger sleeve design is most similar to the leading designs on the market. Its primary feature is a braided nylon mesh that surrounds the entire finger and, when stretched, grips the finger allowing tension to be applied to the digits, as seen in figure 7. The rubber stopper, displayed in the image below, prevents the eye hook from pulling through the mesh of the sleeve. The eye hook is attached to the mechanical portion of the device through a connection method. This eye hook can then be pulled on, tightening and lengthening the braid of the nylon material, which in turn compresses around the finger providing the traction for the design. The final component of this design is the synching rubber band placed at the bottom of the sleeve. This rubber band aids the applicator, as it allows the finger sleeve to connect with the finger before the tension force is applied. This design allows for ideal control over each finger, but in order for the correct compressive forces to be applied, would also require select size to be produced to fit all finger types.

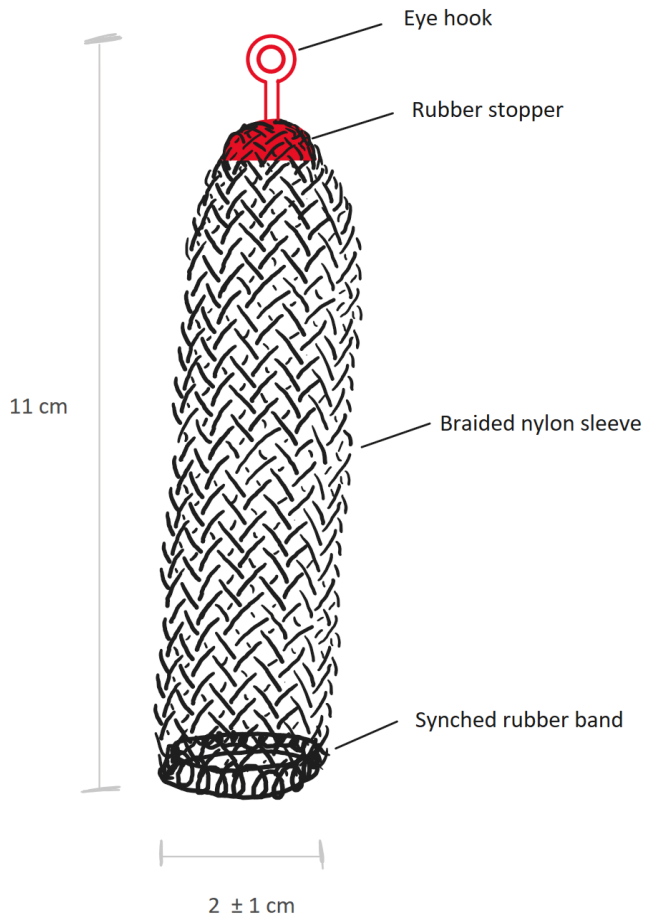


Figure 7: Braided Nylon mesh sleeve design

3.5 Finger Sleeve Design 2 - Hand Brace

The second finger sleeve design is an immobilization device, seen in figure 8. The device consists of a rigid backed plate that helps in immobilizing the hand itself. The rigid backed plate is then surrounded by a foam material that will aid in the overall comfort of the design for the patients. Flexible finger tabs are inserted into the end of the finger structures of the brace that are able to bend over the palm side of the finger to prevent overall finger movements. The hand tabs, as labeled below, function similarly to the finger tabs, but instead of being inserted at the end of the fingers, they erect from the radial and ulnar sides of the hand, immobilizing the lower hand. This hand brace device would be connected to the mechanical frames in a unique way as there is no built-in connection to the frame, which is a particular drawback to this design. This device would be a universal fit for all finger lengths and hand sizes. This could be accounted for with long finger tabs that can aid in the immobilization of the digits and the wrist joint.

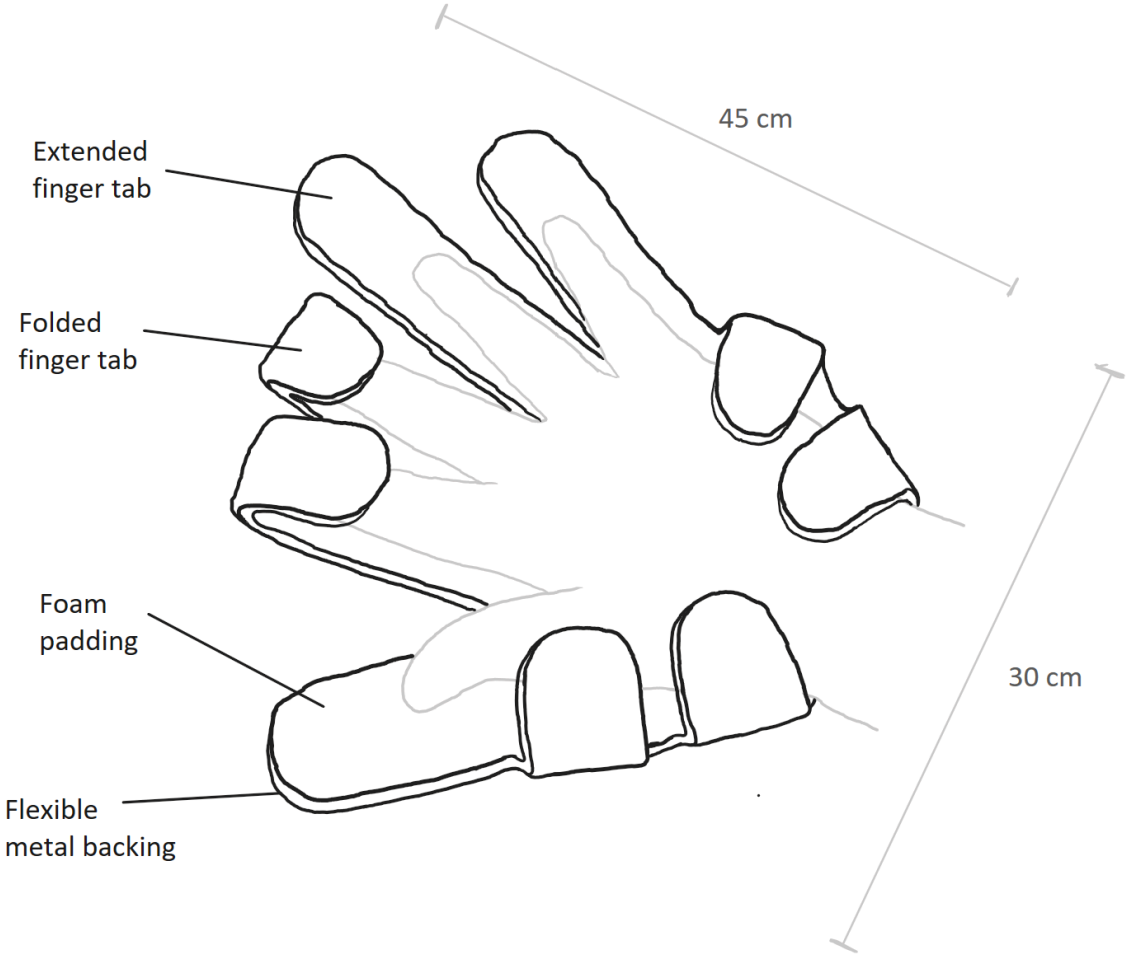


Figure 8: Universal hand brace design

3.6 Finger Sleeve Design 3 - Buckle and Strap

The third design consists of a nylon strip that is tightened around the finger using 2 separate velcro buckles that are fascined down by straps, seen in figure 9. For the connection to the mechanical part of the design, a D ring is placed at the end of the device to allow for connection to the frame. Overall this device is very similar to a standard finger splint, without the rigidity. The flexible nylon finger sleeve allows for slight freedom of movement, creating versatility for the surgeon. The blue strap, seen in figure 9, can slide up and down the length of the sleeve to be secured under the knuckle, aiding in immobilization and traction in the digits. The bottom strap can open as wide as 3 centimeters in order to fit any finger girths. Lengths of the nylon straps will be long enough to ensure any size finger can fit into the design and the buckles will ensure traction for every finger girth.

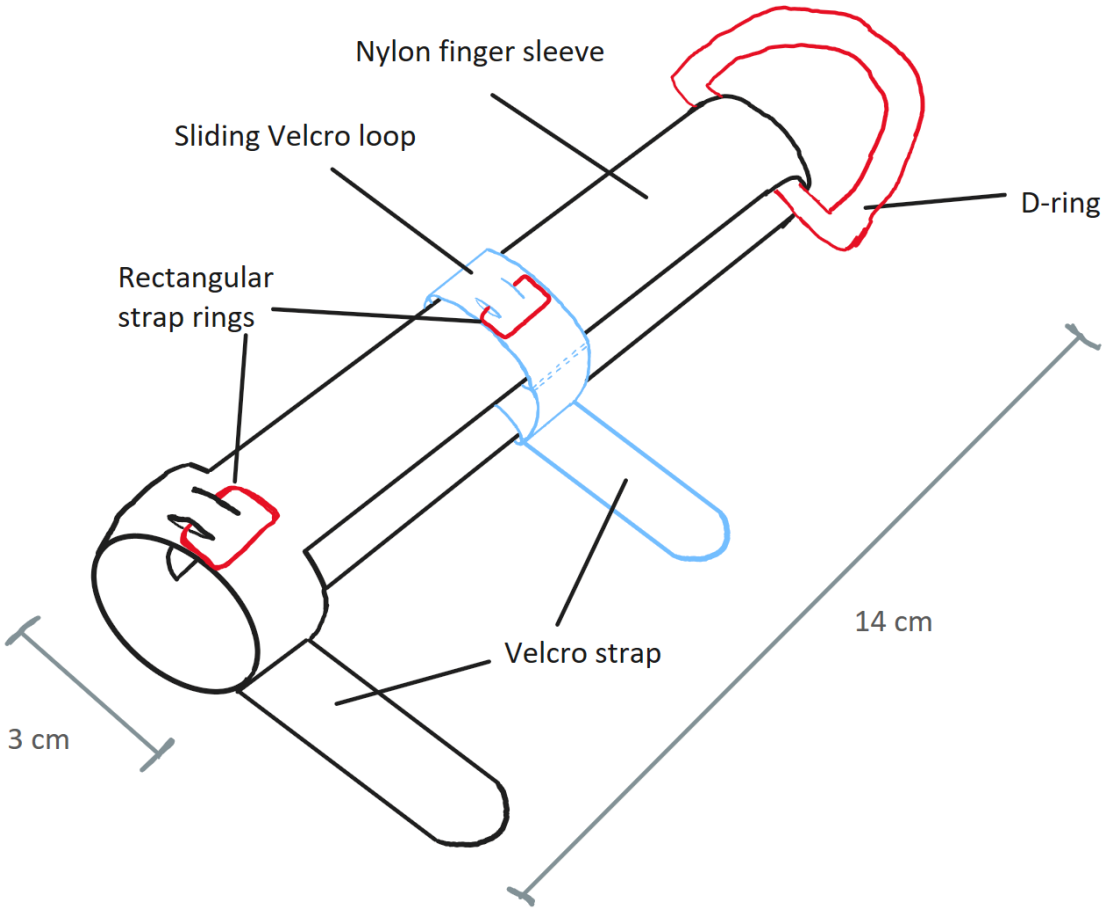


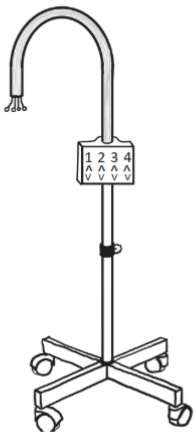
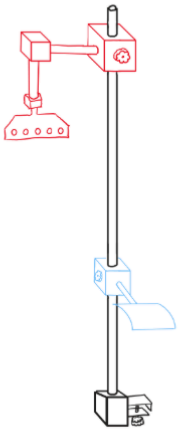
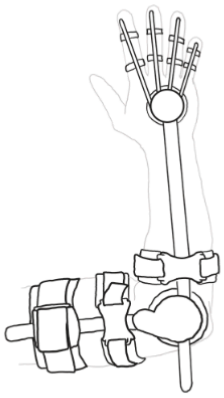
Figure 9: Buckle and Velcro strap sleeve design

4 PRELIMINARY DESIGN EVALUATION

4.1 Design Matrix

Table 1 shows the project scope design matrix for the mechanical portion of the design, which has the categorical rankings explained below.

Table 1: A design matrix created by the team used to rank the three preliminary designs for the mechanical portion of the digital traction device. Each category is rated by importance and is used to determine an overall score for each design.

Design Criteria	Standing Platform 		Bed Clamp & Restraint 		Extension Brace 	
Ease of use (25)	5/5	25	4/5	20	3/5	15
Cost (20)	4/5	16	5/5	20	2/5	8
Reusability (15)	4/5	12	5/5	15	2/5	8
Safety (15)	3/5	9	4/5	12	5/5	15
Ease of Fabrication (15)	4/5	12	5/5	15	2/5	6
Versatility (10)	4/5	8	3/5	6	2/5	4
Total (100)	82/100		88/100		56/100	

Reasonings for Scores

Ease of Use

Ease of use is defined as the device's ability to assist doctors and hospital staff during various procedures while also smoothly integrating into existing hospital practices. This is weighted the highest because the primary goal of the device is to reduce the effort and manual labor required of the medical team in their day-to-day operations.

Cost

Cost is weighted the second-highest because the client's goal is to manufacture the device in Senegal within the hospital's limited budget. Keeping the cost of each traction device low makes it more affordable and accessible, which could significantly improve the hospital's ability to treat its orthopedic patient population.

Reusability

Reusability is defined as the device's ability to withstand the repeated sterilization required in the operating room without losing the qualities necessary for it to function properly. This is weighted highly because it reflects the device's longevity and the number of cases it can be used for before needing replacement.

Safety

Safety is defined as how effectively the device minimizes the risk of harm to patients and hospital staff. This is weighted fairly high because a device that risks harming those around it runs directly counter to a hospital's mission of improving the health of the people it serves.

Ease of Fabrication

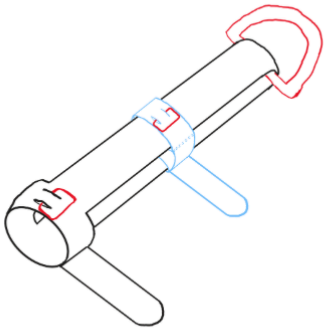
Ease of fabrication is defined as the device's ability to be manufactured on site in Senegal. It depends largely on the simplicity of the design, the ease of producing each component, and the difficulty of assembling them. This is weighted lower because, while still important, it is influenced more by material selection than by the methods chosen.

Versatility

Versatility defines the ability of the digital traction device to be used in a wide range of hospital settings, including the operating room as well as the rehabilitative clinic. Although it is not as important as the device's functionality, adaptability still warrants consideration as the device being effective in different medical contexts is helpful for both users and patients.

Table 2 shows the project scope design matrix for the sleeve portion of the design, which has the categorical rankings explained below.

Table 2: A design matrix created by the team used to rank the three preliminary designs for the sleeve portion of the digital traction device. Each category is rated by importance and is used to determine an overall score for each design.

Design Criteria	Nylon Sleeve 		Buckle and Strap 		Hand Brace 	
Safety (25)	5/5	25	4/5	20	2/5	10
Ease of Fabrication (20)	2/5	8	5/5	20	4/5	16
Cost (20)	3/5	12	5/5	20	2/5	8
Ease of Use (15)	5/5	15	4/5	12	3/5	9
Comfort (10)	4/5	8	3/5	6	5/5	10
Reusability (10)	2/5	4	4/5	8	2/5	4
Total (100)	72/100		86/100		57/100	

Reasonings for Scores

Safety

Safety is denied as to how effectively the design prevents risk to patients health, in this case specifically due to loss of circulation or slippage from device. This is weighted the highest as patient safety is the highest priority in a healthcare setting.

Ease of Fabrication

Ease of fabrication refers to the time and skill necessary to assemble a finger sleeve. This was weighted second highest as the client needs an efficient design to be manufactured in Senegal, and further multiple of the sleeve is required for each device.

Cost

Cost refers to the cost of materials and tools to construct each sleeve. This was weighted second highest as well due to the importance of a cost effective design to be manufactured in Senegal especially with each design requiring multiple sleeves.

Ease of Use

Ease of use refers to how easy the device is to apply to a patient's hand and whether the design gets in the way of any operations. This was weighted next highest as the team wants the design to not impede the work of clinicians within the healthcare setting.

Comfort

Comfort refers to the comfort of the device to the patient both during short and long term use. This was weighted one of the lowest as despite the importance of making a comfortable design for the patient, it's not as important as designing a safe and easily manufacturable device for the design criteria

Reusability

Reusability refers to the ease of cleaning of the device and whether its design allows for reuse. This was rated the lowest as although its valuable to have a device you can use multiple times, due to the necessity of an easily fabricated design quantity should not be a problem

4.2 Proposed Final Design

The proposed final design for the mechanical and sleeve portion of the device is a hybridized bed clamp and restraint with a detachable wheel base, seen in figure 10, that utilizes a buckle and strap design finger sleeve. The decision to go with a hybridized design was based on the close scoring on the mechanical design matrix. Particularly, this new design was made based on the bed clamp and restraints design's ease of use, cost, and reusability. The ease of use of this device comes from its ability to be easily clamped onto a typical patient's bed and the simplistic attachment method. Further the cost of this device sets it apart due to its simplistic design requiring very few intricate parts to manage the device. Similarly the simplicity of the design allows for the device to be more easily cleaned and designed out of parts more resistant to cleaning techniques, making it more reusable. This device struggled in terms of its versatility, but

the standing platform excelled in this category due to its wheel base, allowing for increased transfer mobility and positioning. Therefore, a simple addition of a detachable wheel base was made to the bed clamp and restraint design. The decision to go with a buckle and strap design is due to the device's ease of fabrication and cost as well as a good safety. The device's simplistic design and cheap design material because this design allows for the use of a material within the $50 budget. This allows the device to be both easily fabricated and low cost, allowing for large scale production to accommodate the needs in Senegal. Further the device has a relatively safe design due to the nature of its two contact point design. This design struggled in terms of comfort due to the two strap design. However, after taking into consideration all the aspects in the decision matrix, this was the winning project scope, and this is the direction the team will continue to pursue.

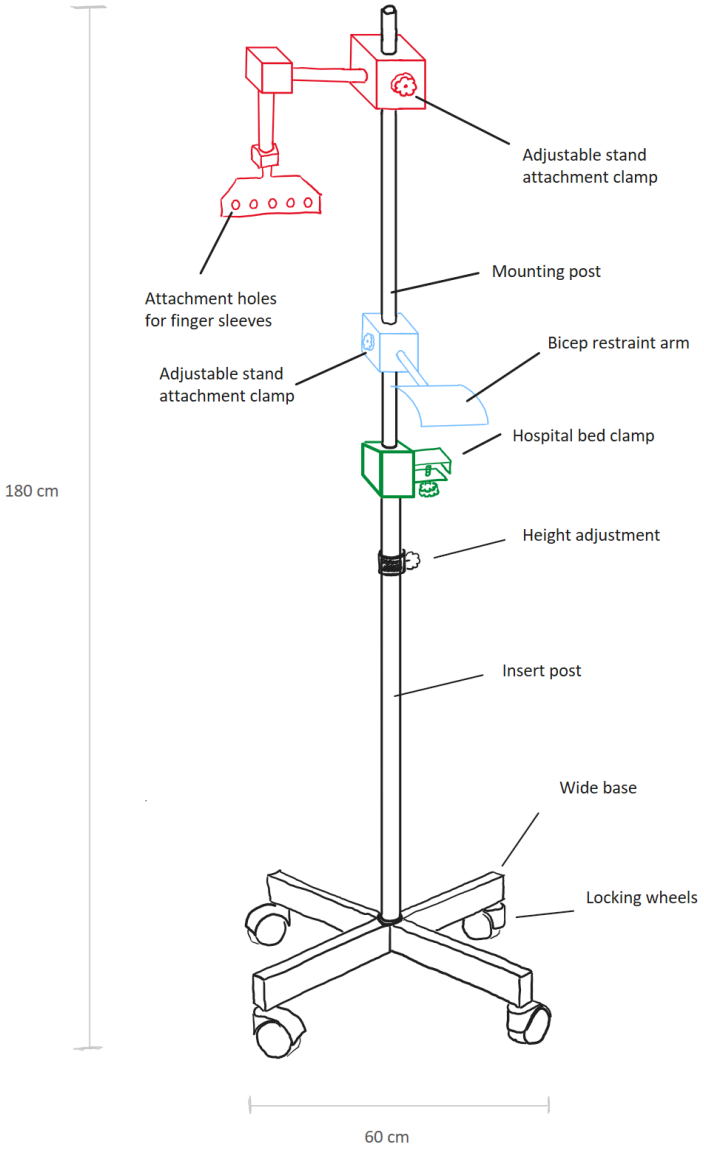


Figure 10. Hybridized final design of mechanical structure

5 FABRICATION

5.1 Materials

Mechanical

For the mechanical component of the design an aluminium rod will be used as the mounting post due to its extremely strong and durable yet reasonably lightweight and abundant [12]. The team will create the adjustable components out of aluminium as these components also need to be durable and be able to withstand any force or moment applied to them. It is important to note that the team is working with a limited budget, so any materials that are given or provided by the UW Madison BME department will be considered. The adjustable plastic knobs seen on this portion of the design will either be purchased and connected to the device via a hex headed screw or 3D printed to allow for a modular fit. As far as the bicep restraint arm, 3D printing is the most viable option to create a comfortable yet effective restraint piece for the brachium of the arm.. Another important note is that all materials will be expected to withstand standard cleaning procedures. Daily operating room use and sterilization could begin to erode, rust, or break down materials, so choosing strong and durable materials is important for 3D printing and metal fabrication in order to maintain patient safety over the shelf life of the device.

Finger Sleeve

The finger sleeve portion utilizes a significant amount of nylon, a cheap, abundant, and strong plastic material for a majority of its components. Nylon was ultimately chosen for its overall strength and workability in the overall fabrication process of the finger sleeves. It is crucial that for the overall design stability is ensured throughout the desired shelflife. The nylon portions of the design will need to withstand daily use and intense sanitation. Ultimately, the Buckle and Strap design was chosen because of its universal nature and ensuring the universality and functionality of the nylon over many applications and rigorous sanitation is required. Next, the team chose to implement velcro for the strap component of the design. Velcro is extremely easy to use and will reduce the application time of the finger sleeves prior to a procedure. A simple hollow rectangular plastic piece will serve as the buckles for each of the straps. Lastly, the D-Ring is highly substitutable and likely to change with the overall connective elements of the design. However, a simple durable plastic or metal D-Ring will be implemented.

5.2 Methods

Mechanical

All components, including the bed clamp, collar assemblies, restraint arm, and traction arm, will be modeled in SolidWorks and exported as .stl files. The bed clamp and attachment collars will include recessed cavities for heat-set threaded inserts and set screw channels. These

files will then be prepared for printing using Ultimaker Cura. Printing will be completed using the Ultimaker S5 available in the Wendt Design Innovation Lab. Polylactic acid (PLA) filament will be used with the printer parameters set to Wendt Design Innovation Lab standards besides a layer height of 0.2 mm and infill of 30%. Once the parts have all been printed, brass M6 heat-set threaded inserts will be installed into all designated recesses using a temperature controlled soldering iron. The inserts will be pressed flush into the plastic and allowed to cool for a secure fit. A 50 cm long, 25.4 mm diameter aluminum rod will serve as the mounting post and each printed clamp or attachment collar will be slid onto the rod and secured using the M6 set screws threaded into the heat-set inserts. The order of the mounting post from top to bottom should be: traction arm, bicep restraint arm, and bed clamp, leaving at least 10 cm of open rod at the bottom for insertion into the wheeled base.

To construct the base, a metal band saw will be used to cut 25 x 25 x 2 mm aluminum square tubes into a 60 cm bar and two 28.75 cm bars. The two shorter bars will intersect on the sides of the long bar, at its center. Using four aluminum 90° L-brackets at each corner, 6 mm holes will be marked and drilled through the square tubing so that M6 bolts, washers, and lock nuts can be used to fasten the base together. Using the metal band saw, aluminum tubing with an outer diameter of 38.1 mm and an inner diameter of 25.4 mm will be cut to 14 cm in length. At the very center of the intersection between the square tubes, a 38.1 mm diameter hole can be drilled through one side of the tube using a manual milling machine. The aluminum tubing will be inserted into this hole and the junction will be filled with JB Weld and allowed to fully set. Finally, four 25 mm caster wheels will be aligned on the bottom of the square tubes at each end so that 6mm holes can be marked and drilled through the square tubing. The wheels will then be fixed to the base with M6 bolts, washers, and lock nuts.

Finger Sleeve

Using a Cricut Maker 3, a template containing a long T-shape with two slits, a 104 x 12.7 mm rectangle with two slits, and two 40 x 12.7 mm rectangles, seen in figure 11, will be cut out of a nylon fabric sheet. The 104 x 12.7 mm nylon strip will be folded into a loop, overlapping the two ends by 1 cm and securing them together using fabric adhesive. The 40 x 12.7 mm strips will be attached parallel on the inside of the loop, one centered under the slits and the other centered under the overlapping ends of the loop, by placing 1 cm of fabric adhesive on each end of the strip. This creates two slots on the loop between the layers of nylon fabric. The long end of the T-shaped strip will be inserted into the slot with the two slits. The same end will then be pushed through a 20 cm D-Ring, before being inserted into the other slot on the loop. The T-shaped strip will then be folded over on itself so that the flap of the T can be butted up to each other and laid on top of the long end, making sure the outer edges are all aligned and that each flap overlaps 1 cm before securing with fabric adhesive. At this point, 12.7 mm rectangular rings can be clipped around the two fabric hooks created by the slits. Finally, 12.7 x 100 mm double sided velcro strips can be wrapped around the two loops of the finger sleeve and secured with fabric adhesive, making sure to only glue half way around the loop starting from one end of

a ring. If later testing shows that the fabric adhesive does not withstand forces to the finger sleeve stated in appendix 10.1, stitching can be added to the connections for reinforcement.

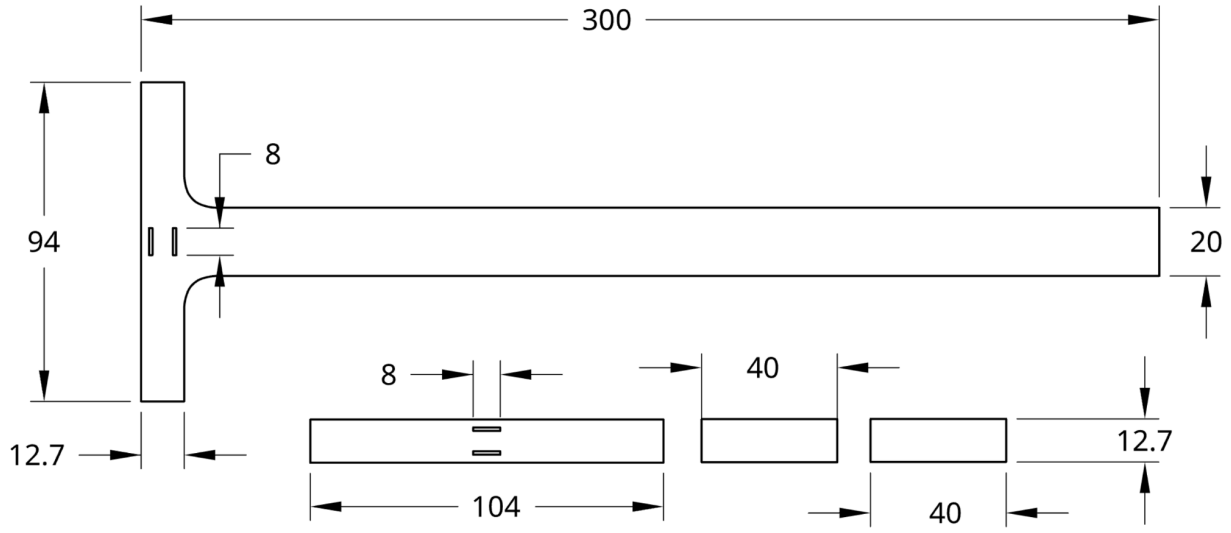


Figure 11. Cricut Maker 3 template for nylon fabric sheet (units = cm)

6 TESTING & RESULTS

After fabrication of the mechanical and sleeve portion of the device, its performance and safety will be assessed through mechanical, physiological, and user-centered testing. First, the stand's mechanical integrity will be verified using a static proof load test in accordance with OSHA §1926.251(a)(4), which mandates that custom clamps and lifting accessories be proof-tested to 125 % of their rated working load limit (WLL) to ensure structural safety [13]. The stand will be mounted and then loaded vertically at its distal attachment point to 1.25× WLL for a half hour while monitoring for deformation or structural compromise. If no damage occurs, a further ultimate load-to-failure test will be conducted to determine the breaking load and calculate the design safety factor, targeting ≥ 4× WLL as recommended for medical support mounts [14]. To ensure physiological safety, vascular perfusion checks will be performed during device use using pulse oximetry and capillary refill testing to confirm that the device does not impede blood flow to the digits, methods supported by standard clinical vascular assessment practice [15]. In parallel, surface electromyography (EMG) will quantify forearm muscle activity to determine whether the device reduces muscular effort or induces compensatory activation, following protocols established in upper-limb orthosis research [16]. Finally, participants will complete comfort and usability questionnaires at 5 and 30 minute intervals to evaluate subjective comfort, pain, and perceived exertion. Together, these complementary tests will verify that the device is structurally sound, physiologically safe, and comfortable for extended clinical use.

7 DISCUSSION

This design allows for a universal and highly versatile approach capable of functioning for the traction device needs in Senegal. The low material cost and the use of simple mechanical components provide an affordable yet stable option for finger traction. This is especially important in Senegal, where access to specialized orthopedic equipment is limited due to economic constraints and uneven healthcare infrastructure. Many hospitals in low-resource settings face challenges such as shortages of functional devices, limited maintenance capacity, and overcrowded wards [17]. The ability of this design to be mobile by being mounted on wheels or used as a bed clamp, enables healthcare providers to share one device between rooms addressing the shortage of equipment without sacrificing treatment quality. In addition, the incorporation of universal sleeves allows the same structure to be used for multiple patients with proper sterilization, helping reduce both production costs while maintaining ethical infection-control standards [18]. From an ethical standpoint, accessibility and patient safety are prioritized through the use of materials that are low-cost yet biocompatible and easy to disinfect. The design also considers equity, as it can serve hospitals in a range of different socioeconomies, helping reduce disparities in orthopedic care availability. Ultimately, the goal of this device is to improve the treatment of hand fractures and related injuries while ensuring affordability, durability, and patient safety, key ethical and design priorities for sustainable healthcare innovation in Senegal.

8 CONCLUSION

Orthopedic injuries to the upper extremity are highly prevalent in the field of medicine and often require expert medical treatment due to their anatomical complexity. A key instrument used to treat these injuries is a digital traction device. This piece of equipment is used in a plethora of surgical and rehabilitative settings to stabilize the upper extremity and relax the regions of the body requiring treatment. This design is relatively low-cost and also versatile due to its ability to transition between a variety of treatment settings within the hospital. Once the mechanical and finger-sleeve portions of the model are created, a method for connecting them into one unified model will need to be determined.

For future work, the team will need to confirm the materials to be used for the mechanical and sleeve portions. This will require us to consider the cost of the materials available to us as well as their durability and resistance to cleaning procedures that will be necessary in the operating room. Testing also needs to be evaluated on our design in accordance with the testing section listed in this report

9 REFERENCES

[1] V. Candela, P. Di Lucia, C. Carnevali, A. Milanese, A. Spagnoli, C. Villani, and Stefano Gumina, “Epidemiology of distal radius fractures: a detailed survey on a large sample of patients in a suburban area,” Journal of Orthopaedics and Traumatology, vol. 23, no. 1, p. 43, Aug. 30, 2022. DOI: 10.1186/s10195-022-00663-6. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC9428104/

[2] B. Choudhry, B. Leung, E. Filips, and K. Dhaliwal, “Keeping the Traction on in Orthopaedics,” Cureus, vol. 12, no. 8, Article e10034, Aug. 2020. DOI: 10.7759/cureus.10034. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7515792/

[3] M. Soumah, 'Digital Traction - Condensed Questions from Previous Email and Meeting', 2025

[4] D. Haughton, D. Jordan, M. Malahias, S. Hindocha, and W. Khan, “Principles of hand fracture management,” Open Orthop J, vol. 6, pp. 43–53, 2012, doi: 10.2174/1874325001206010043.

[5]“Hand Fixation» Reison Medical®,” Reison Medical, Apr. 08, 2025. https://reison.se/product/hand-fixation/ (accessed Sep. 30, 2025).

[6]K. Akhtar, D. Akhtar, and J. Simmons, “A readily available alternative to Chinese finger traps for fracture reduction,” Royal College of Surgeons of England, https://publishing.rcseng.ac.uk/doi/full/10.1308/rcsann.2013.95.2.159 (accessed Sep. 9, 2025).

[7]A. Zolotov, “Handmade Traction Wrist Tower,” *J Wrist Surg*, vol. 7, no. 5, pp. 441–444, Nov. 2018, doi: 10.1055/s-0038-1649504.

[8] “Flexor tendon mechanism,” AO Foundation, 2019. [Online]. Available: https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/further-reading/hand-flexor-tendon-mechanism. [Accessed: Dec. 3, 2024].

[9] “Fig. 3. The bone structure of the human hand including the forearm and...,” ResearchGate. Accessed: Oct. 06, 2025. [Online]. Available: https://www.researchgate.net/figure/The-bone-structure-of-the-human-hand-including-the-forearm-and-wrist-1-7-CMC_fig1_369946938

[10] M. Zhang and A. F. Mak, “In vivo frictional properties of human skin and five materials: aluminium, nylon, silicone, cotton sock, Pelite,” Prosthetics and Orthotics International, vol. 23, no. 2, pp. 135–141, Aug. 1999. DOI: 10.3109/03093649909071625. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/10493141/

[11] “Pape Samb – Jamarek.” Accessed: Oct. 05, 2025. [Online]. Available: https://jamarek.org/wps-members/petter-nilsen/

[12] L. Cui, K. Liu, and X.-G. Chen, “Recent advances in cost-effective aluminum alloys with enhanced mechanical performance for high-temperature applications: A review,” Materials & Design, p. 113869, Mar. 2025, doi: https://doi.org/10.1016/j.matdes.2025.113869.

[13] Occupational Safety and Health Administration, “Rigging equipment for material handling; custom-designed accessories must be proof-tested to 125 % of rated load,” 29 CFR 1926.251(a)(4), Aug. 15, 2002. [Online]. Available: https://www.osha.gov/laws-regs/standardinterpretations/2002-08-15-0

[14] Healthcare Technology Specifications, “Medical equipment mounting and support standards,” HealthcareTec, 2024. [Online]. Available: https://www.healthcaretec.com/specs

[15] K. R. Giele and N. J. Beasley, “Assessment of digital vascularity in the hand and its clinical applications,” J. Hand Surg. Br., vol. 12, no. 1, pp. 75–80, 1987. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/6869487/

[16] R. L. Lieber and G. J. Fridén, “Functional electromyography of forearm muscles during orthosis-assisted positioning,” J. Hand Surg. Am., vol. 8, no. 2, pp. 135–143, 1983. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC11902658/

[17] M. E. Osei-Tutu, A. F. Agyeman, and B. S. Boateng, “Challenges and opportunities for biomedical equipment in sub-Saharan Africa: A review,” Pan African Medical Journal, vol. 37, no. 192, pp. 1–8, 2020.

[18] J. Ogden, S. Karim, and L. Diallo, “Ensuring infection control in medical device reuse in low-resource settings,” Global Health Science and Practice, vol. 10, no. 3, pp. 564–572, 2022.

10 APPENDIX

10.1 Product Design Specification

Function

Design a device that allows for precise digital control and support of the components of the human hand through the use of Japanese finger sleeves or a similar universal type of support. This device will be designed to allow for controlled and stable traction during relevant procedures so that proper positioning of the hand can be attained with minimal manual effort.

Client requirements

- The device must support the patient's hand for approximately 50 minutes during fracture casting and be usable during surgery.
- Patients lie with their elbows bent at 90° and their hands suspended by finger sleeves; the sleeves must not compress the fingers, as this could cause stiffness.
- Reusable (due to economic constraints, single-use is not feasible), sterilizable design required.
- Materials must be:
    - Strong, elastic, and latex-free (non-allergenic).
    - MRI-compatible (no metal components).
- Sizing:
    - Multiple sleeve sizes needed.
    - An adaptive "one-size-fits-all" or an adjustable option are preferred.
- Functionality:
    - Provide a high-friction grip to allow stabilization and dexterity during traction and surgical use without restricting circulation.
    - The design must allow for the natural flexion and extension of finger joints, ensuring the tendons can glide smoothly within their sheaths during any minor patient movement or adjustment [1].
- Smart/Innovative features (desired but not mandatory):
    - Sensors to track finger pressure, bending angles (0–90°), and usage duration.
    - Alert system if complications occur: optional.
- Must be durable, cost-effective, and suited for high patient volume (~25,000 orthopedic patients every 6 months).
- No copyright required; aim for a "modern, smarter" tool.

Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance requirements**
        i. The sleeve must securely support the full weight of a patient's hand and forearm through a single fingertip without tearing, stretching permanently, or slipping off. The team's target is for the sleeves to support a static load of at least 22-44 N per finger as a safety factor.
        ii. The device must maintain its elasticity, strength, and surface texture through a minimum of 50 cycles of use.
        iii. The inner surface of the sleeves must provide sufficient friction to prevent the finger from slipping out under load.
        iv. The outer attachment point must securely hold the suspension mechanism.
        v. The sleeve material must stretch to accommodate various finger diameters, with the team's goal being a 15-25% stretch beyond a relaxed state. This retraction should be enough to provide a secure and snug fit while not being so tight that it causes harmful or uncomfortable finger constriction.
        vi. If implemented, the device will have "smart" monitoring capability that measures the traction force in each finger. The target shall be to keep the displayed force within 0.5–5 N of the actual load in order to accurately detect delicate manipulation or alert the physician if a dangerous level of force is being applied. The sensor would also have integrated wireless (e.g., Bluetooth) transmission for real-time data analysis.

    b. **Safety**
        i. All materials must be medical-grade, non-toxic, and hypoallergenic (specifically latex-free) to avoid skin irritation or allergic reactions.
        ii. The design must avoid finger compression to prevent cutting off circulation (ischemia) or causing nerve damage during the 50-minute procedure.
        iii. The entire device must be made from non-metallic, MRI-compatible materials to ensure it is not a projectile risk and does not generate heat or artifacts that could harm the patient or corrupt imaging data.
        iv. The device must be designed and tested to have a significantly higher load-bearing capacity than expected in use to prevent catastrophic failure (e.g., tearing) that could result in patient injury from a falling arm.
        v. The design and materials must be compatible with standard hospital sterilization techniques (e.g., steam autoclave, chemical sterilants) without degrading, to prevent cross-contamination between patients.

c. **Accuracy and Reliability**
    i. If multiple sizes are produced, each size must consistently and accurately fit the intended range of finger diameters.
    ii. Any integrated sensors that are implemented (e.g., for force) must provide accurate and repeatable readings within the specified target ranges (e.g., ±0.1 N accuracy for force sensing) to be clinically useful for monitoring.

d. **Life in Service**
    i. The finger sleeves must reliably perform at least 500 full uses over their service lifetime. Each use is 50 minutes under load, so a total active operational time of 420 hours.
        1. Idrissa Pouye General Hospital receives 25,000 orthopedic patients every 6 months. Assuming that 17.5% of all orthopedic visits are DRFs, the finger sleeves will be used about 8750 times per year [2].
        2. The finger sleeves should maintain full function after 2 years.
        3. There will be a stock of 36 sets of finger sleeves assuming 25 DRFs per day and a 1.5x sterilization turnover buffer.
    ii. Elastic and sensor components should endure 100,000 loading cycles within the expected operating force range (0.5-50 N), with sensor accuracy drift less than ±5% [3].

e. **Shelf Life**
    i. In storage, device components should retain functionality for at least 3 years under temperatures between 10-30 °C, in relative humidity less than 70%, and away from direct UV light.

f. **Operating Environment**
    i. Device must function in standard operating room conditions: 20-24 °C, 20-60% relative humidity [4].
    ii. Surfaces should be resistant to corrosion or degradation by blood, saline, antiseptics, and common disinfectants.
    iii. Device must be able to tolerate occasional jostling or movement without loss of alignment or sensor calibration.
    iv. Device must be MRI compatible with no ferromagnetic metal parts and any electronics shielded or safely located to avoid interfering with imaging.

g. **Ergonomics**
    i. Limit peak interface pressure to 50 N/cm², below reported pressure pain thresholds [5].

ii. Inner finger sleeves must provide a coefficient of friction of 0.4 under standard operating room conditions to ensure grip, while remaining below 1.0 to avoid excessive shear and possible skin damage [6].
iii. Limit axial traction force per digit to 50 N to avoid excessive loading on finger joints and the DRF site [7].

h. **Size**
   i. The device must fit within the surgical field without interfering with other instruments [8].
   ii. Should accommodate all hand and finger sizes specifically for the Senegalese whose typical finger size is 8.26 cm for females and 8.69cm for males [9].
   iii. Must be compact enough to not block MRI coils or distort imaging [10].
   iv. Adjustability is an important component, both to increase or decrease tension or create smaller or larger overall structure [11].

i. **Weight**
   i. Must be lightweight for easy handling and help reduce surgical fatigue in a delicate surgical procedure.
   ii. Heavier components risk displacement forces within the MRI machine. Therefore, lower weight improves safety [12].
   iii. Smaller and lighter japanese finger sleeve components means less surface area contact with skin, reducing risk of irritation [13].

j. **Materials**
   i. Materials must be non-ferromagnetic, non-conductive, and biocompatible. Plastics, ceramics or composites, as well as titanium are all possible materials. They must be able to handle sterilization methods [14].
   ii. No material can be irritable to the skin, causing redness, swelling, burning, or itching [15].

k. **Aesthetics, Appearance, and Finish**
   i. Must be finished with a non reflective material, which will avoid glare from surgical lights.
   ii. Include any padding where soft tissue would ever come into contact with solid material, for patient safety.
   iii. The device has no major need to be aesthetically pleasing, as it will need to be more functional than anything.

2. **Production Characteristics**
   a. **Quantity**
      i. The client's goal for the project is to develop a single digital traction device that aids performance and reduces the difficulty of standard orthopedic hand and wrist procedures. The product should be able to accurately manipulate finger tension in both the right and left hands during

surgery while still allowing the client to easily maintain its function and sanitation through extensive use.

b. **Target Product Cost**
    i. The client has not given the project a set budget yet for prototyping. They mentioned that they would pay for things as the team needs them.
    ii. The university allots a budget of $50 for use in the Design Labs.
    iii. The device is intended for use in a hospital in Senegal, where economic resources are more limited, roughly 40 times lower GDP per capita than the US. The end product should be relatively lower in cost compared to similar products on the market [16].

3. **Miscellaneous**
    a. **Standards and Specifications**
        i. International Standards
            1. ISO 13485:2016: Medical devices: Quality management systems [17]
                a. Covers requirements for the quality management system for medical devices. Globally recognized and expected by regulators worldwide.
            2. ISO 14971:2019: Medical devices: Application of risk management to medical devices [18]
                a. Methodology for identifying, evaluating, and controlling device risks.
            3. ISO 10993-1:2018: Biological evaluation of medical devices: Evaluation and testing within a risk management process [19]
                a. Provides framework for biological safety assessment of materials in contact with the patient's skin or body.
            4. ISO 15223-1:2021: Medical devices: Symbols to be used with information to be supplied by the manufacturer [20]
                a. Standardized labeling.
        ii. United States Additional Regulations
            1. 21 CFR Part 820: Quality System Regulation [21]
                a. The FDA's legally binding quality management regulation for medical devices marketed in the U.S.
    b. **Customer**
        i. The potential customers for this device include teaching hospitals, surgical centers, rehabilitation clinics, and any other medical facility that performs upper-extremity orthopedics. At this stage, the client will be the primary source used to validate the device's ability to securely hold individual fingers and apply precise, adjustable traction to each digit. Since the device is intended for use in resource-constrained settings such as Idrissa

Pouye General Hospital in Senegal, the customer is particularly interested in a cost-conscious and sterilizable design that minimizes the need for replacement. They are also looking for a modular approach that allows a single device to be compatible with MRI and accommodate a wide range of finger sizes. Long-term, the customer envisions expanding use of the device to other medical facilities where reproducible digital traction would improve workflow and clinical outcomes.

c. **Patient-related concerns**
    i. This device will be used during delicate orthopedic procedures where precise hand positioning is essential, making patient safety a top priority. To protect patients from injury, the design must maintain structural integrity under duress and also provide consistent traction forces without exceeding safe limits for finger joints. This means the sleeves must support the full weight of the patient's upper arm while avoiding any sort of constriction that could cut off circulation or cause nerve injury. The materials used in the device must be medical-grade, hypoallergenic, and non-metallic to prevent skin irritation and ensure MRI compatibility. Also, the device's surfaces must resist degradation from blood, saline, and any disinfectants common to a medical setting.

d. **Competition**
    i. Competing Design #1: MPR Hand Traction System [22]
        1. The MPR Hand Traction System is a modular device that suspends the patient's hand using finger traps and an adjustable frame that allows stable positioning during orthopedic procedures of the upper extremity surgeries. It also offers adjustable traction and can accommodate a wide range of hand sizes.
        2. While the product fits many of the client's criteria, it provides limited adjustability for fine-tuning individual finger forces and also has a metal frame that makes it incompatible with MRI environments. Furthermore, MPR does not list the cost of the device publicly due to prices being negotiated on a contract basis, making it difficult to assess its affordability for resource-limited hospitals.

    iii. Competing Design #2: Standard Finger Trap Suspension Systems [23]

        1. This device uses a stainless steel chain-and-pulley mechanism to distribute traction weight across three or more digits and prevent overloading of a single finger.
        2. The system is fully autoclavable, making it a common option for hospitals that are looking to avoid single-use devices.

3. Although this option is simple, it again lacks the ability to independently adjust traction forces for each finger and also does not offer any built-in monitoring to ensure consistent loading. This can lead to variability and makes it difficult to replicate the specific traction conditions needed for delicate upper extremity procedures.

References

[1] "Flexor tendon mechanism," AO Foundation, 2019. [Online]. Available: https://surgeryreference.aofoundation.org/orthopedic-trauma/adult-trauma/further-reading/hand-flexor-tendon-mechanism. [Accessed: Dec. 3, 2024].

[2] V. Candela, P. Di Lucia, C. Carnevali, A. Milanese, A. Spagnoli, C. Villani, and Stefano Gumina, "Epidemiology of distal radius fractures: a detailed survey on a large sample of patients in a suburban area," Journal of Orthopaedics and Traumatology, vol. 23, no. 1, p. 43, Aug. 30, 2022. DOI: 10.1186/s10195-022-00663-6. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC9428104/

[3] B. Choudhry, B. Leung, E. Filips, and K. Dhaliwal, "Keeping the Traction on in Orthopaedics," Cureus, vol. 12, no. 8, Article e10034, Aug. 2020. DOI: 10.7759/cureus.10034. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7515792/

[4] ASHRAE, ANSI/ASHRAE/ASHE Standard 170-2017: Ventilation of Health Care Facilities, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA, USA, 2017.

[5] Moon Young Park, Doyeon Han, Jung Ho Lim, Min Kyung Shin, Young Rok Han, Dong Hwan Kim, Sungsoo Rhim, and Kyung Sook Kim, "Assessment of pressure pain thresholds in collisions with collaborative robots," PLoS ONE, vol. 14, no. 5, Article e0215890, May 02, 2019. DOI: 10.1371/journal.pone.0215890. [Online]. Available: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0215890

[6] M. Zhang and A. F. Mak, "In vivo frictional properties of human skin and five materials: aluminium, nylon, silicone, cotton sock, Pelite," Prosthetics and Orthotics International, vol. 23, no. 2, pp. 135–141, Aug. 1999. DOI: 10.3109/03093649909071625. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/10493141/

[7] B. Choudhry, B. Leung, E. Filips, and K. Dhaliwal, "Keeping the Traction on in Orthopaedics," Cureus, vol. 12, no. 8, Article e10034, Aug. 2020. DOI: 10.7759/cureus.10034. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7515792/

[8] ASTM International, Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment, ASTM F2503-20, West Conshohocken, PA, USA, 2020.

[9] N. E. Sahin, Rukiye Sumeyye Bakici, S. Toy, and Z. Oner, "Evaluation of Hand Morphometry in Healthy Young Individuals from Different Countries," International Journal of Morphology, vol. 42, no. 4, pp. 991–998, Aug. 2024, doi: https://doi.org/10.4067/s0717-95022024000400991.

[10] ASTM International, Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment, ASTM F2503-20, West Conshohocken, PA, USA, 2020.

[11] A. Zolotov, "Handmade Traction Wrist Tower," J Wrist Surg, vol. 7, no. 5, pp. 441–444, Nov. 2018, doi: 10.1055/s-0038-1649504.

[12] ASTM International, Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment, ASTM F2503-20, West Conshohocken, PA, USA, 2020.

[13] International Organization for Standardization, Biological Evaluation of Medical Devices—Part 23: Tests for Irritation, ISO 10993-23:2021, Geneva, Switzerland, 2021.

[14] ASTM International, Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment, ASTM F2503-20, West Conshohocken, PA, USA, 2020.

[15] International Organization for Standardization, Biological Evaluation of Medical Devices—Part 23: Tests for Irritation, ISO 10993-23:2021, Geneva, Switzerland, 2021.

[16] The World Bank Docs, "SELECTED INDICATORS," 2016. Accessed: Oct. 09, 2025. [Online]. Available: https://thedocs.worldbank.org/en/doc/b3502c65235d8c72aef5f34d87ed6298-0500062021/related/data-sen.pdf*

[17] ISO, ISO 13485:2016 – Medical devices – Quality management systems – Requirements for regulatory purposes, International Organization for Standardization, 2016. [Online]. Available: https://www.iso.org/standard/59752.html

[18] ISO, ISO 14971:2019 – Medical devices – Application of risk management to medical devices, International Organization for Standardization, 2019. [Online]. Available: https://www.iso.org/standard/72704.html

[19] ISO, ISO 10993-1:2018 – Biological evaluation of medical devices – Part 1: Evaluation and testing within a risk management process, International Organization for Standardization, 2018. [Online]. Available: https://www.iso.org/standard/68936.html

[20] ISO, ISO 15223-1:2021 – Medical devices – Symbols to be used with information to be supplied by the manufacturer – Part 1: General requirements, International Organization for Standardization, 2021. [Online]. Available: https://www.iso.org/standard/78688.html

[21] U.S. Food and Drug Administration, 21 CFR Part 820 – Quality System Regulation, U.S. Government Publishing Office, 2023. [Online]. Available: https://www.ecfr.gov/current/title-21/chapter-I/subchapter-H/part-820

[22] "MPR Hand Traction System - MPR Orthopedics," MPR Orthopedics, Nov. 22, 2022. https://mprortho.com/product/mpr-hand-traction-system (accessed Sep. 17, 2025).

[23] "Equalizing Device shown with Finger Traps | David Scott Co," Davidscottco.com, Jul. 11, 2024. https://www.davidscottco.com/product/equalizing-device-shown-with-finger-traps/ (accessed Sep. 17, 2025).

10.2 Expense Spreadsheet

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
Makerspace 3D Printing Costs										
									$0.00	
									$0.00	
Other Supporting Purchases										
									$0.00	
									$0.00	
								TOTAL:	$0.00	
								Budget:	Undecided	
								Financial Standing:	GOOD	