Design of an Endoscopic Spine Trainer

BME Design 200/300

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Abstract:

      The ability for a surgeon to train the skills necessary for a procedure prior to performing the surgery is important for the success of the surgery and confidence of the surgeon. The medical field has advanced recently for spinal surgeons as many procedures can be done endoscopically. However, a simulator to practice the hand-eye coordination skills for this type of procedure is very expensive. For this project, we are designing a low cost, low-technological endoscopic spine trainer for surgeons to use globally.

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Based off of the results of our design matrix we have decided to focus our attention on the separate boxes design as it scored the highest overall and scored the outright highest in the most criteria. This design scored the highest in all but the degree of accuracy which is our most important criterion, but it still does a good job at replicating each task separately. We will now talk to our client about our chosen design and confirm that he agrees we should formulate the separate boxes design.   10

1. Introduction

1.1 Motivation

The motivation for our endoscopic spine training simulator comes down to one simple thing: universality. We want our project to reach all corners of the world and be used by anyone from any part of surgical practice. The need for our project stems from the expensive simulators that are currently on the market. Our device will be necessary as it will be easy to build and enables adaptability to the user to allow anyone to use our project to better perfect their techniques for surgery. It isn't about the anatomy, but rather the surgeons experience with the tools.

1.2 Existing Devices/ Current Methods

The competing design that was most synonymous with our project was the Simbionix Spine Mentor. This training simulator was realistic in its function as well as its appearance. The Spine Mentor also included a virtual reality function which allows the surgeon to see in real time what they were doing. This spine mentor is $6500 and was well above our budget as well as not being as affordable for everyone [1].

1.3 Problem Statement

Minimally invasive spine surgery is becoming more commonplace; however, there is minimal opportunity in spine surgeon residency training (neurosurgery and orthopedics). The tools that are used for these procedures are significantly different from the standard procedures performed today. There is a need for a low cost simulation environment to be developed to provide spine surgery trainees with the practice and training space to develop the fundamental scope handling and manipulation skills necessary to perform minimally invasive endoscopically-based surgical treatments. Ideally, it will be made with simple materials to allow for its building and use globally.

2. Background

2.1 Background Research

2.1.1 Relevant Physiology and Biology

We first started off our research by looking into the different types of endoscopic spine surgery. The first type is an endoscopic discectomy. This type of surgery specifies in removing herniated disks from any given part of the spine. The second type of surgery is endoscopic foraminotomy. This type is used to relieve pressure on spinal roots caused by bone spurs, disk

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herniation, and scar tissue. The third type of surgery is endoscopic facet rhizotomy. This type of surgery revolves around deadening affected nerves in the spine that cause pain. The last type of surgery we found was lumbar laminotomy which is a non traditional surgery and treats spinal stenosis which is the narrowing of the spinal passage. By looking up all these types of surgery, we can get a better understanding of the procedures that might be used to practice on with our prototype [2].

We also looked up how surgeons put in the cannula. We did this because it is a very important part in spine surgery and even though we will not be focusing on it in our prototype, we wanted to understand how it works so we can adjust our design thoroughly. We learned that cannula placement is a minimally invasive surgery that has been perfected based on the x-rays, fluoroscopy, and many studies. The cannula then can be perfectly placed with enough room to allow the endoscope to slip in. [3] By knowing this, we don't have to adjust the hole for any other reason and we can make sure that the only thing we need is to make it big enough to fit the cannula and endoscope.

2.1.2 Design Research

First we did more research on the tools that the surgeons would be using with our prototype. It is assumed that the surgeons will have access to the tools that they would use during normal non invasive spine surgery when they are practicing. The endoscopes that may be used consist of two different types. One is a laparoscope (used inside an abdominal cavity) and the other is an arthroscope (used inside a joint). These endoscopes are typically 5-7mm without the use of a canula or 14-18mm if they use a cannula [4]. The other tools that are not necessary but may be used include the cannula, bevel, and surgical grabber. These were discussed by our client Dr. Brooks but the universality of our prototype usal with multiple different kinds of surgery leaves other tools as options as well.

2.2 Client Information

Our Client, Nathaniel Brooks, is a neurosurgeon that specifies in spinal surgery - more specifically. Those involving herniated discs and spinal tumors. He got his Phd at Medical College of Wisconsin, Milwaukee in 2002 and served a Fellowship in Cleveland Clinic Spine Institute [5].

2.3 Design Specifications

Dr. Brooks would like us to focus on three main surgical tasks to mimic in our design: sweeping away tissue, learning to target with an angled lens on the endoscope, and poking holes in membranes. He also mentioned that he would like us to focus on the tasks of the box as opposed to making it anatomically relevant in order to create a design that hones in on

reproducing the skills needed for endoscopic spinal surgeries. The box needs to be lightweight in order to be carried around and used anywhere and safe for the user through wear and tear. Please see the complete list of design specifications in our PDS found in Appendix A. Ideally, this box would be able to be replicated easily with materials found at a hardware store so it can be used globally given How To Guidelines from us. All of this needs to be done within our budget of $200.

The client also has a bonus design idea of eliminating the need for an endoscope in order to train with the box. Instead he would like to us to somehow incorporate a cell phone. Dr. Brooks is aware that this want could be a separate design problem on its own and may be left for future design groups to do due to time constraints of only a semester long project.
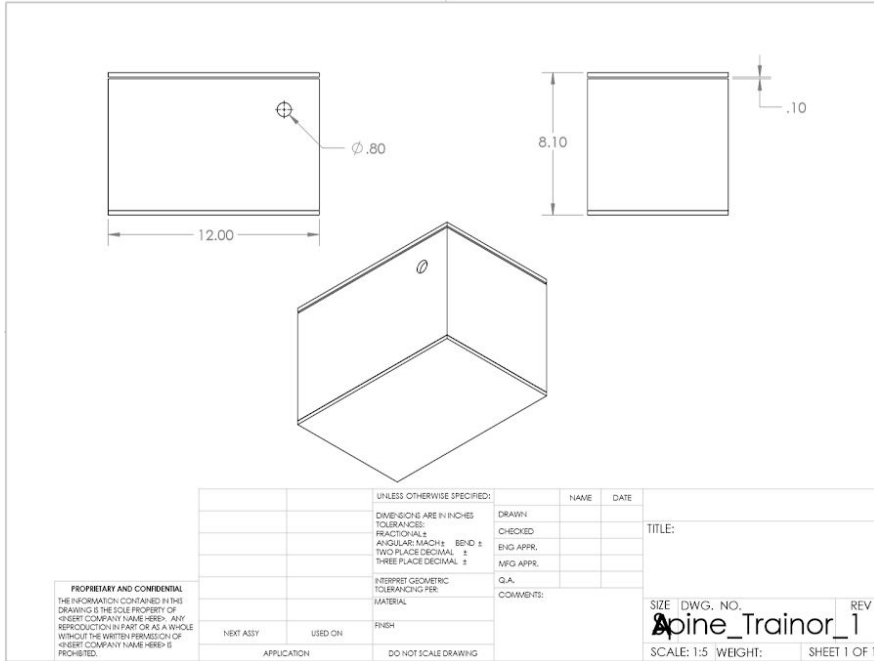
3. Preliminary Designs

3.1 Preliminary Designs

3.1.1 Interchangeable
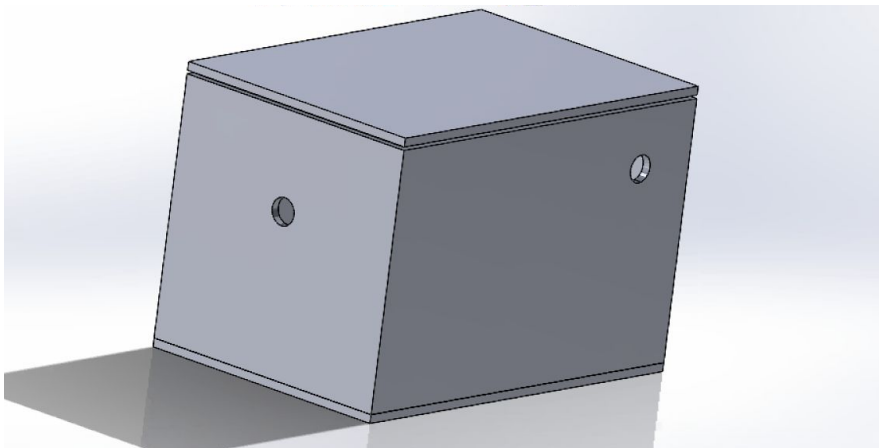
**Figure # 1:** Interchangeable design created in Solidworks.

Figure # 2: Dimensions/Schematic of the Interchangeable Design.

We will create one box that is specifically created for ease of access. We will do this by having hinges on the box that allows the whole inside of the box to be on view. This allows the user to interchange the inside of the box with different supplies which allows a surgeon to practice various types of surgery. It will we 8"x12"x8" as seen in Figure #2 and made of plywood to keep the box from being too heavy. It will have one opening that can be accessed by various tools as seen in Figure #1.

3.1.2 Comprehensive
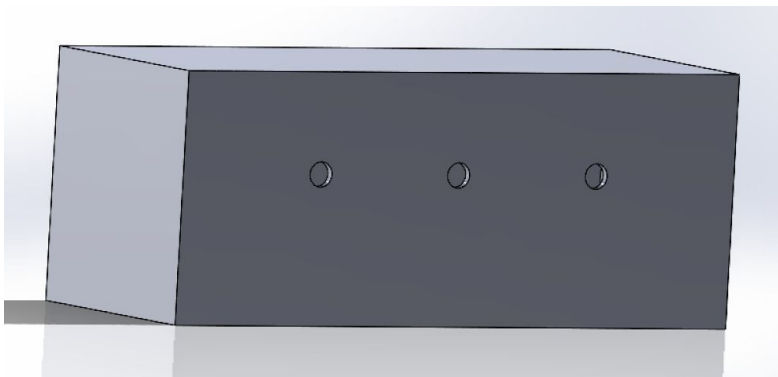
Figure #3: Comprehensive Design as a whole in Solidworks.
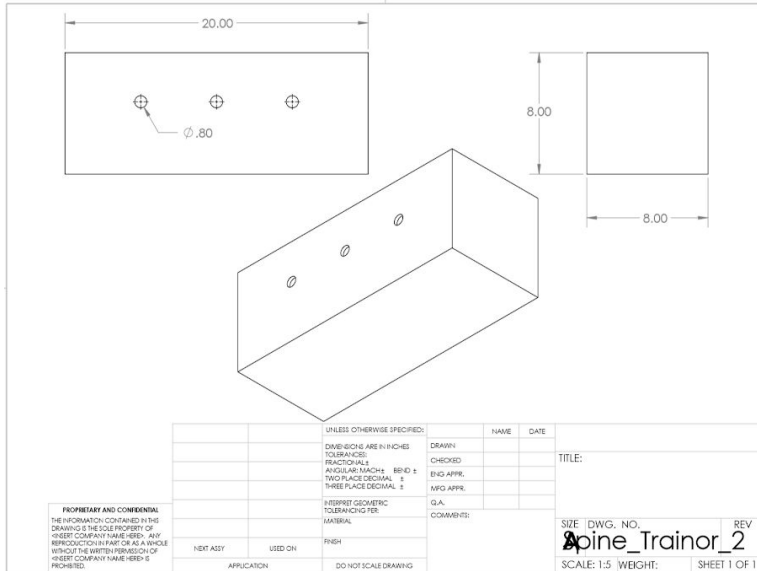
Figure #4: Comprehensive Design schematics in Solidworks.

This box will be our comprehensible box. Currently it will be 8"x20"x8", as seen in Figure #4, and made of plywood, but may be subject to elongation. It allows multiple openings to practice multiple skills at one with various tools. This will also include hinges for easy access. Having a set inside to the box for certain tasks will allow for easier substitutions of materials.

3.1.3 Separate
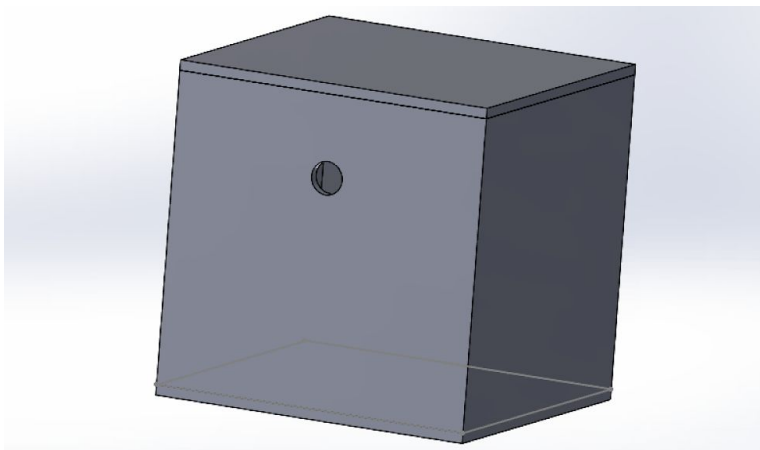
Figure #5: Separate Box Design created in Solidworks.
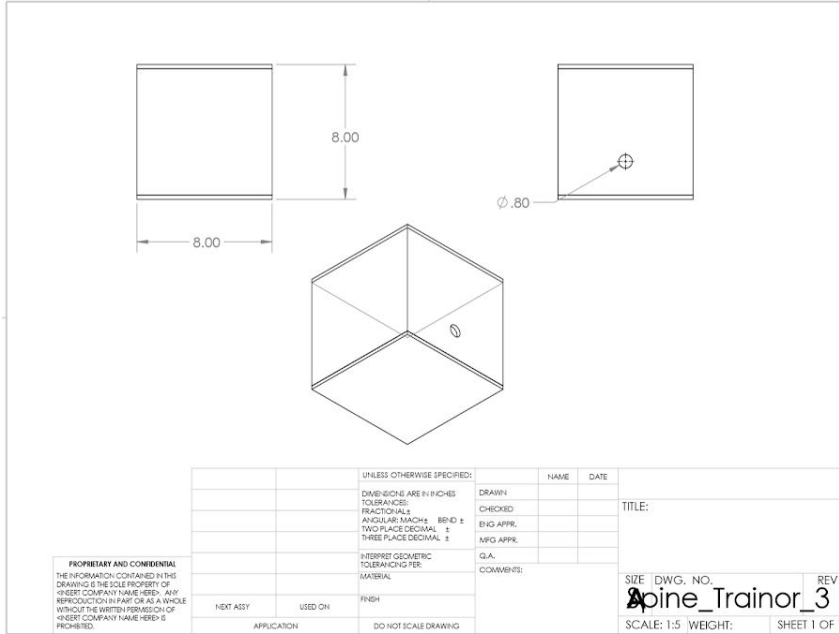
Figure #6: Separate Box Design Specifications.

We will create three boxes that have different tasks in each box. This would allow the surgeon to go back and forth from multiple tasks or be specific and practice only one at a time. Each box will we 8"x8"x8", as seen in Figure #6, and made of plywood to keep the box from being too heavy. Each box will also include hinges so someone can easily access the inside of the boxes. The multiple openings in the box provide access for the surgeons tools as seen in Figure #5.

4. Preliminary Design Evaluation

4.1 Design Matrix

	Design	Interchangeable	Comprehensive	Seperate
Criteria (weight)				
Degree of Accuracy (30)		18	27	20
Ease of Construction (20)		17	12	18
Translatability (20)		13	10	15
Ease of Use (10)		7	9	9
Materials (10)		8	8	8
Time (10)		7	6	8
Total (100)		70	72	78

4.1.1 Summary

The design matrix we created has six criteria in descending order of importance to our design. Each criteria was weighted appropriately so that the more important criteria have precedence over the others. Typically safety is the highest design criterion but the safety of all three designs are comparable. Therefore, degree of accuracy was weighed the highest because the main purpose of our spine trainer is to adequately prepare the surgeon to carry out the necessary tasks of minimally invasive spine surgery. This criterion refers to the accuracy of the surgical task, not the anatomical accuracy. Ease of construction and translatability were weighed highly as well because our client specifically stated that he wanted this trainer to be able to be built by any hospital employees anywhere in the world. In order for that to be a priority we made sure that our proposed final design was simple and easily understood by any professional. Ease of use, materials and time were weighed the lowest because they are the criteria that we believed were the least critical to our proposed final design. Ease of use involves how simple the design is to actually practice the required skills on. Materials are the elements required for the construction and upkeep of our design throughout its lifetime. Finally time is just how long we believe this design will take to formulate and how long it takes to reset after each completion of the required task.

After we discussed each criterion of the design matrix as a team we assigned values for each criterion for all of our three designs. The design with the highest value for each criterion is highlighted in green as well as the design with the overall highest score. The values are somewhat arbitrary, however, we know what each design would look like and therefore we were able to assign the values accordingly. For degree of accuracy the comprehensive box scored by far the best as it would do the best job at accurately representing and testing all the tasks required in an endoscopic surgery. For ease of construction and translatability the separate boxes design scored the highest because it is the most simplistic design. This allows it to be the most easily replicated compared to the interchangeable (which requires complex construction of removable tasks) and the comprehensive (which requires a complicated setup of the materials inside the box as all of the tasks are involved). The interchangeable box design scored lower than the other two designs in ease of use as the user must swap out the setup for each different task they would like to complete. All designs scored the same for materials as they all require almost the exact same amount of materials to construct and reset. Finally the separate boxes design scored the highest in the time criterion. Since all the designs will take a similar amount of time to build, the deciding factor was that the separate design takes the least amount of time to reset as each task is kept separate.

4.2 Proposed Final Design

       Based off of the results of our design matrix we have decided to focus our attention on the separate boxes design as it scored the highest overall and scored the outright highest in the most criteria. This design scored the highest in all but the degree of accuracy which is our most important criterion, but it still does a good job at replicating each task separately. We will now talk to our client about our chosen design and confirm that he agrees we should formulate the separate boxes design.

5. Discussion

       While we have not begun testing our product, we have been able to use our time to focus in on exactly what we are designing and how that will fit the needs of our client. Initially we created a design matrix that focused on three specific endoscopic spine surgeries and how each of our different box designs would accurately replicate them. After meeting with our advisor we worked through changing our design ideas to focus on tasks, techniques, and accuracy. Ultimately, our design is meant for surgeons to practice and perfect the techniques used in endoscopic surgery. For our purposes, the anatomy of a spine and all of its surrounding parts are not of importance and because of this our design not only aids practicing neurosurgeons but also any surgeon practicing endoscopic surgery techniques.

6. Conclusions

       With the growing field of endoscopic spine surgery, there is also a growing need to train neurosurgeons in this field. Simulators exist today to help with this need; however, they are very expensive and not accessible to most practicing surgeons. For this reason we are designing a low cost simulator for practicing the fundamental techniques and coordination necessary for endoscopic spine surgery. Thus far, we have solidified three design ideas and are planning on confirming a final design choice with our client in the near future. Once we have confirmation we will formulate a design plan so that we can begin fabrication as soon as possible. Before we consider our design complete, we plan on testing our prototypes in lab at the University Hospital where we have endoscopic surgical tools available to us to analyze how well our design is able to fit its purpose and enhance our design as needed.

7. References

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 [3] "Journal of Spine," *Omics*. [Online]. Availible:
https://www.omicsonline.org/open-access/a-new-progression-towards-a-safer-anterior-percutane ous-endoscopic-cervical-discectomy-a-technical-report-2165-7939-1000329.php?aid=78246 [Accessed: 01-October-2018]

[4] "Minimally Invasive, Endoscopic, and Laser Spine Surgery: Facts & Fiction," *Paul Jeffords, MD*. [Online]. Available:

https://www.pauljeffordsmd.com/minimally-invasive-endoscopic-and-laser-spine [Accessed: 05-October-2018].

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8. Appendix

   A. PDS:

Preliminary Product Design Specifications
Design of a Spine Trainer

Client: Dr. Nathaniel Brooks

Advisor: Walter Block

Team: Shannon Sullivan - Team Leader
        Yoon Cho - BPAG
        Austin Gavigan - BWIG
        Madison Hodgson - Co-Communicator
        Katarina Martinet - BSAC
        Sophia Nehs - Co-Communicator

Function: Minimally Invasive Spine Surgery is becoming more commonplace; however, there is minimal opportunity in spine surgery residency for neurosurgery and orthopedics training because the tools that are used for these procedures are significantly different from the standard procedures performed today. There is a need for a low-cost simulation environment to be developed to provide spine surgery trainees with the practice and training space to develop the fundamental scope-handling and manipulation skills necessary to perform minimally invasive endoscope based surgical treatments. Ideally, it will be made with simple materials to allow for its building and use globally.

Client Requirements:
- Low-tech design with simple materials available at any hardware store
- Mimic the targeting with the angled lens on endoscope, sweeping away tissue, and poking holes through membranes as tasks to train hand-eye coordination surgical skills
- Create a how to for creating the box and setting up the surgical spine training tasks
- Base on an air-environment
- Focus on tasks for surgical skills and not the anatomy
- No 3D printing allowed

Design Requirements:

1. Physical and Operational Characteristics
   a. *Performance Requirements:* Must be able to use the box for practice of each surgical task up to 50 times.
   b. *Safety*: Must prevent injuries to the user as the product undergoes wear and tear from the surgical tasks training.
   c. *Accuracy and Reliability*: Must never break during use.
   d. *Shelf Life:* Our goal is for the box to be used by one person for a year prior to needing to buy more materials in order to replace those used for training.
   e. *Operating Environment:* The product must be able to be used with an endoscope for surgical practice or with a lens extension off of a cell phone if the product is updated.
   f. *Ergonomics*: The product should be comfortable enough for the user to carry, place down, and use without causing any more stress to the body during training the surgical tasks than a typical spinal procedure would.
   g. *Size*: The box must be 8in x 6in x 12in to allow for training use with multiple depths.
   h. *Weight:* Must not exceed 5 lbs in weight
   i. *Materials:* Materials must be simple and durable. The materials must be bought from a hardware store and allow for easy assemble of the box. The materials must also allow for training tasks at multiple depths.
   j. *Aesthetics, Appearance, and Finish*: Aesthetics are not a main concern, but the product must still look professional.
2. Production Characteristics

a. *Quantity*: Three boxes each with different insides that would help simulate different surgical environments. Each box would have a different surgical task inside.
　　　b. *Target Product Cost*: The product must be built under our $200 budget.
3. Miscellaneous
　　　a. *Standards and Specifications:For our project we don't expect to run into any problems with international or national standards. All of our resources we are using in our prototype are specifically chosen to be easy to use and make.*
　　　b. *Customer: Trying to reach out to Dr. Brooks currently so we can successfully fill this section out.*
　　　c. *Patient Related Concerns: Not applicable, the product just needs to be safe to the user training.*
　　　d. *Competition: There are high tech versions of spine simulators that already exist, one example is the SPINE MENTOR. This simulator has the appearance and feel that goes along with minimally invasive spine surgery. 3D printing was used to make the simulator appear realistic and virtual reality technology was used to show surgeons exactly what they were doing inside the simulator.*