Project Number: <ME-ECC-A901>

REDESIGN OF A DENTAL MIRROR CLEANING DEVICE

A Major Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

in Mechanical Engineering

by

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Date: April 26th, 2010

Approved:

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Keywords
1. Mouth Mirror
2. Cantilever Beam
3. Biomedical Engineering
4. Mechanics

Abstract

The current method for cleaning dental mirrors during use is disruptive and inefficient; our goal was to improve upon a previous design for a cleaning device that would allow for the mirror to be cleaned while still in use, eliminating the need to stop and clean the device by hand. We also attempted to fix some of the flaws of the earlier design, such as issues with the mirror's visibility, slippage, and hindrance. We developed a new prototype which featured increased visibility and efficiency.

Acknowledgements

We would like to acknowledge the numerous people for their help and contributions to our MQP.

Professor Eben Cobb, Ph.D.: our project advisor whose advice and support we would not have completed this project without.

Lisa Anderson, C.D.A.: our project sponsor.

David Nill & Nicholas Careau: the previous MQP team whose work we expanded upon

Russell Morin: the WPI Design Studio technician who assisted us with the rapid-prototyping process.

Dr. Michael Koprowski, D.D.S.: a family dentist who provided us with a dental mirror and insight into its use.

Mrs. Elizabeth Matrow: a speech/language pathologist who supplied us with samples of and recommended biocompatible materials.

The WPI Mechanical Engineering Department.

Authorship

This section is devoted to breaking down this paper and the accompanying body of work based on the primary author of each section.

Elizabeth Ray was the primary author for the abstract, initial acknowledgements, introduction, background and the initial results and conclusions sections. Ms. Ray also developed the initial design sketch #1.

Robert Matrow was the primary author for the nomenclature, design, and iteration process sections, and was responsible for editing and formatting the final paper. Mr. Matrow also developed the initial design sketch #2 and developed all subsequent CAD and SolidWorks models and drawings used for this MQP, including those used to create the prototypes.

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Nomenclature

CAD: Computer-Aided Design

SolidWorks: The primary CAD software used for this project.

RP Machine: A Rapid-Prototyping machine which uses ABS plastic to produce quick and inexpensive models.

Dental Mirror: a.k.a. mouth mirror; the small mirror used by those in the dental profession for viewing within the patient's mouth.

Biocompatible Material: any material suitable for use in contact with living tissue that does not have any severe negative effects to such tissue.

Autoclave: the sterilization unit used by dentists to clean tools between uses.

Introduction

Dental mirrors are an essential tool for any kind of dental procedures, whether it is a simple cleaning or a full-on operation. The mirrors are used not only to see the teeth and aid the dentist and assistants with visibility, but also occasionally used to hold the cheek back during certain procedures. They are an extremely vital tool, but too often the mirrors become dirty with debris or misty with liquids, which is where the need for a dental mirror cleaning device arose. Dentists frequently need to stop a procedure in order to clean off their dental mirror, which not only disrupts their work, but is also highly unhygienic, as the dental mirror invariably is simply wiped off on not sterile cloths.

For this project, the goal was to re-design a dental mirror cleaning device, one which would help to eliminate the problems described above; it would allow for the user to easily clean the mirror without having to pause during a procedure and possibly contaminating the mirror at the same time.

Background

Before we began to draw up design plans for a new cleaning device, we first looked into a variety of fields to get an idea of what things we would need to be thinking about while creating designs. Our group spent a fair amount of time researching not only the previous MQP group's design, but we also researched designed that are patented and currently on the market. We wanted to look at these designs and determine what advantages and disadvantages there were to each of them, hoping to base our design off the conclusions we drew from looking at those designs.

Material selection was a very important pre-design process. We knew that the material would need to fit certain design specifications (such as flexibility, durability, and the ability to withstand autoclaving) and considered what kinds of materials had the most desirable properties. The process of selecting the right material was important, because our designs would rely on what the materials could and could not do.

Few calculations needed to be made; the friction force between the wiper and mirror was negligible, as was the friction force between the handle and the cleaning attachment. Since we knew the design would basically act as a Cantilever beam, we had to do some calculations in order to determine maximum deflection, which will be discussed later.

Researching the Previous MQP

A previous MQP group had designed the first prototype of the dental attachment. During a trial period it was found that the mirror suffered from many disadvantages and failed in certain important areas.

The most significant failure of the attachment device was that it was much too large, and its bulky design obstructed the user's view of the mirror. In this design, the device also only attached to the thin neck of the mirror and not the handle. This was problematic and caused issues during operation; the device would frequently slip and go off track, thus making it more difficult, if not impossible, to properly clean the mirror. The old device also suffered from not being able to withstand cleaning; an autoclave runs at 30PSI for approximately 35 minutes at a temperature of 275 °F. Under these conditions, the device melted. This was due to the fact that the device was designed only with ABS plastic (which is used in rapid prototyping) in mind. ABS plastic does not fit the desirable design requirements; hence, the device melted and warped.

Figure 1: Previous MQP Design

It was concluded that the previous prototype was a failure in many areas, and thus our group set about establishing a series of design specifications that our new design would have to meet. We based some of these design specifications off of the previous MQP design, in an effort to hopefully correct many of the issues with the old design. Our main priority in designing a new device was to minimize the size of the attachment as much as possible. We focused on ways that we could both improve the visibility of the mirror and decrease the slippage of the device while in use.

Researching Currently Marketed Designs

For background research, we began to look into some of the current, patented dental mirror cleaning devices. We wanted to get a sense of how other people had approached the problem and see if we could work to find a way to combine certain desirable properties from these and the previous MQP design to create a completely new device which would fix our project specifications.

The two previously patented designs that we looked at both involved self-cleaning dental mirror devices. Both designs proposed attaching nozzles to the mirror to allow water and air to be siphoned across the mirror's surface in order to clean it. The mirror would be attached to air and water supply streams that are normally used during cleaning or operation. Looking at these designs, we saw that both of them called for a complete redesign of the dental mirror by widening the handle to allow for the water and air streams to be placed inside.

This was problematic because we did not want to redesign the dental mirror *itself*, but rather, design an attachment. The other problem with the current patented designs was that they siphoned water into the mouth, which is already done through the use of another piece of dental equipment; we felt that it was completely unnecessary to have two streams of water being directed into the mouth at once. [9, 10]

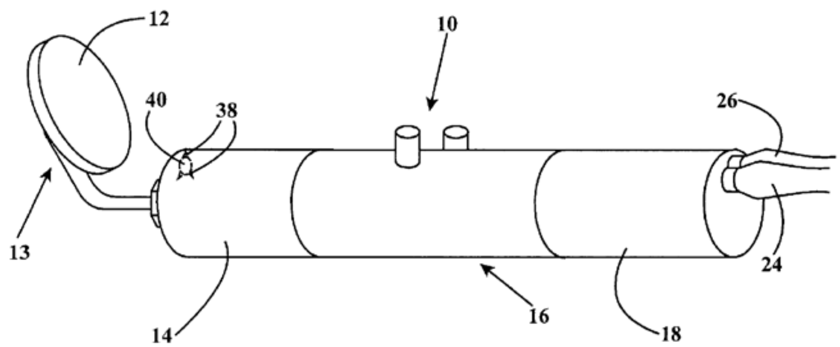

Figure 2: Patented Self-Cleaning Mirror Design [9]

Looking at these patents and the previous design, it became clear to us that we would need to come up with a completely new design for the dental attachment, as nothing else came close to filling our design specifications.

Material Selection

We knew that the device would need to be designed with certain materials in mind, as the device would need to be to withstand autoclaving. We looked into different types of materials and their properties to find the best fit. Originally we wanted the attachment to made with stainless steel, as that is the kind of material used for regular dental tools and we knew it would be able to withstand autoclaving conditions. However, our group realized that in order to get the proper flex of the device, the material would need to be very thin and a thin piece of steel could create sharp edges and be potentially harmful to both the user and patient. Finally, we decided that the device would have to be made out of a safer material, such as plastic.

We began looking into types of materials that could be used in our design. Using CES Selector, we were able to narrow the search down to a few different types of materials given the design properties we were looking for. The most notable materials that we found were Polyethylene terephthalate (PET), Polycarbonate, and Polyamides (such as nylon or aramids).

PET, which is used in soda bottles, was strongly considered by the group, as it had the most desirable traits among all three materials: a low Young's modulus, extremely cost-efficient, recyclable, and with a high melting point. However, the drawback to PET is that it has been known to be a health hazard; it releases endocrine disruptors under common conditions, and the risk of leaching increases as a function of temperature. Because of the potential health issues, PET was ruled out as a suitable material.

Next, our group looked at Polycarbonate, which is used for a wide variety of purposes, including drinking bottles. Like PET, Polycarbonate had many of the desirable traits that we were looking for in a suitable design material, but it was lacking in the most important area: its melting point was much too low. The melting point of Polycarbonate is 267 °F, while the minimum heat dental tools are autoclaved for sterilization is 275 °F. Being able to withstand autoclaving was one of the most important design specifications of this device, so Polycarbonate was subsequently ruled out as a viable material to use.

Our group then researched Polyamides, such as Nylon, which features a high melting point (approximately 374–663 °F) and a relatively low Young's modulus (approximately 290-580 ksi). It is also recyclable and very cost-efficient, which were two other advantages of this material. Since Polyamides are used for things such as toothbrush bristles, we knew that it would be completely safe to use. Unlike PET, Polyamides do not have any harmful health-related side effects, and unlike Polycarbonate, Polyamides have a very high melting point, which made it much more desirable a material to use. Although Polyamides had the highest Young's modulus, this is a trait that can be reasonably neglected, given the small size of the cleaning attachment.

From all of this we were able to determine that a Polyamide material (for example, Nylon) would be the best suited material to use in the design of this device if it were to be manufactured. It has the properties to not only withstand being autoclaved, but is also durable enough to withstand constant use.

Calculating a Cantilever Beam

In order to get an idea for the amount of bend we would need for the device, we calculated the maximum deflection using the equations for Cantilever Beams.

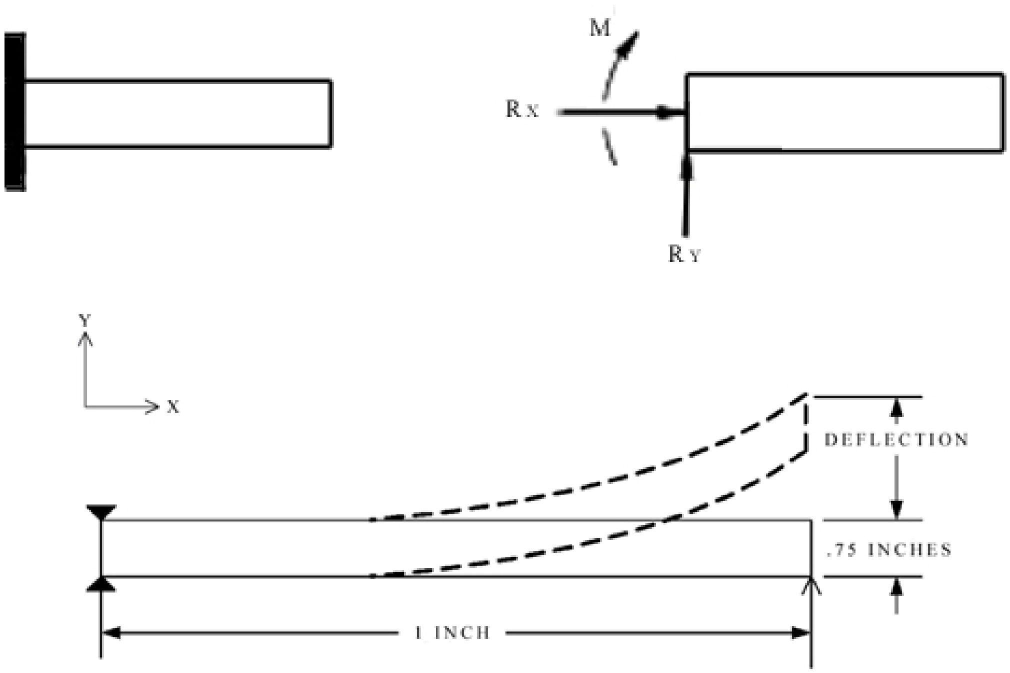

Figure 3: Cantilever Beam Free Body Diagrams

We calculated the maximum deflection of the beam through a series of equations. The first thing we did was calculate the force, using the following equation:

$$P = (\delta_{max3}EI) / l^3$$

Where P was the concentrated load at the free end, E was the beam's elasticity, I was the moment of inertia around the beam, was distance between the handle and the top of the dental mirror, *l* was the length of the device, and δ_{max} was the maximum deflection. Solving for P, we were then able to use the deflection angle equation:

$$\theta = Pl^2 / 2EI$$

We used these equations to find the angle of deflection of the device for the different iterations. Substituting in the correct values from the Second Iteration into the equations, we found that the force (P), was 5.805 lbf and that the angle of deflection (θ), 64.458°. The applied force for the Second Iteration was nearly 6 lbf using ABS plastic, which was much too large of a number. The angle of deflection was also quite large, being calculated at approximately 65°.

The Beta Assembly, which was also designed from ABS plastic, presented much lower calculated values of both force and angle of deflection. For the Beta Assembly using ABS plastic, we found the P = 0.019 lbf and the angle of deflection was 16.114°. When we calculated the Beta Assembly using a Polyamide material (i.e., Nylon), we found that P = 0.103 lbf and the deflection angle was 18.357°. These results were slightly higher than the results calculated from the same design using ABS plastic, but were much lower than the results from the Second Iteration (ABS plastic). The results were lower due to design changes in the length of the device.

We finally calculated the force and angle of deflection for the final design, using both the values for ABS plastic and the values from a Polyamide material. When calculating the force and angle of deflection for the final design using ABS plastic, it was calculated that P = .135 lbf and the angle of deflection = 18.417°. We substituted in the values for a Polyamide material, we found that P = .154 lbf and the angle of deflection was 20.979°. We thus determined that the maximum deflection of the beam would be approximately 21°, as a Polyamide material would be best suited for the device.

A complete collection of the calculations used to determine the values described in this section can be seen in Appendix C: Cantilever Beam Calculations.

We knew that we would need to be able to achieve this maximum deflection, and thus were able to determine more criteria to be added to our list of design specifications: length and thinness. After obtaining all the necessary information, we were able to begin to move forward and start to come up with some preliminary design sketches.

Design

The goal of this project was to design a cleaning attachment for a dental mirror. Since we were not the first group to do such a project, we used the previous team's work as a starting point for our own designs. The previous design had the flaw of being "too large" which "obstructed the operator's view of the dental field." It was from these critiques that we began the redesign process.

Initial Designs

Our primary desire was to develop designs which would hold the attachment better to the tool but would at the same time reduce how much the attachment obstructs the mirror. After a period of concept discussion and basic sketches we produced two distinct designs.

Design #1

The first proposed design took a different approach to cleaning the mirror surface. The sketch of design #1 can be seen below in Figure 4. Instead of the cleaner attaching to the top surface of the tool, it would clip to the side which would increase the view of the mirror when looking at it straight on. With this design, the operator would apply pressure to Point A which would move the wiper across the mirror to Point B. Once the pressure was removed from Point A, the spring arm would return the wiper to Point C. This design is akin to a windshield wiper on a car, with the same benefits and detractions. The key benefits are that neither the wiper nor the main body of the attachment blocks the view of the mirror. On the reverse, the main detractor for this design is the necessity to have constant pressure applied to prevent the wiper from streaking. Also, this is a complex design requiring numerous pieces with tight prototyping tolerances, all working in series.

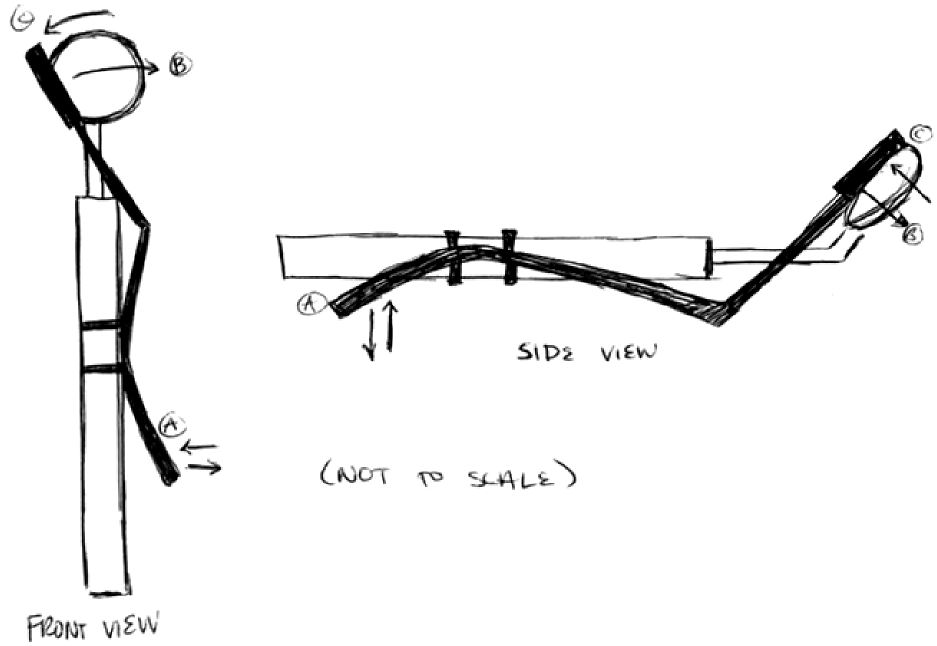

Figure 4: Original Sketch of Design #1

Design #2

The second proposed design took the original approach to the cleaning of the mirror. The original sketch for design #2 can be seen below in Figure 5. Like the design presented by the previous MQP team, this design attaches to the top of the mirror handle. This design is two main components, the carrier and the shunt. The shunt is the long component that contains the wiper blade and slides along the tool. The carrier connects the shunt to the tool, and keeps the shunt oriented with the mirror surface. When a forward force is applied at Point A of the shunt, the wiper is pushed up the surface of the mirror to Point B. When a backward force or pulling action is applied to Point A, the wiper retracts to Point C. This design is akin to a squeegee with a linear motion rather than the rotational motion of a windshield wiper. The benefit of this design is its simplistic motion and that it only features two components. The detraction however is that the main shaft of the attachment will need to be flexible enough to allow for it to bend to clean the mirror yet at the same time apply enough force to ensure a proper cleaning. Additionally the attachment affixes to the top surface and therefore has the potential to block the view of the mirror, so to counteract this detraction; the size of the attaching components will be minimized for the purpose of optimizing the visibility.

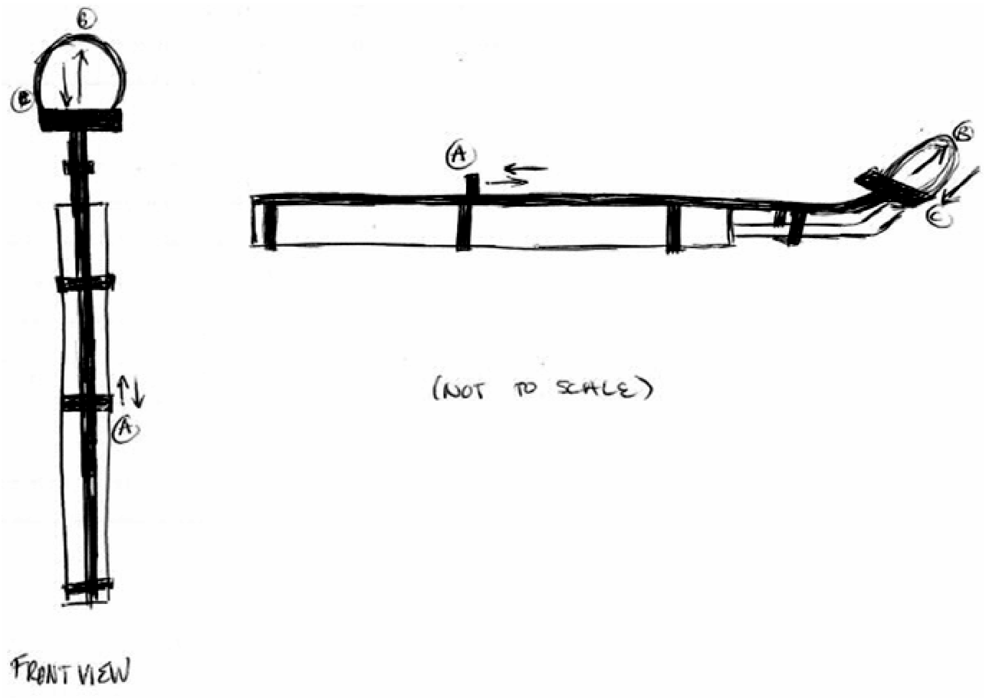

Figure 5: Original Sketch of Design #2

Design Selection

As a team, we decided that it would be in our best interests to focus on a single design. For this reason we began to determine which of the initial designs would be best to have as our primary design. The first step in this decision process was to refine the designs and create CAD model versions of them.

Design #1's complexity proved to be a challenge to model with our level of experience with SolidWorks. The determining of the dimensions for the spring-action wiper arm was riddled with difficulties because of the limitations of the dental mirror and how and where the attachment would be connected to the tool. We understood that a design that was difficult to model would be just as, if not more, difficult to construct. Additionally, after observing how the mirror is held by the operator and the positioning of the mirror with the patient's mouth, we determined that the side-mounted approach was not feasible.

Design #2's more simplistic nature was much easier to model. The basic motion meant that more efforts could be focused on determining the dimensions and refining the shape. The SolidWorks model of Figure 6 shows how the carrier was simplified to connect at a single location on the neck of the tool. Additionally, one can see how the single raised rib has transformed into a raised section with cut grooves.

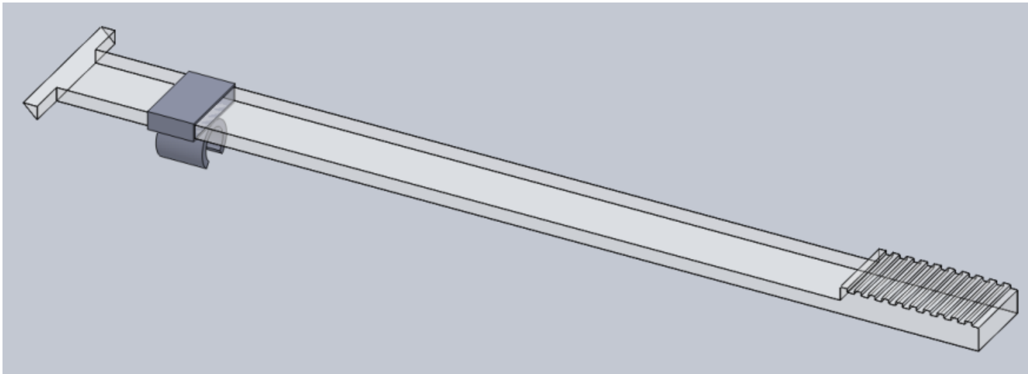

Figure 6: Design #2 Initial SolidWorks Model

After comparing the revisions and discussing the benefits and disadvantages of the two designs, we decided to focus on using design #2 as the base for the next iteration.

The Iteration Process

The next step in the design process was to analyze the existing design to determine and then repair any major faults. Following that, the new design would be tested and then scrutinized with the endeavor of producing a superior design. To assist with the iteration process, we acquired a dental mirror and used it as the base for our following designs. A SolidWorks mock-up of the mirror can be seen in Figure 7.

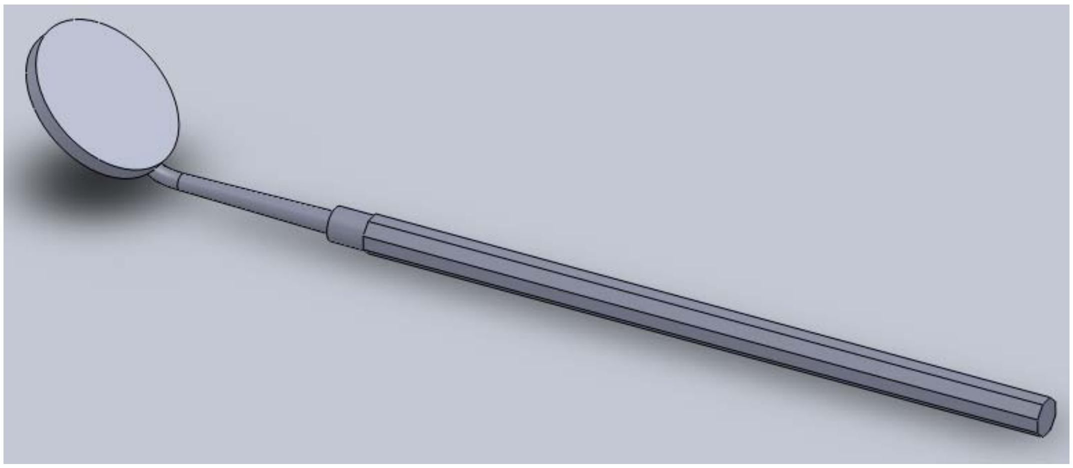

Figure 7: Dental Mirror

Second Iteration

The second iteration was the next step in the improvement of the determined initial design. We also planned to have it serve as the first physical prototype which would allow us to better analyze the design before then making more improvements.

To determine the second iteration, we first looked at the carrier for Figure 6, which can be seen exclusively in Figure 8. This design is simply an oblong top section which connects to the shunt and the round lower section which connects to the neck of the mirror. A major point of concern with this design is the tangential connection between these two sections. We determined that the best way to improve this flaw would be to increase the area of connectivity between these two sections. Another noted flaw was the thinness of the top section which was too small to be rapid prototyped accurately. This was simply improved by increasing the thickness of that area. The length of the piece was also decreased to allow for better bending of the shunt.

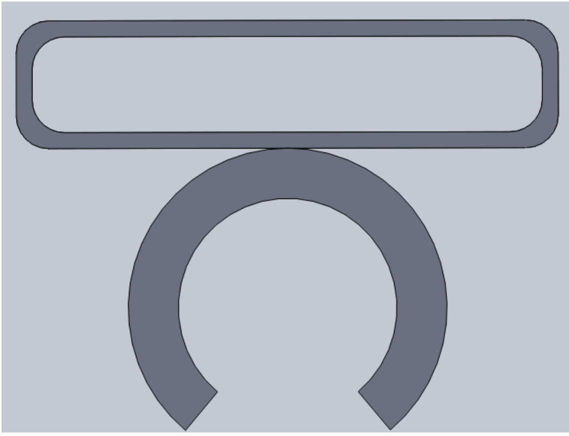

Figure 8: Design #2 Carrier

We then implemented the aforementioned changes and created an updated carrier component, as seen in Figure 9. This iteration functions in the same what that the initial design did but features the desired improvements and fewer curves which were removed to improve the ease of prototyping.

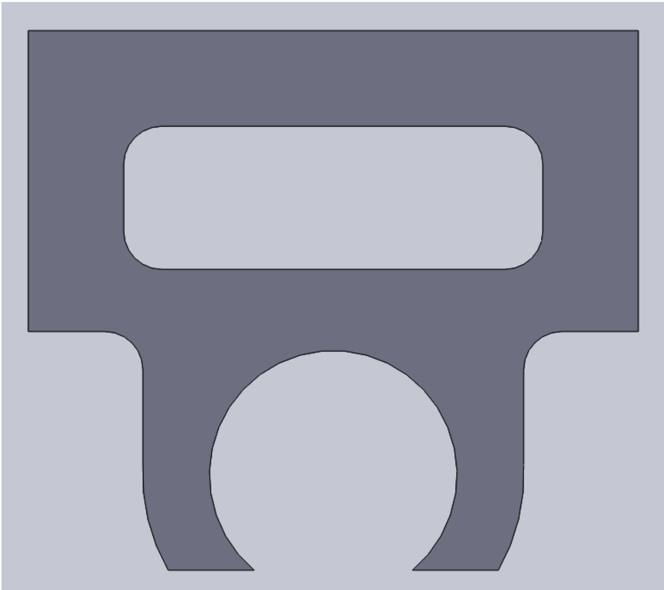

Figure 9: Second Iteration Carrier

We next set about implementing changes to the shunt component of the attachment, seen in Figure 10. One aspect of the initial shunt component design which we sought to improve was the raised section with cut grooves used to manipulate the shunt. It seemed to be a waste of resources when the same feature could simply be implemented into the main body of the shunt without any major disadvantages.

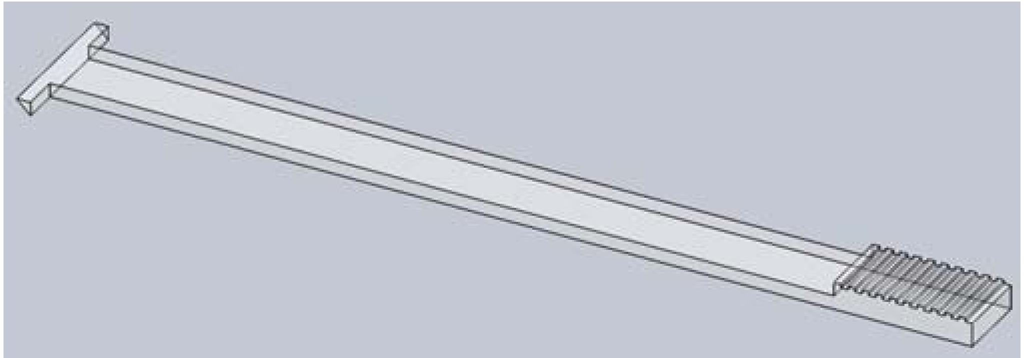

Figure 10: Design #2 Shunt

Another concern with the initial design was the possibility for the attachment to rotate around the neck of the tool disturbing the alignment. We saw no way to easily correct this problem by modifying the carrier so we instead edited the shunt. The mirror that we acquired, Figure 7, featured an octagonal handle and it was this geometric characteristic that we choose to use to ensure alignment. We decided that adding an octagonal section to the underside of the shunt would hold it in the desired position without interfering with the operation of the attachment. We chose to decrease the width and thickness of the shunt to allow for a better bend to clean the mirror surface. We applied these changes to the initial shunt design and created the second iteration shunt, Figure 11.

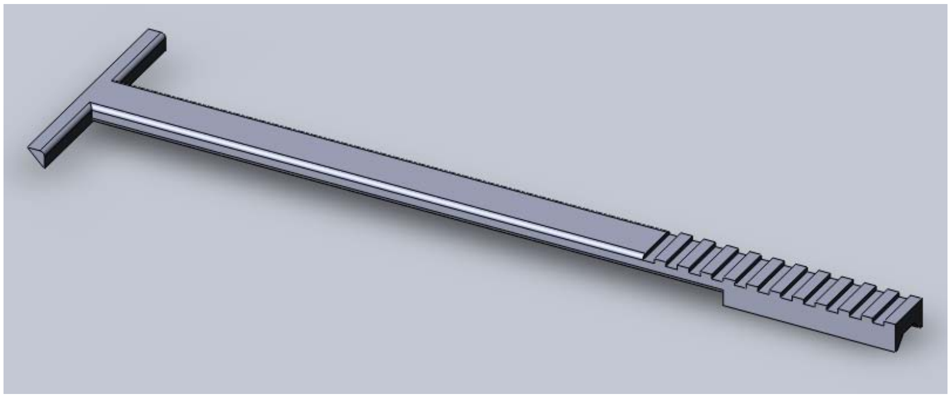

Figure 11: Second Iteration Shunt

Second Iteration Results

Once the designs had been reworked and new SolidWorks models had been created, we called upon the assistance of Russell Morin to have the parts rapid prototyped. Due to the geometries of the parts, they needed to be manufactured together since there would be no other way to attach the two parts. We therefore used the assembly seen in Figure 12 to create the prototyped part.

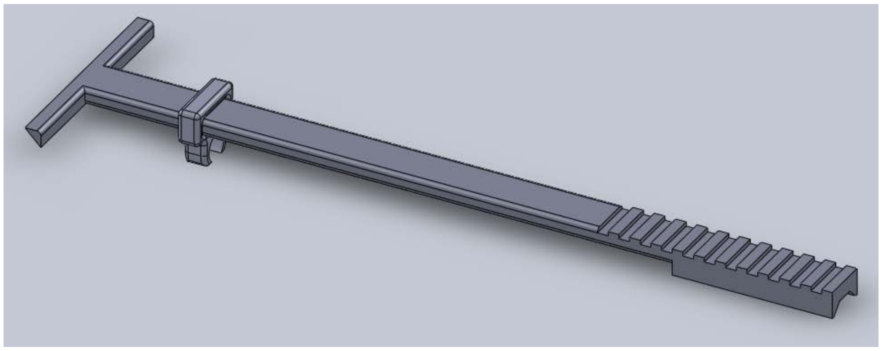

Figure 12: Second Iteration Assembly

Once the part had been prototyped we tested it by attaching it to the mirror. This seemingly simple act of usage produced considerable results. While attempting to position the attachment onto the desired location on the neck of the mirror, the carrier fractured. The two fracture points, red being the first and purple the secondary, can be seen in Figure 13. The red fracture occurred when pushing the carrier up the tapered neck, the increasing diameter of the mirror affecting the fixed diameter of the carrier. We desired for there to be force holding the carrier in place, but the force was too great for this design. The purple fracture occurred when the carrier was pushed further up the neck after the initial fracture.

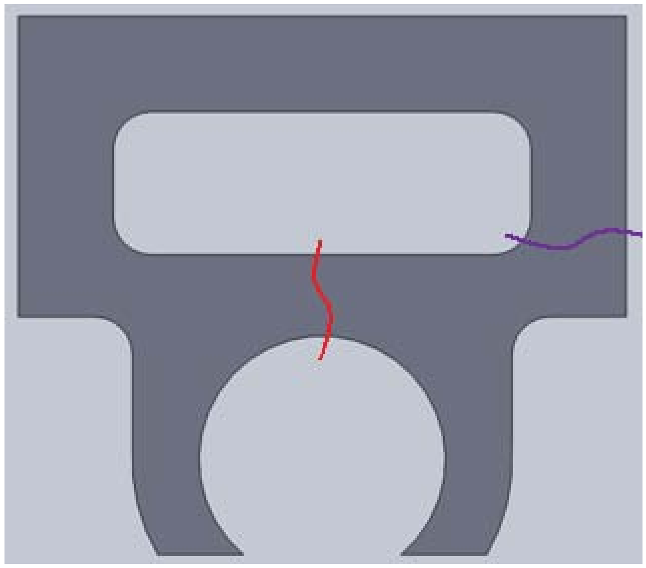

Figure 13: Fracture Lines on Second Iteration Carrier

We also realized that the current positioning of the wiper end of the shunt was not positioned properly for sliding up the mirror but instead would collide with the base of the mirror surface. The positive outcomes of this design were that we determined the key points of failure, making the direction for the next iteration that much clearer. Additionally, the octagonal section on the shunt worked superbly in preventing the attachment for rotating about the tool. The cut grooves for shunt manipulation were of sufficient size and placement for ease of use, yet the overall length of the shunt seemed too small when held with the tool in one's hand. A photograph of this iteration and the fracture of the carrier can be seen below in Figure 14.

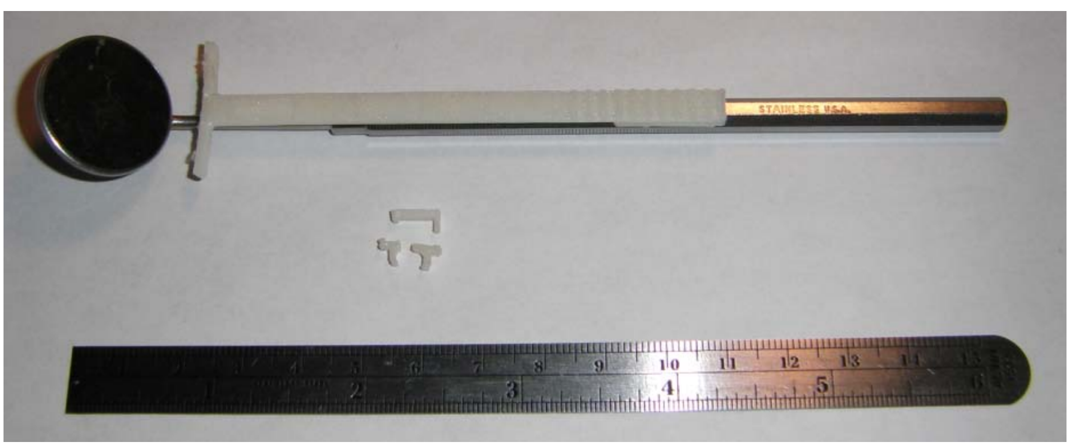

Figure 14: Photograph of Second Iteration Prototype post-fracture

Third Iteration

Following the success and failure of the second iteration, we began work towards the third iteration. This iteration went in two distinct directions; the first, Three Alpha, focused primarily on fixing the failures of the second iteration while Three Beta took the approach of removing those points of failure and modifying the successful aspects to accomplish the same ends.

Three Alpha

For Three Alpha we decided to use what we had learned and approach the attachment in a slightly different direction. Instead of manufacturing the wiper and shunt as one piece, the approach of it being two separate pieces that were then joined using an adhesive has used and then assembled. This would also mean that the attachment could be manufactured as three separate parts. The wiper would also need to be larger to allow for a greater area on which the wiper blade could be attached and to prevent the collision with the mirror surface by having it positioned initially on the very bottom of the mirror. The wiper in Figure 15 features approximately 200% of the original surface area, an improved angle to better interact with the mirror surface, and an extrusion by which to connect to the shunt.

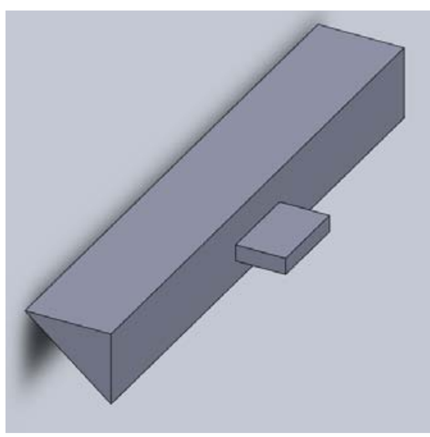

Figure 15: Iteration Three Alpha Wiper

As discussed earlier, there were a number of improvements to be made to the shunt. The length was extended for greater ease of use, the grooves were adjusted in quantity to better suit the extended length, and a notch was added to accommodate the extrusion of the wiper. The size of the notch is slightly greater than that of the wiper extrusion of allow for proper adhesion. Since this wiper design has initial contact with the mirror surface, as mentioned above, the need for alignment is reduced. It was because of this that we decided to remove the octagonal section on the underside of the shunt so as to improve manufacturing. This modification and the separation of the wiper from the shunt allowed us to re-orient the piece for manufacturing. This rotation of the part within the rapid prototype machine causes a change in the striation alignment which imbues the part with an increased bending strength. The Three Alpha shunt is seen below in Figure 16.

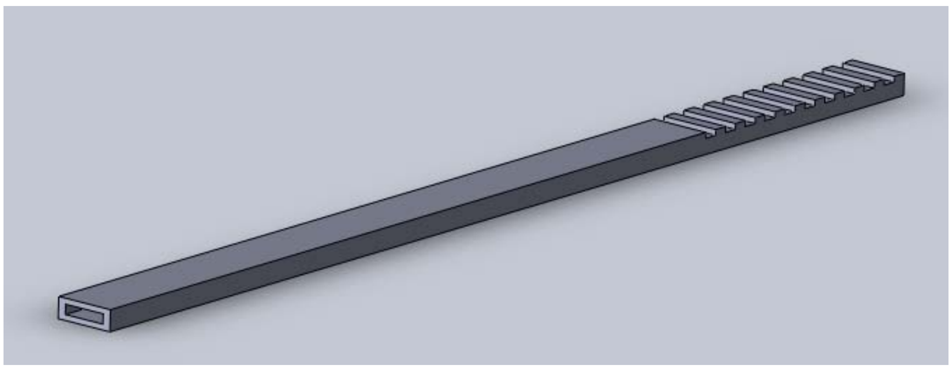

Figure 16: Iteration Three Alpha Shunt

Another way that this iteration took a different approach than previous iterations was that in regards to the carrier, minimizing the material used became a secondary concern. The second iteration carrier had failed due to its thinness in certain regions and the force-based attachment method. As seen in Figure 17, we altered the force-based attachment so that is would fully enclose the neck of the mirror. The diameter of the carrier hole was designed to be two thousandths of an inch smaller than the maximum diameter of the mirror neck with the hope of this creating a snug fit. The thickness of the failed regions was increased to prevent any future fractures.

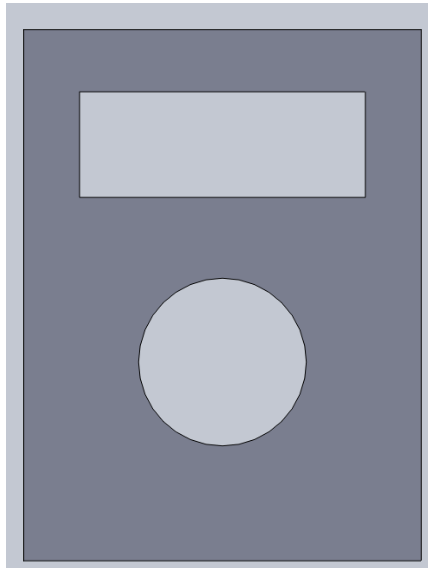

Figure 17: Iteration Three Alpha Carrier

Three Alpha Results

Once the designs had been reworked and new SolidWorks models had been created, we again called upon the assistance of Russell Morin to have the parts rapid prototyped. Since this design was to be assembled after the manufacturing process instead of during the process, the parts could be made separately which reduced both time and cost. Once the parts were manufactured, we built the assembly seen in Figure 18 and Figure 19 to create the prototyped part.

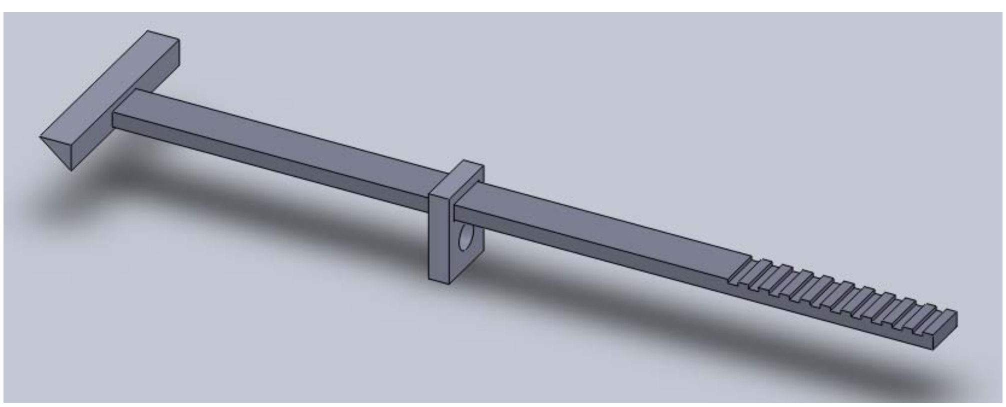

Figure 18: Iteration Three Alpha Assembly

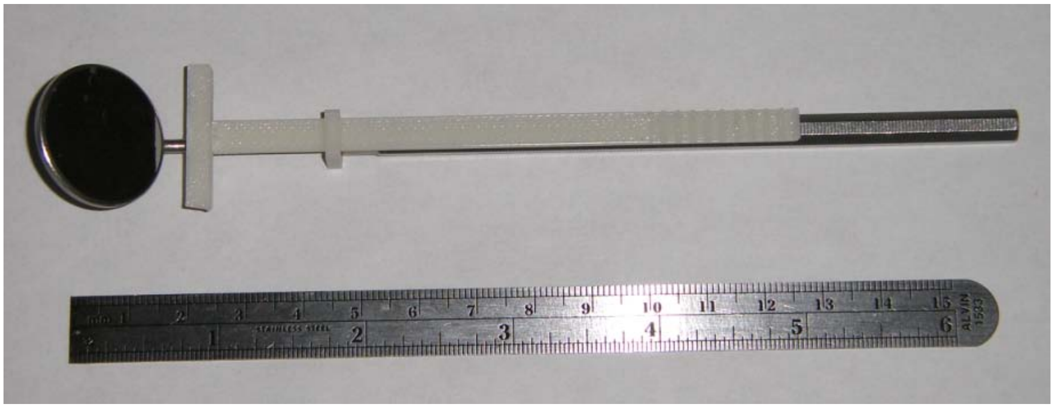

Figure 19: Photograph of Iteration Three Alpha assembled and attached to the Dental Mirror

Mr. Morin warned us that some of the parts for this design were "on the brink of being unbuildable". This was not surprising but we had assumed that the tolerances of the schematic and the RP machine would be acceptable for such small pieces. Upon close inspection of the components, we could see negative space on the upper half of the carrier and on the connecting extrusion of the wiper. These parts would need to be redesigned to remove these holes before another iteration of this design could be completed. The tolerances were such that the difference between the notch of the shunt and the connecting extrusion of the wiper was small enough that friction alone held the pieces together without the need for adhesive. Additionally, we decided against using adhesive on this model to better explain the connecting geometry to our sponsor. The next step of analysis was to attach the model to our dental mirror. We discovered that the carrier did slide onto the curved neck of the mirror as designed but instead attached between the neck and the handle in the threaded section where the two tool pieces screw together. This failure of design was in actuality a success as the carrier was now held in place by the joining of the tool. We had initially discounted this method as a successful means for attachment. The attachment was able to bend as needed to clean the surface of the mirror and the carrier worked to keep the alignment accurate. However, the shunt had no constraint other than the carrier to prevent it from rolling to the side because of the curvature of the mirror handle. For a future iteration of this design, we would re-implement the octagonal section from the second iteration.

Three Beta

Three Beta was developed with the concept of removing the failures and expanding the successful aspects of the second iteration. Since the carrier had been a source of problems for both our designs and those of the previous MQP team, we challenged ourselves to design an attachment that did not have the traditional carrier. The octagonal section on the underside of the shunt had accomplished the goal of providing alignment so it was decided that this aspect should be modified to compensate for the removal of the carrier. The octagonal section was extended to fully encircle the far end of the mirror handle, a callback to aspects of the design #2 sketch. By replacing the traditional carrier with the attaching octagonal section we developed an all-in-one attachment that would be easier to manufacture than previous attachment designs. As was done with Three Alpha, the shunt was extended in length, the wiper surface area was increased and its angle adjusted. The all-in-one attachment of iteration Three Beta can be seen below in Figure 20.

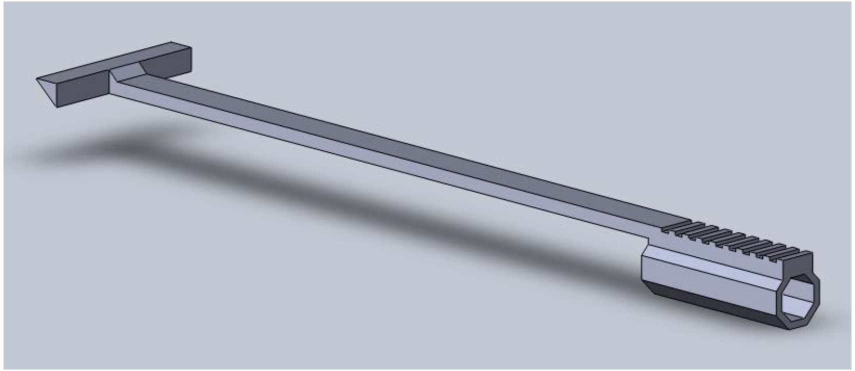

Figure 20: Iteration Three Beta All-in-One

Three Beta Results

Once the design had been reworked and the SolidWorks model had been created, we had the part rapid prototyped. The standard cleaning method used to remove the RP machine filler material from the part was insufficient as we needed to use additional methods to completely remove this material from the octagonal region before the part could be used in conjunction with the mirror. Once the excess material was removed, we attached the device to the mirror, as seen in Figure 21 to begin testing and observation.

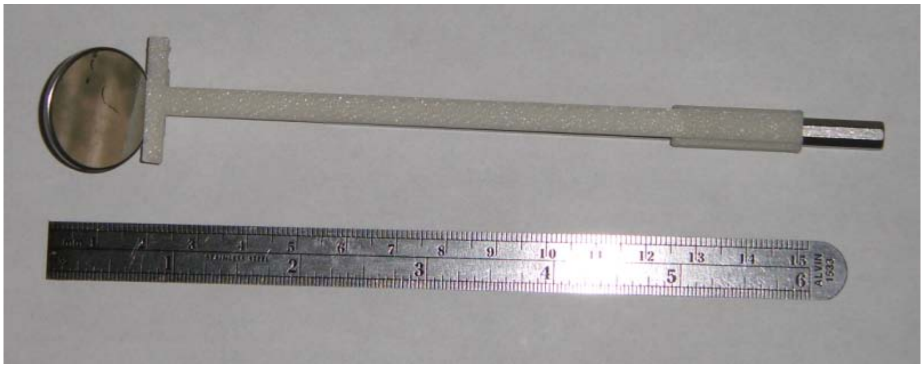

Figure 21: Photograph of Iteration Three Beta attached to the Dental Mirror

Of all the designs thus far, the octagonal section kept the attachment most aligned with the mirror's surface, allowing only the smallest of rotations. Over time and demonstration of the part, the rotation increased marginally as a result of wear on the ABS plastic of the prototype, but never to the extent of being misaligned. The low horizontal profile of this design prevented it from obscuring the mirror's surface nearly as much as previous designs. The increase in size of the wiper worked as expected by preventing any impeding collisions with the mirror surface.

Despite the numerous successes of this design there were still some aspects that could be improved upon. The overall length of the attachment, which had been too short in the previous iteration, was now excessively long making it cumbersome. This length shifted the corresponding features of the octagonal section and the cut grooves back. This location and the overall size of the octagonal section made the design uncomfortable to hold for long periods of time. After inspection of the part and its corresponding SolidWorks model, we realized that a typographical error in dimensioning caused the prototype to be longer than intended along with the corresponding detractions. Another aspect that could use improvement relates to the octagonal section, the top edge of which was not flush with the underside of the shunt as it had been in the second iteration design. It instead lowered the octagonal section which had the result of lifting the main body of the device off of the top-side of the mirror handle.

Additionally, the angle of the wiper blade is such that it is in full contact at the base of the mirror but when moved up the mirror, the flat surface re-angled such that it was no longer in full contact with the mirror surface. This overlooked design flaw could be avoided either through the positioning of the rubber wiper that attaches to this device or by adjusting the angle of the wiper blade.

Final Design

The final design was the culmination of all design work completed for this project. It is built off of the successes and failures of both our designs and the designs of the previous MQP team. We approached this design as we had all previous designs, by first inspecting the prior designs for successes and failures and searching for a means to improve them. Upon seeing the success and approval of iteration Three Beta, we knew that the final design should follow along those lines.

The simplicity of an all-in-one design was desired even though it limited the overall ease of manufacturing. The attachment method of enclosing part of the mirror handle instead of the neck was another leap forward and aspect to be further developed. Even if the mirror handle was not octagonal, the encompassing attachment design would only need to be slightly modified in order to work.

To increase the comfort to the user, we decreased the length of the octagonal section by 50%. This decrease in material has the additional benefits of reducing the amount of material required and improving manufacturability. Since not all users hold the tool in the same orientation, we extended the section of cut grooves to cover more of the tool surface. To further improve comfort to the user, and to correct a foolish error of Three Beta, we decreased the overall length of tool. It was decided to address the wiper blade angle alignment concern through careful positioning of the rubber wiper.

The final design of the dental mirror cleaning attachment can be seen below in Figure 22.

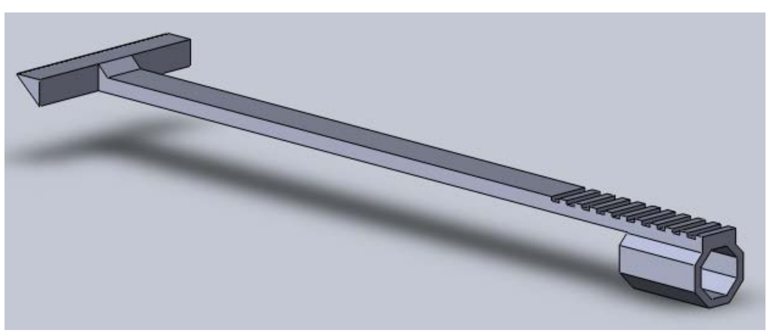

Figure 22: The Final Design

Conclusions and Recommendations

We concluded that our final design was the best. Not only were we able to fulfill all the design requirements with it, but we were able to create a very simple cleaning device that was incredibly easy to manufacture and extremely cost-efficient to produce. This new design increased the visibility of the dental mirror by approximately 85%, when the device was attached to the handle, which was a significant improvement over the previous MQP design. The alignment of the device on the mirror's handle was also improved; attaching the device to the base of the handle instead of the neck insured that the wiper would not go off track and slide off the mirror while in use. Our device could also be easily modified for different design conditions, such as a round handle instead of the hexagonal handle that our test mirror had.

While the prototype was created with ABS plastic through use of rapid prototyping, we would recommend that the device would be best designed using a Polyamide material, perhaps Nylon. Nylon's properties would allow for it to be autoclaved without warping or melting the device and its low Young's modulus would ensure that it has the right amount of flex needed for the appropriate maximum deflection of this device. It is currently manufactured as toothbrush bristles, proving that it has no harmful health-related side effects. Because it is extremely cost efficient, the device itself would be very cheap to manufacture and produce on a large scale. Nylon also has the added benefit of being recyclable material, which means that our dental device is "green," and thus biocompatible.

Appendix A: References

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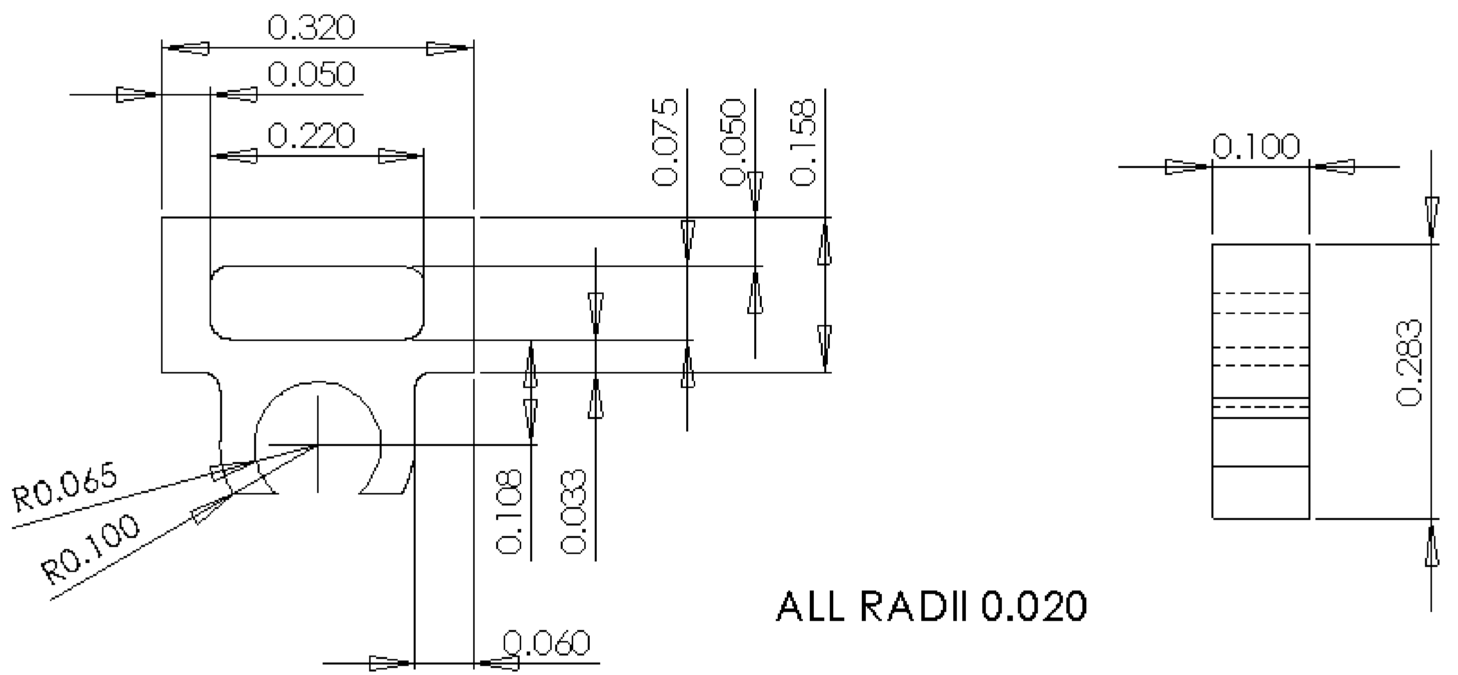
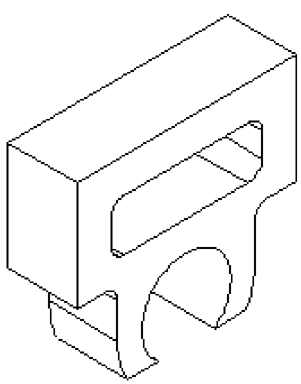
Appendix B: SolidWorks Drawings

This Appendix is dedicated to the SolidWorks drawings of each component of each prototyped design.





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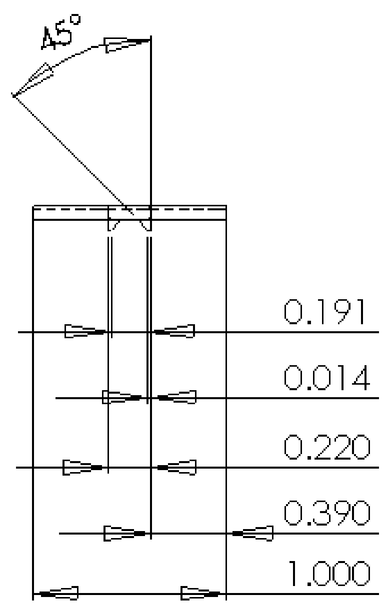

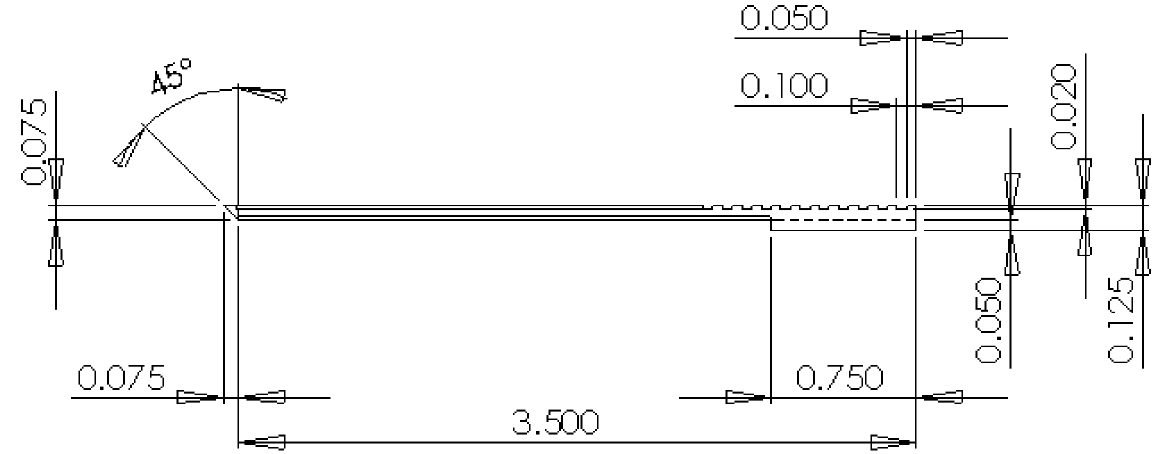

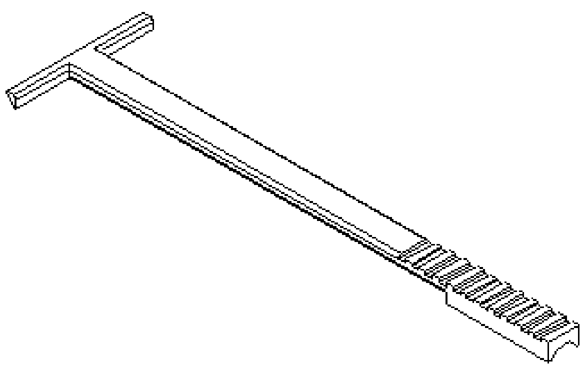

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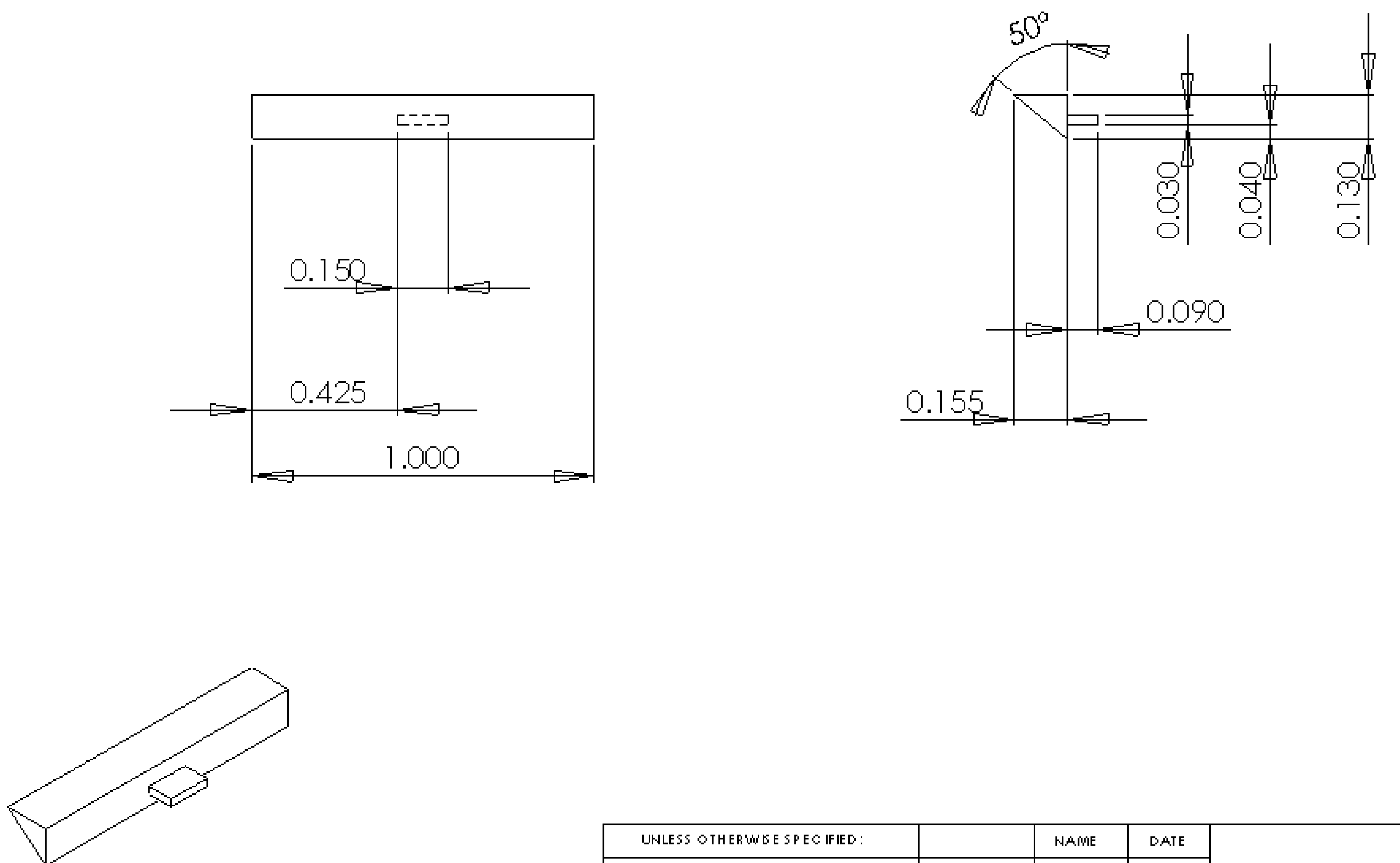

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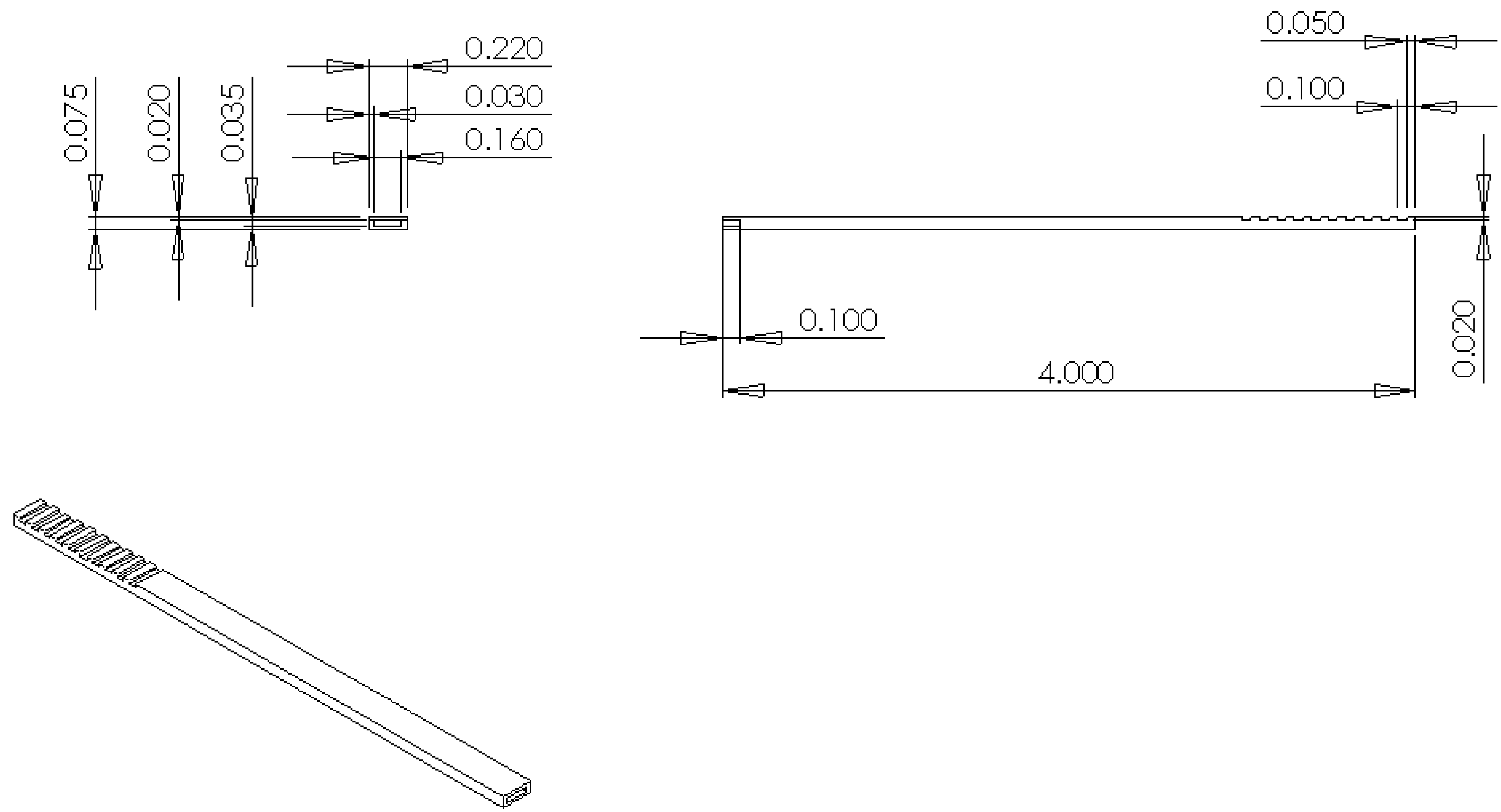

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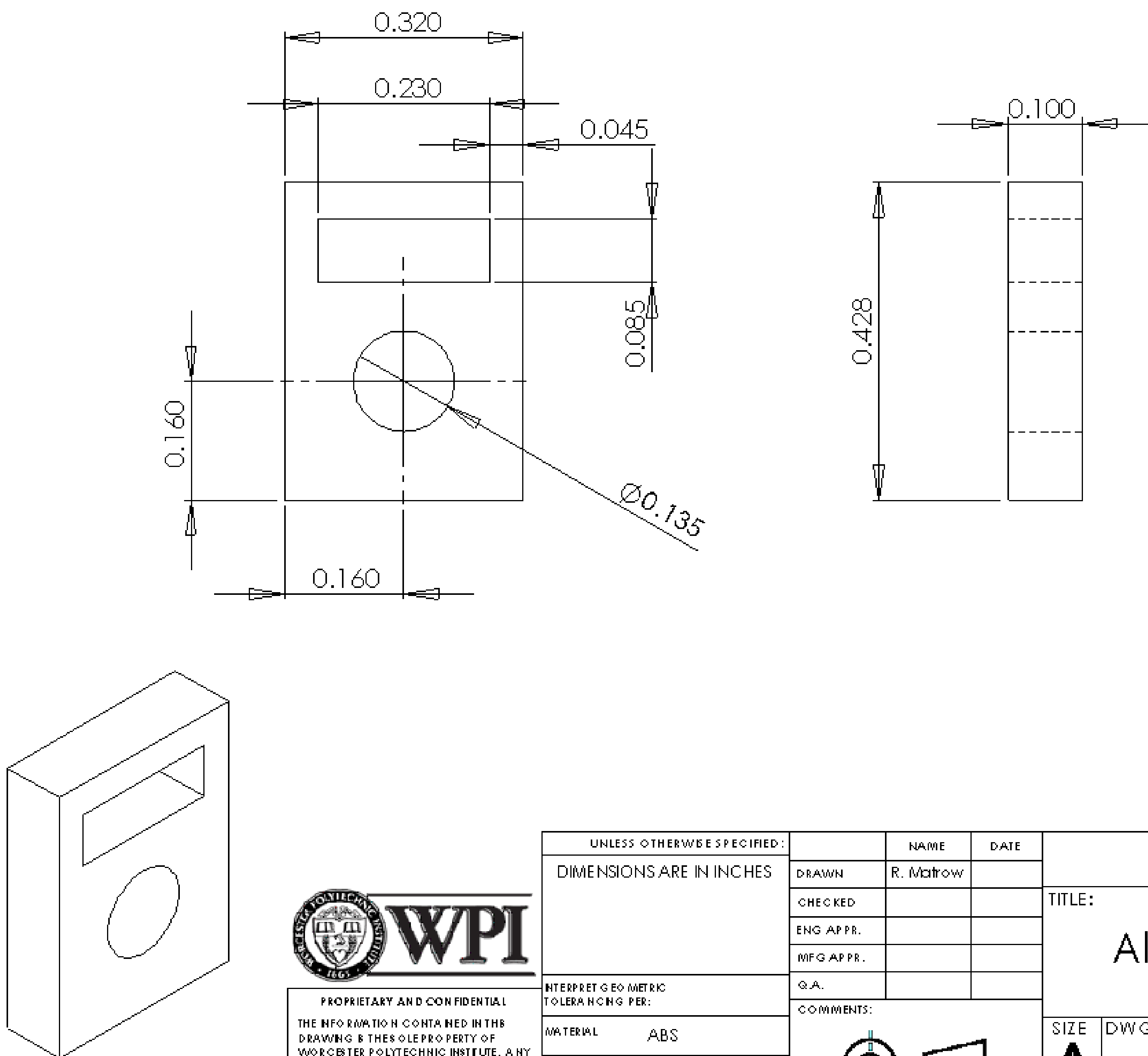

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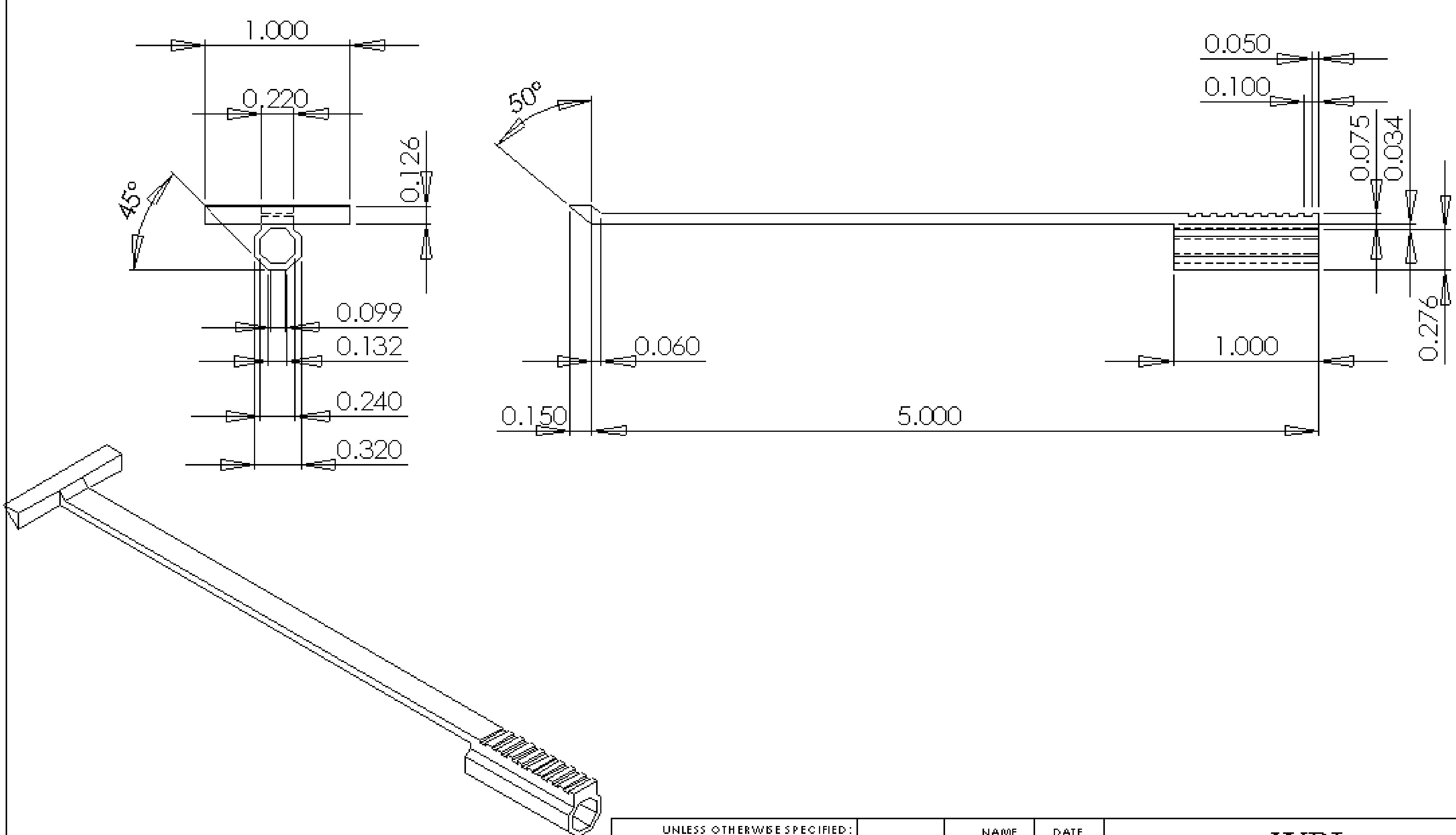

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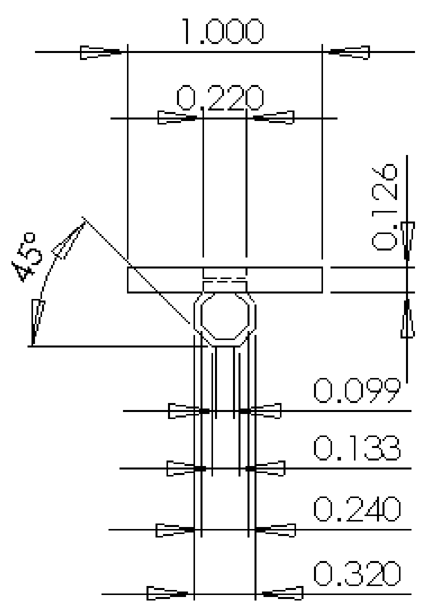

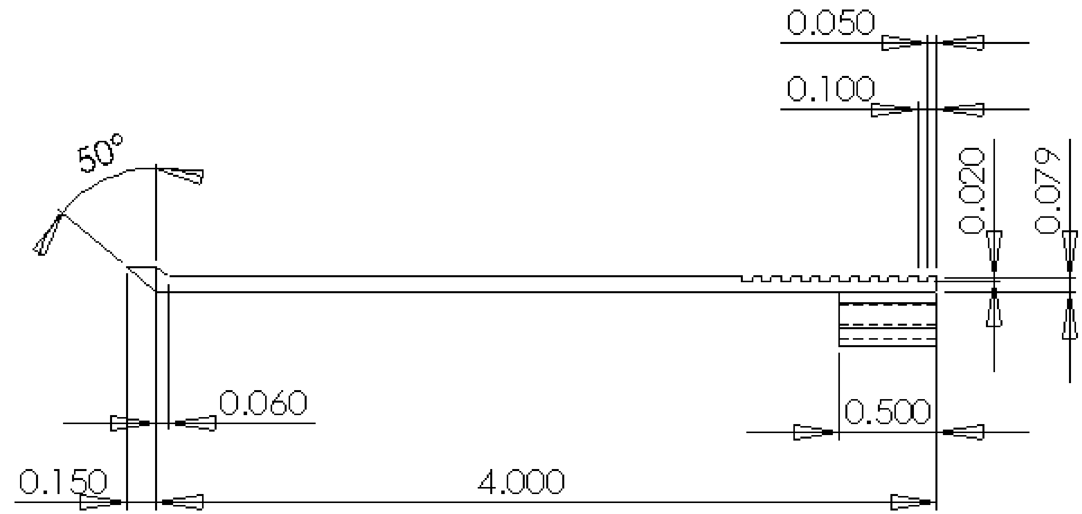

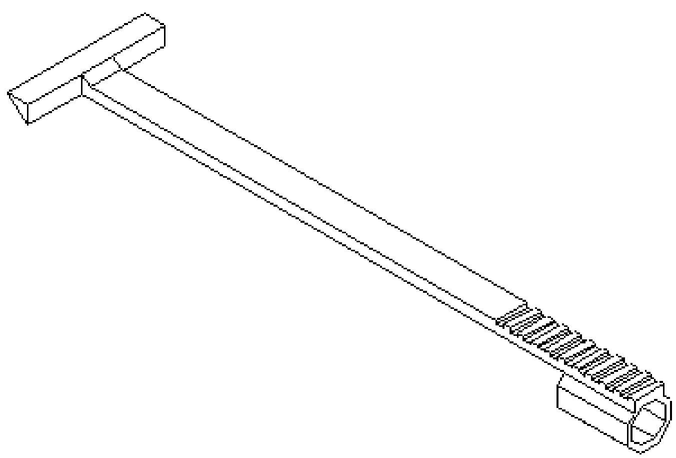

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TITLE:

Final Design Assembly

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5 4 3 2 1

Appendix C: Cantilever Beam Calculations

Cantilever Beam Calculations

Part 1: Second Iteration
using ABS plastic

Known Variables

$h := 0.075in$ $b := 0.220in$ $E := 2.3GPa = 3.336\times 10^{5}\cdot psi$

$I := \frac{b\cdot h^{3}}{12} = 7.734\times 10^{-6}\cdot in^{4}$ $l := 1in$ $\delta_{max} := 0.75in$

Force Calculation

$$P := \frac{\delta_{max}\cdot 3\cdot E\cdot I}{l^{3}} = 5.805\,lbf$$

Deflection Angle Calculation

$$\theta := \frac{P\cdot l^{2}}{2E\cdot I} = 1.125$$

Assume this result is in radians.

$$\theta\cdot\frac{180}{\pi} = 64.458$$

The deflection angle is approximately 65 degrees for this design.
This result corresponds to the approximated physical measurement.

Part 2: Beta Assembly using ABS Plastic

Known Variables

$h_b := 0.075in$ $b_b := 0.220in$ $E = 2.3\cdot GPa$

$I_b := \frac{b_b\cdot h_b^{3}}{12} = 7.734\times 10^{-6}\cdot in^{4}$ $l_b := 4in$ $\delta_{max} = 0.75\cdot in$

Force Calculation

$$P_b := \frac{\delta_{max}\cdot 3\cdot E\cdot I_b}{l_b^{3}} = 0.091\cdot lbf$$

Deflection Angle Calculation

$$\theta_b := \frac{P_b \cdot l_b^{\ 2}}{2E \cdot I_b} = 0.281$$

Assume this result is in radians.

$$\theta_b \cdot \frac{180}{\pi} = 16.114$$

The deflection angle is approximately 16 degrees for this design, a reasonable result considering the greatly increased length.

Part 3: Beta Assembly using Polyamides

$$E_{pa} := 0.38 \cdot 10^6 psi$$

Since the dimensions have not changed, we use the same Moment of Inertia from Part 2.

Force Calculation

$$P_{pa} := \frac{\delta_{max} \cdot 3 \cdot E_{pa} \cdot I_b}{l_b^{\ 3}} = 0.103 \cdot lbf$$

As expected, considering the increase in the modulus of elasticity, the force is greater than in Part 2.

Deflection Angle Calculation

$$\theta_{pa} := \frac{P_{pa} \cdot l_b^{\ 2}}{2E \cdot I_b} = 0.32$$

Assume this result is in radians.

$$\theta_{pa} \cdot \frac{180}{\pi} = 18.357$$

The deflection angle is approximately 18 degrees for this design, a reasonable result considering the increased modulus of elasticity.

Part 4: Final Assembly using ABS Plastic

Known Variables

$h_f := 0.075in$ $\qquad$ $b_f := 0.220in$ $\qquad$ $E = 2.3 \cdot GPa$

$$I_f := \frac{b_f \cdot h_f^3}{12} = 7.734 \times 10^{-6} \cdot in^4 \qquad l_f := 3.5in \qquad \delta_{max} = 0.75 \cdot in$$

Force Calculation

$$P_f := \frac{\delta_{max} \cdot 3 \cdot E \cdot I_f}{l_f^3} = 0.135 \cdot lbf$$

Deflection Angle Calculation

$$\theta_f := \frac{P_f \cdot l_f^2}{2E \cdot I_f} = 0.321$$

Assume this result is in radians.

$$\theta_f \cdot \frac{180}{\pi} = 18.417$$

The deflection angle is approximately 18 degrees for this design.

Part 5: Final Assembly using Polyamides

Known Variables

$$h_f := 0.075in \qquad b_f := 0.220in \qquad E_{pa} := 0.38 \cdot 10^6 psi$$

$$I_f := \frac{b_f \cdot h_f^3}{12} = 7.734 \times 10^{-6} \cdot in^4 \qquad l_f := 3.5in \qquad \delta_{max} = 0.75 \cdot in$$

Force Calculation

$$P_{pa} := \frac{\delta_{max} \cdot 3 \cdot E_{pa} \cdot I_f}{l_f^3} = 0.154 \cdot lbf$$

Deflection Angle Calculation

$$\theta_{pa} := \frac{P_{pa} \cdot l_f^2}{2E \cdot I_f} = 0.366$$

Assume this result is in radians.

$$\theta_{pa} \cdot \frac{180}{\pi} = 20.979$$

The deflection angle is approximately 21 degrees for this design.