I. Problem Statement/Research Question and Background

Oral hygiene is often taken for granted by the general population as a simple and mundane task. However, for individuals with motor function disabilities this task can become difficult both for the individual and their caregivers. Currently many people with disabilities lack the manual dexterity and strength to use a conventional toothbrush [1]. The tÜthbrush is an electric toothbrush that has been created with a unique mouthpiece attachment with curved bristles along the entire track that brushes all of a person's teeth at the same time. This product was designed with the hopes that a solution could be provided to a person with disabilities or their caregiver so that the task of brushing teeth will be less stressful and easier to accomplish on a regular basis.

The initial design of the tÜthbrush is based on U.S. Patent #9,308,065, owned by Dr. Mark Steiner [2]. The goal for this project has been to work with Dr. Steiner on improving his design to be easier to use and more inclusive of all age groups. Initially research was carried out to figure out the common roadblocks that a person with disabilities may face when it comes to executing manual tasks. Technology studies were then conducted to understand the current guidelines for manufacturing a toothbrush so that the team could consider the steps to mass-manufacture the product once a design was finalized. Research was also done to collect the data of average mouth sizes and maximum mouth opening across as many age groups as possible. The adult mouth size data [3] was abundant but data to create a child-sized mouthpiece proved to be more difficult [4].

Initially the prototype that was provided to the team was designed to only fit an average adult mouth size and was created out of one solid piece of milled nylon. The completely rigid base plate caused the mouthpiece to be difficult to insert into a user's mouth and one size greatly limited the demographic of users. Upon completion of the research there are several design solutions being developed to address the challenges of adaptability and ease of use.

II. Methods/Approach/Solutions Considered

The first solution that the team addressed was the variety of mouthpiece sizes available. The research that was conducted in the first semester shows that children have not only a smaller mouth than adults, but also a more "V"-shaped mouth rather than a "U" [3] [4]. The team has been able to manufacture multiple mouthpieces using the data of average mouth size and shape for different ages as seen in Figure 1. The creation of multiple mouthpiece sizes will make the product more marketable and could lead to regular tooth brushing habits from a younger age.

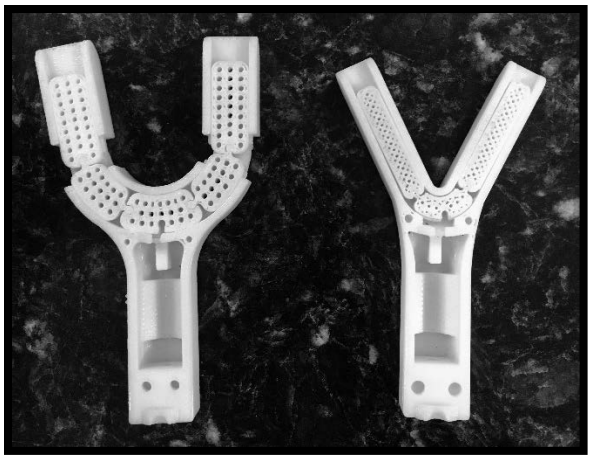

Figure 1: Adult and Child-Sized Mouthpiece

The second proposed solution was to create a “hinge” on the mouthpiece. This hinge allows the sides of the mouthpiece to bend inward for insertion into the mouth and then flex back to the equilibrium position once it has been inserted. The addition of the hinge allows the team to address both adaptability and ease of use. In order for the track to return to its original shape after being inserted into the user's mouth, a silicone coating will be applied to the hinge.

Another solution that was explored was to prevent the bristle heads from being able to fall out of the track during use. The original prototype had a slight angle on the inner walls of the track to keep the bristle heads wedged in but there are obvious safety concerns associated with that design. The team decided to use a tongue-and-groove connection between the track walls and the sides of the bristle heads in order to secure the bristle heads in the mouthpiece. By restraining the heads within the track, this will improve the safety of the toothbrush to reducing the chance of a choking hazard.

A future consideration that has been made is to create a double-sided track that will be able to brush the top and bottom rows of teeth at the same time. The double-sided track will address the ease of use by eliminating the need to flip the toothbrush from the top teeth to the bottom teeth. After a visit to the Conductive Education Center of Orlando (CECO) the team has also considered the importance of creating an entirely custom handle for the toothbrush as well. During the tour of their facilities it was observed that most of the electronic equipment that the students use incorporate large external buttons to start and stop the device and often have a larger surface to grip. These advancements are ones that the team would like to incorporate as part of the overall product once the mouthpiece design is perfected.

In order to handle the mass-manufacturing aspect so that the tÜthbrush can be brought to a larger market, it was decided that the use of injection molding and overmolding would yield the best results. Injection molding would be utilized for the

manufacturing of the solid mouthpiece components while the overmolding would be responsible for the silicone-like coating over the hinges. For prototyping purposes, the solid pieces of the mouthpiece are being 3-D printed and the team has purchased the materials to apply a silicone exterior manually.

III. Description of Final Approach and Design

In order to improve the design of the tÜthbrush the prototype dimensions were first replicated using SolidWorks. From there, modifications have been made to the mouthpiece to fit the requirements discussed earlier. Although it was proposed to create the double-sided track initially, the sponsor ultimately made the decision to keep it one-sided until that design was perfected. For the hinge idea, the overall mouthpiece was thickened and then separated into three interlocking parts. The separation created the curved "bottom" of the U-Shaped track which connects to the handle and two "legs." The first prototype that incorporated the hinge design held the pieces together with pins but since it posed the threat of being a choking hazard the later iterations were designed so that the legs "snap" into place.

As previously mentioned, the original prototype had the bristle heads wedged into the track which created an extremely high possibility that the heads might detach during use causing the user to choke on them. In order to fix this problem, the walls of the mouthpiece were thickened and a groove was inserted inside the track walls. The heads were also redesigned such that the sides had a projection that fit inside the grooves of the track. Another addition was the extension of the ends such that the bristle heads would not slide out of the ends of the track during use.

Another modification implemented in the new design is the linkage support. A curved channel was added to the base of the "U" which will guide the rod that moves the bristle heads when the toothbrush is in use. Additional support material was also added in the base plate to support the linkage. The linkage itself also received a makeover – the channel for the toothbrush motor was extended to reflect the profile of the rest of the linkage and then a cut was extruded to serve as a guide for the motor. The purpose of these was to make it easier for the user to attach the toothbrush to a third party handle.

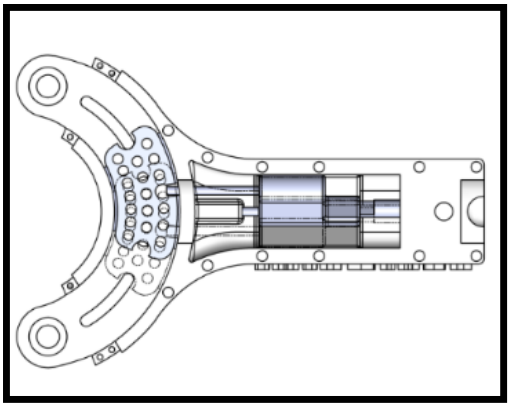

Figure 2: tÜthbrush Drive Mechanism

For aesthetic and comfort purposes, much of the square corners present in the original mouthpiece design were filleted. The name of the product was also added to the side. The child sized mouthpiece has many similar features except the shape of

their mouths is more "V" shaped so the hinges were no longer needed. The prototypes are being 3-D printed by the UCF Manufacturing Lab [5]. Once printed, bristles are inserted into the heads and the outside of the mouthpiece will be coated in Dragon Skin Silicone for both comfort and U-shape retention after insertion.

IV. **Outcome**

Originally the prototypes that were created in SolidWorks were run through a variety of tests in order to ensure that the prototypes would be able to withstand some general real-world parameters. Tests were run to ensure that an average bite force would not break the hinges and stress and vibration analysis was done to verify the necessary structural integrity. Future testing will be done with the 3-D printed prototypes to compare the theoretical results obtained from SolidWorks with actual results.

Since this product deals so closely with people the team knew that some of the best data would be obtained through the feedback of people with disabilities and their caregivers. In early January the team found information on the Abilities Tech Expo that was taking place in Orlando, Florida on March 3 and 4, 2017 [6]. This expo hosted exhibitors that specialized in assistive technologies to showcase products that were in all stages of development. The Abilities Tech Expo also included a developer's showcase that allowed groups to pitch their product to a panel of judges as well as exhibit during the entire expo.

Figure 3: Prototype for Abilities Tech Expo

Prior to the expo the students and faculty members of the Conductive Education Center of Orlando (CECO) invited the developers showcase groups to tour their facilities and meet some of the students and parents that were in need of the assistive technologies that were being created. The team brought the original prototype to get initial feedback on the concept of the tÜthbrush as an improvement to the current tooth brushing methods. The initial prototype sparked interest so the team manufactured the next iteration of prototypes with the hinge and prepared to showcase at the Abilities Tech Expo.

During the expo the team was able to obtain feedback from many of the parents, children and educators that work with people with disabilities. Participants were able to view the prototypes and share their experiences with us as far as their

current tooth brushing methods and challenges that they encounter that had not come up in prior research. Availability of a child-sized mouthpiece was the main question that was asked at the expo followed by inquiries of if the product was able to be purchased yet.

V. Cost

The initial prototype consisted of an Oral B 1000 electric toothbrush handle which has continued to be used throughout the duration of the product. The handle can be purchased from most major retailers at about $30. Dupont, a toothbrush manufacturer, offered to provide a sample of Nylon toothbrush bristles at no cost for our prototypes but calculations were done to determine the actual price for the amount of bristles that would be used in one toothbrush.

The purchase price of a 2lb. package of Dragon Skin Silicone that is going to coat the mouthpieces cost $34. In order to coat one toothbrush head only about $2 worth of material was used. Based on the prices of the UCF manufacturing lab, the total cost to 3-D print an entire toothbrush head has averaged at $25. Altogether the price of a prototype without the handle is estimated to be about $27.

Once full-scale production methods can be used to manufacture this product the overall cost will decrease considerably. The toothbrush head will be created using injection molding for the solid base and overmolding for the exterior and the hinge. There will also be access to the standard machinery used to insert bristles into toothbrushes, unlike the prototype heads, whose bristles were inserted by hand. If the product were produced in a large scale, the price of the mouthpiece will drop dramatically to an estimated $5.

The team strongly believes that this product should be easily affordable for people with disabilities and their caregivers so the target sale price is $30 for a full mouthpiece with all of the bristle heads. Since the hinge has been added to the prototypes this will allow for easy disassembly of the mouthpiece so that the bristle heads can be replaced as needed without having to purchase an entirely new mouthpiece package.

VI. Significance

The tÜthbrush serves as a long-term advancement in the oral hygiene of people with disabilities. Current toothbrushes require too much movement for many people with motor function disabilities to use independently, and studies have shown that if someone else is responsible for the oral health of an individual that the frequency and quality of brushing is severely lacking. With the modifications that have been made to the design to include a functional child-sized mouthpiece the team also

hopes to provide a product that will help instill good tooth brushing practices from a young age.

The manufacturing techniques that have been researched will make sure that the tÜthbrush is available to the public at a reasonable price and that the cost of replacement remains low as well. The overall goal is that the tÜthbrush will become a product that can be implemented in the lives of people with disabilities and become a tool that gives them a greater level of independence.

Acknowledgements and References

[1] "Practical Oral Care for People with Cerebral Palsy," National Institute of Health, August-2014. [Online]. Available: http://www.nidcr.nih.gov/oralhealth/Topics/DevelopmentDisabilities/PracticalOralCarePeopleCerebralPalsy.html

[2] Steiner, Paster, & Walczyk, 2016, “Tooth Cleaning Mechanism,” U.S. Patent 9,308,065.

[3] Al-Zubair. "Determinant Factors of Yemeni Maxillary Arch Dimensions." The Saudi Dental Journal. Sana’a University, 5 July 2016. Web. 26 Oct. 2016.

[4] Al-Zubair, Nabil Muhsen. "The Relationship between Mandibular Arch Length and Widths in a Sample of Yemeni Subjects with Normal Dento-Skeletal Relationship." Journal of Orthodontic Science. Medknow Publications & Media Pvt Ltd, Oct.-Nov. 2013. Web. 24 Oct. 2016

[5] UCF Admin April 11, 2017 Print Article. "Manufacturing Lab." *College of Engineering and Computer Science*. University of Central Florida, n.d. Web. 12 Apr. 2017.

[6]Carina Marketing. "2017 Abilities Tech Expo." *Abilities Tech Expo* | *Make It Possible*. CECO, n.d. Web. 12 Apr. 2017.