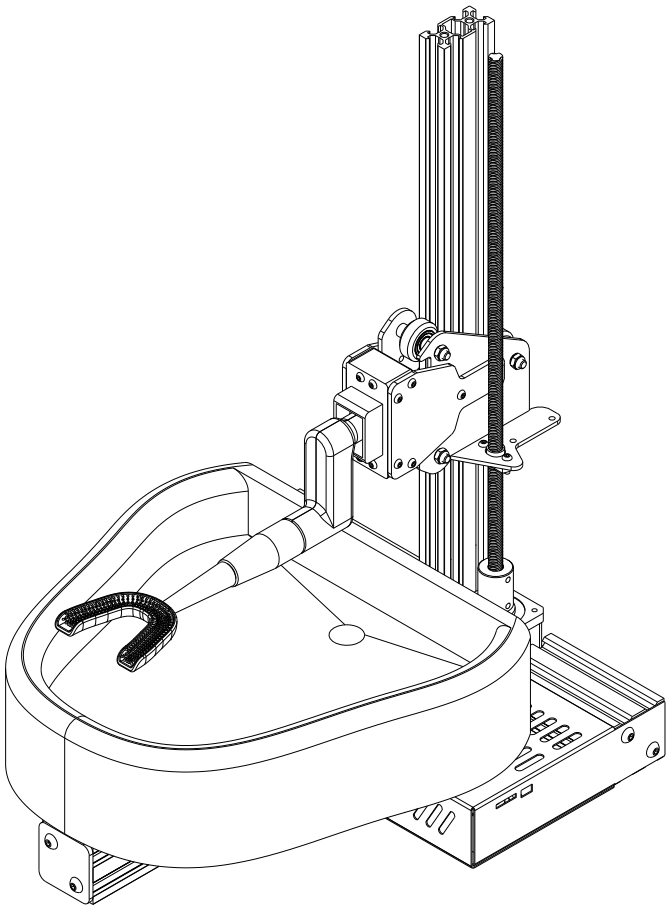
École Polytechnique Fédérale de Lausanne

Microengineering Master's Program

Products Design & Systems Engineering

Brush'it



Group 8 : **SCIPER N° :**

Samira Lena Tscherrig	330271
Kelan Alexander Solomon	312367
Joël Wagnières	301438
Mehdi Amor	296831
Maxence Audran Sylvain Georges Dominjon	316536

Professor :

Yves Bellouard

Edoardo Charbon

Supervisor :

Barış Can Efe

Fall 2023

Executive Summary

In the US, the occurrence of mental distress is 4.6 times more frequent among people with disabilities compared to adults without disabilities [4]. The loss of independence can be considered a fundamental factor when it comes to mental health: mundane tasks such as personal hygiene, eating, or drinking may seem trivial to most. Still, they can become considerable hurdles when they depend on another person's help to accomplish. Offering individuals the opportunity to reclaim even a small measure of independence in their daily tasks holds the potential for substantial positive impacts on mental health.

Brush'It fulfils an unmet need on the current market: an automatic, all-in-one solution to help people with hand mobility disabilities brush their teeth. For some, dental hygiene may seem like a familiar and easy task that can be accomplished on "auto-pilot", but it may not be accurate for those with limited hand mobility. Our product is aimed at at-home users and institutions such as hospitals and care homes, where it could have the added benefit of reducing the workload of already overburdened care workers. In addition, this at-home use is essential as it can be used for the aftercare done by occupational therapists.

Brush'It is a toothbrushing station that can be wall or table-mounted. It consists of a wash basin for rinsing and cleaning and a horizontal arm with, at its end, a U-shaped brush intended to clean all teeth at once. Nozzles protrude from the basin floor, supplying the brush with toothpaste and water for cleaning, and an elevator raises and lowers the mouthpiece to the user's height.

The personalised button activates the toothpaste application, raising the mouthpiece for user access. Vibrations clean the teeth; after use, the mouthpiece automatically returns to the basin for rinsing. Safety features include an emergency stop button, mechanical fuses, and protection against entanglement with hair or objects.

There are already patented U-shaped electronic toothbrushes on the market, even with automatic toothpaste dispensing, but they must be hand-held during use. A patent for a mechanism for injecting substances through slits, similar to the mechanism used in Brush'It to dispense toothpaste, also already exists. However, combining all these functions in one product still needs to be patented, which makes Brush'It unique: it is a fully automatic and easy-to-use toothbrushing station.

The prototype demonstrates the process of hand-free toothbrushing and proves that the concept of Brush'It works. However, to bring Brush'It to the market, the mouthpiece needs to be improved. Collaboration with researchers and dental institutions is necessary to design it so teeth are brushed efficiently without damaging the gums. We would also like to implement optional features such as an adjustable user height.

To develop the prototype, the work was divided into the following functions: the toothpaste dispensing mechanism, the lift and the horizontal arm. In the first phase, all team members worked on the mechanical design of these functions. In the second phase, the designed parts were manufactured, the mechanical aspects improved, and the electronics and software developed.

Contents

1 Product concept

1.1 General description

Individuals with hand disabilities face challenges in daily oral care tasks, especially with the standard solution of manual toothbrushing due to limited hand dexterity and coordination. The precise movements required during toothbrushing and struggles with toothpaste application can result in inadequate oral hygiene.

The Brush'it hands-free toothbrushing station redefines dental care with its innovative features and user-friendly design. This product introduces a U-shaped toothbrush that operates hands-free, incorporating a rotating and vibrating mechanism for effective teeth cleaning. Key features include automatic toothpaste dispensing and cleaning, ensuring a hassle-free brushing experience. With a focus on accessibility, the station is designed for easy installation with wall-mounting capabilities and a water supply connection. This hands-free toothbrushing solution is tailored for individuals seeking a modern and convenient oral care option, particularly benefiting those with limited hand dexterity or disabilities. The Brush'it station simplifies the teeth cleaning routine, offering a comprehensive and accessible solution for users of diverse needs.

1.2 Brief market analysis

The market analysis for the Brush'it hands-free toothbrushing station reveals a significant client base in Switzerland and across the broader European Union. In Switzerland, where approximately 19% of the population is aged 65 or older, totalling around 1.5 million people and projected to rise to 30% by 2060, the ageing demographic presents a robust market. Moreover, around 18% of the Swiss population, roughly 1.7 million individuals, live with some form of disability, indicating substantial potential clients for a product addressing hand disabilities.

Expanding to the EU, which hosts around 120 million people aged 65 or older and approximately 15% of the population, roughly 80 million individuals living with some form of disability, further emphasises the market potential.

1.3 Unique selling points of your product

What sets Brush'it apart is its integrated dental hygiene system, harmonising components like the U-Brush, toothpaste dispensing, and water supply. It is not just a toothbrush but a part of the lifestyle. The key highlight is its hands-free functionality – autonomously managing toothpaste application, self-rinsing, and providing a vibrating brushing action. Designed for convenience, it is compact and can be effortlessly wall-mounted, enhancing the ease of incorporating it into your oral care routine. Additionally, customisation options, including the possibility of collaborating with dentists to create custom arches, cater to individual needs, making Brush'it a personalised solution for oral health.

2 Technical solution

2.1 Technical and functional requirements

Collectively, we defined our product requirements as must-haves and optional to ensure a smooth operation. This provides a clear guideline for the rest of the project, allowing us to prioritise tasks efficiently.

Must-haves:

- Both the upper and lower teeth arcades should be effectively cleaned
- Swappable brush head
- Hands-free flipping of the brush
- Automatic vertical lift for the brush at the user-specified height
- Toothpaste should be dispensed automatically when the device is initialised
- After use, the brush will be cleaned automatically
- Ensure compatibility with both the tap and greywater systems
- Reliable electronic, software and user input control
- The product is designed to ensure the safety of the user, both electrically and mechanically

Optional:

- Emergency stop input for the user
- Customizable user input that can be adjusted to accommodate different types of disabilities
- User-configurable settings allow users to adjust the brush height and brush time
- Rinsing of the entire sink with tap water
- Companion app for configuration, either via Bluetooth or wifi
- Descaling process to ensure the longevity of the device

2.2 Design phase: solutions explored

Elevator

To enable users with hand disabilities to use the brush and to provide the necessary automatic functions, such as toothpaste dispensing and cleaning, a lifting mechanism was required. This lifting mechanism is needed to raise the brush to a specific height and be strong enough to withstand the mechanical load while also being safe for the user. It was also important that the mechanism had some protection against foreign objects, such as hair, and was water-resistant.

Initially, we considered using a timing belt as both the elevator's driving mechanism and ingress protection. However, integrating the driving and protection functions into one component resulted in numerous design constraints. Therefore, we divided the driving and protection functions into two separate elements, making the design more straightforward.

For the final design, we used a lead screw with a nut on the elevator to provide a robust driving mechanism 13. For protection, we implemented a recirculating belt to fill the linear opening of the elevator. To power the elevator, we used a stepper motor as the driving mechanism, which, when coupled with an adequate driver, can provide control over the motor's torque and angular position.

Front-end mechanism for the brush

During our meeting with two dentists, we discussed whether it would be better for the toothbrush to clean both the upper and lower arcade of teeth or one side first, followed by flipping the brush for the other side. We concluded that a single arcade brush would be easier to manufacture and customise for the end user and more accessible to interact with. However, this decision would transfer complexity to the front-end mechanism, which would now need to provide a swappable mounting point for the brush, a vibration source, and a half-turn flipping mechanism.

In the earlier stages of the project, we also considered using a bistable half-turn mechanism, which would be triggered by the linear motion of the elevator and a sliding piece that would serve as an end-stop to trigger this mechanism. The user could then slide this end stop to modify the maximum height and position at which the brush flipping would happen. However, we concluded that while this solution was great for the user's height, it would be nearly impossible to implement for the toothpaste dispensing and water cleaning station, requiring both flipping and raising the brush simultaneously. Therefore, we implemented a servo motor with an off-axis transmission to allow for water tightness from the bottom sink and flipping at any position of the U-shaped brush, both for the refilling and cleaning station and for the user 15.

Finally, the vibration would be provided by an eccentric rotating mass powered by a Maxon A-max DC motor. The motor is decoupled from the vibration created by the eccentric mass of the flexible shaft and the silicone coupler for the U-brush mounting point 16.

Refilling and Cleaning Station for the Brush

To ensure that our device can be used hands-free and without any hassle for an extended period, we must include a cleaning and toothpaste dispensing component in our design.

Initially, we considered incorporating micro-channels into the flexible material of the brush, which would directly apply toothpaste onto the bristles. However, this option was quickly dismissed due to its complexity and feasibility within the given project timeframe. A feasible solution is adding a nozzle at the bottom of the sink and dispensing toothpaste into the U-shaped brush 25.

The high viscosity of the toothpaste will keep it in the brush until the user interacts with the device. Upon initialisation of the device by the user, toothpaste will be applied to prevent it from drying out. To further prevent the toothpaste from drying and clogging the pipe system of our product, we plan to add a one-way valve, similar to an aortic valve. Please look at Annexe 7.4 for detailed illustrations of the toothpaste mechanism. For cleaning the brush, two water jets will be released from the sides of the sink to rinse the brush after use. The brush vibration will be triggered with the water, which will help clean the brush effectively.

2.3 Technical Choices Made for Key Elements

Since a few of the main technical choices have been explained in the previous section, this section will focus more on specific technical choices such as electronics, toothpaste dispensing pumps and the mouthpiece.

Electrical Design

Our project's electrical design focuses on driving various motors with specific functionalities like positioning, maximum allowed torque, and rotational speed. Additionally, we aim to design an intuitive and robust user interface with a foot switch button and software for precise positioning and triggering of multiple events.

The Arduino Mega 2560 is at the centre of our electrical design. It is a minimalist development microcontroller board based on the ATmega 2560, clocked at 16 MHz. It offers 8kB SRAM, 256kB FLASH, and 4kB EEPROM, which is more than enough for our project. The board also includes multiple hardware interfaces such as I2C, SPI, UART, external hardware interruption pins, and PWM channels that will be used for the numerous motor drivers and limit switches 23.

To drive the vibration motor, toothpaste pump, and water supply solenoid, we selected a development board from Adafruit based on the DRV8871 from Texas Instruments. This H-bridge motor driver offered us all the necessary features for driving different DC motors and solenoids, such as current regulation via an internal voltage reference and a resistor, over-current protection (OCP), PWM control for current chopping, and a broad operating voltage supply from 6.5 V to 45 V with a maximum current of 3.6 A. Overall, this component is robust, easy to use, and offers flexibility for our design.

We wanted a robust, feature-full and easy-to-use stepper motor driver for the elevator's stepper motor. This would allow us to control the motor's torque, report any miss-steps during operation, and control phase current. Hence, we ordered our driver from DigiKey and opted for the TMC2660-BOB from Trinamic Motion, a stepper motor driver development board. This board is equipped with all necessary shunt resistors and passives for the TMC2660 and is easy to prototype. In our case, it was the perfect choice as this driver offers three patented features from Trinamic, which were well-suited for our application. The first feature is the so-called CoolStep, which allows a tunable load-dependent current to significantly reduce the heat generated from the stepper motor during the idle and active phases. The second feature is the SpreadCycle, which summarises a true sine wave applied to the stepper motor to reduce noise during operation. Finally, the main feature of interest for us is the StallGuard2, which offers sensorless motor load detection after a short calibration with the motor. These features allowed us to reduce the required power and protect the user from any incident with the linear stage, as the motor's load is limited to not hurt the user.

Finally, our system is powered by an external isolated brick switch-mode power supply from MeanWell. We selected the following model: GSM60A24-P1J, which provides 24V at 2.5 A for a total of 60 W, which is oversized for our project. We took special care to choose a fully plastic-enclosed medical power supply to have improved galvanic isolation with the main voltage to protect the user further and ourselves during prototyping. The 24V is then used with DC-to-DC converters, such as the R-78E5-1.0 from Recom, to generate all required voltage rails for the ATmega2560, such as 5V and 3.3V, with adequate decoupling capacitors.

The electronics were initially tested on a breadboard with the final design of the circuit,

which allowed us to test all hardware interfaces, such as SPI and the multiple PWM signals for driving the motors at different speeds. Finally, the circuit was transferred on a perforated board and soldered with all connections available for the final assembly of the prototype. Ultimately, we are happy with our electronics, as we had little to no issues with this side of the project 24.

Toothpate Dispensing Tank

Initially, we planned to use a commercially available toothpaste tube and pump the toothpaste through a peristaltic pump to the nozzles. However, we faced a problem when the peristaltic pump proved too weak to push the toothpaste through the silicone tubing. Moreover, the pump was relatively cheap, and the motor and its reducing gearbox needed to be more robust to handle the high mechanical load, which would result in poor mean time before failure. Therefore, we had to come up with an alternative solution. We redesigned the system to use a lab syringe that could be easily refilled and replaced. The syringe is pushed by a lead screw, which is driven by a Maxon DC motor with a gearbox, coupled to a threaded rod that serves as a cheap lead screw 19.

Mouthpiece

The mouthpiece plays a crucial role in our system, as the quality of the user experience and effective teeth cleaning depends heavily on it. Initially, we attempted to produce our brush using a 3D-printed two-piece mould for silicone. This would allow us to manufacture a U-shaped silicone piece with holes to insert a soft brush from the market. However, we soon discovered that teeth cleaning is a complex field that requires multiple studies and testing before releasing a product into the market. After consulting with a dentist, we decided that, for this project's scope, it would be more prudent to purchase an existing brush from the market and adapt it to our design. Our main goal is to design an autonomous station rather than focus solely on teeth cleaning for the final proof of concept. Therefore, we ordered a brush from the French company Y-Brush and modified its mounting end to fit our design 15.

Vibration Motor

We initially planned to use a VZ6DL2B vibration motor from Vibronics as a vibration source, but it was too big for our swapping mechanism and would require upscaling. Instead, we opted for a flexible shaft with an eccentric mass driven directly by the rotor of a Maxon A-max motor. This motor offered superior performance and a wider range of reachable frequency. With a voltage supply of 24 V, we were able to control the motor current with PWM chopping. When we tested multiple vibrating brushes from the market, we found that the vibration frequency needed to be more well-defined, apart from ultrasonic brushes, whose frequency sits in the 10 kHz range. This was because most entry and mid-range products used a DC motor powered by an alkaline battery, which caused the voltage to drop and the frequency of the motor to decrease 16.

In the end, most brushes were situated around 200 Hz. We determined this frequency using a quick FFT with the microphone from a smartphone, as we wanted to keep the brush intact. With our previously discussed design, we can easily reach a sufficient frequency for the Y-brush of 250 Hz, and most of the vibrations are directly transferred to the brush, and little vibrations are transferred to the structure.

2.3.1 Concept of Operation

The operational concept of Brush'It is illustrated in Figure 1. To simplify user interaction, pressing the black button initiates regular operations such as teeth brushing and cleaning, while the red button can be used for emergency stops. Additionally, the buttons can be swapped for devices tailored to specific disabilities. Our prototype provides two barrel jack connections for each button.

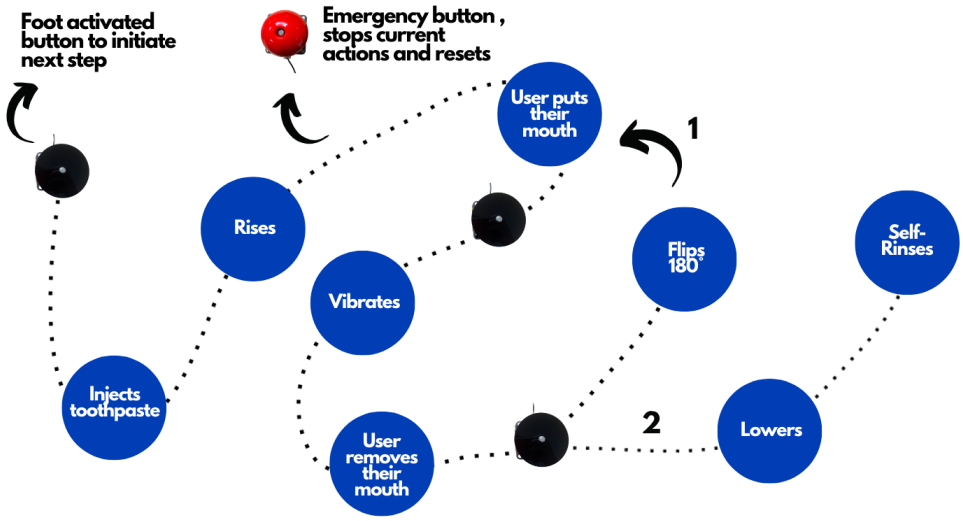


Figure 1: ConOps diagram describing Brush'it's steps of action

When the user presses the button, toothpaste will be applied, and the mouthpiece will rise for the user to access it. Once the user places the mouthpiece in the mouth and presses the black button again, the mouthpiece will vibrate to clean the lower jaw. Further button presses will initiate a 180-degree rotation to clean the upper jaw, with automatic descent for cleaning and readiness. The red button is an emergency stop, ensuring the user's safety and interrupting the process when needed.

2.3.2 Key Elements in the Design

The first key element of our prototype is the front-end mechanism for the U-shaped brush. As explained in section 2.2, the front-end mechanism is one of the critical elements of our design. This system has multiple functions, such as vibrating the brush, providing a hot-swappable mounting point, and a flipping mechanism for the brush. The system is water-resistant and offers hands-free device usage with the elevator.

The second key element in our design is the toothpaste dispensing station with the pump. Since it is impossible to pump toothpaste directly from the tube due to varying viscosity, we implemented a quick prototype for the toothpaste tank with a lab syringe, enabling easy refilling. This system also allows the user to select any toothpaste and can be easily serviced by any caretaker of a person with disabilities to refill the tank.

The third key element of our design is the connection to the water system, which provides direct access to a tap water supply and a grey water exhaust. Our prototype is fitted with a water solenoid with a Swagelok thread, to which we fitted a garden hose connection. The grey water exhaust is a washing machine-type pipe connection for easy installation with the grey water drain of any sink.

Finally, the last key element of our prototype is the two user control buttons, which we selected for their ease of use by those with reduced dexterity, whether with their hand or foot. Our prototype offers standard barrel jack connections, allowing customisable buttons that suit users with varying disabilities.

2.3.3 Further Optimisation of Key Elements

We have achieved our design goals for the front-end mechanism of the brush. However, due to the large size of the servo motor, we had to implement an off-axis transmission, which made the design more complex. To optimise the design further, we recommend using a compact DC motor with a gearbox and an encoder for the flipping function closest to the brush vibrator motor.

Our toothpaste dispenser prototype has a minimalist refilling station for the mouthpiece, but it can be improved. The bottom sink was 3D printed with the newly acquired Prusa XL available for students at the SPOT. However, due to high demand, we managed to get only one-time slot. As a result, our design is minimalist, and the technician of the printer couldn't guarantee a successful print. For future improvement, the station could be directly implemented in the design of the sink with toothpaste nozzles, water jets for cleaning, and water splash prevention features such as curved walls.

We recommend improving the connection with the water system with a pressure-releasing valve that allows our prototype to function with varying water pressure. The water jet exit was only implemented with a silicone tube with end caps serving as a nozzle. This function could be improved and implemented directly into the sink's design 22.

Our prototype offers a robust and minimalist user interface composed of a simple footswitch and an emergency button. One can tailor custom switching mechanisms to suit users with different types of disabilities. The emergency stop button could also be implemented into a circular handle around the device that can be easily triggered with either knees or hands with reduced dexterity and be reset into position to re-enable the full function of the device.

2.4 Manufacturing choices and proposals for future production

2.4.1 Prototype fabricaton

We managed to complete our prototype by finding most of the required components through refurbishing and dumpster diving at EPFL. We used aluminium profiles from an Ender 3 3D printer that we found in the trash to create the mechanical backbone of our prototype. By kit bashing the printer, we obtained a linear bearing with a base that could withstand a large

amount of force and used it as a mounting base for the mouthpiece front end.

All electronic components were ordered from reputable brands and sources, which allowed us to have little to no issues with this aspect of the project. For the wiring connections, we used standard Molex connectors and push-to-release board connectors found in industrial machines in DIN rail electronic boxes to offer us flexible and reliable connections when needed.

We manufactured many structural elements from PMMA cutting with a CO2 laser available at the SPOT and the SKIL to produce planar components quickly. For 3D components, we extensively utilised the numerous available 3D printers at the SPOT and the SKIL, including the newly acquired Prusa XL, due to its high printing volume and speed.

We used refurbished medical-grade silicone whose expiration date was reached. We were given to us for free by a local medical company to manufacture the many water seals, vibration dampening, and flexible structural elements.

One challenging aspect of our prototype was protecting it from water spills, the user's hair or fingers. We made the front end as water-resistant as possible, and for the electronics, we protected everything with a PMMA panel pass-through hole only when necessary. We used a standard off-the-shelf transport belt to protect the user from the device for ingress protection for the elevator.

Finally, we utilised biocompatible silicone tubing with a Swagelok connector for reliable toothpaste and water tubing connections. The water inlet is a standard garden hose for the demonstration.

2.4.2 Final product

We want to clarify that the final product will differ significantly from our current prototype. The prototype is mainly focused on testing the concept and optimising its function at an early stage of development. It also allows us to test the ergonomic functionality of the device, including user inputs and interactions.

We rely heavily on simple prototyping means such as 3D printing, CO2 PMMA laser cutting, and developing electronic boards to manufacture prototypes. Due to the limitations of our budget and timeframe, the components used in the prototype are basic in their features and implementation. These limitations heavily influence the design of our current prototype.

As we transition from prototyping to market production, several key considerations must be considered to ensure a successful and cost-effective development process. The initial prototype focused on concept testing and functionality optimisation and served its purpose in the early stages of development. Now, to transform it into a market-ready product, strategic adjustments are necessary.

Means of Production Selection

In transitioning from a prototype to an early production stage market-ready product, the choice of production methods plays a pivotal role. The production methods would also heavily influence the design due to their advantages and limitations. For example, most of the structure of our prototype could be rethought with plastic injection moulding as a production method, offering

the ability to create intricate shapes and mounting points to reduce fastener dependence during assembly and enhance water resistance by utilising ultrasonic welding or plastic fusing glue to provide a good seal quality. By implementing functional features into structural components, we can significantly reduce the complexity and cost of assembly of our initial prototype while keeping the same functionalities, reducing assembly errors, and improving overall quality for a larger production volume.

Material Selection

When choosing materials for our product, we prioritise biocompatibility to ensure user safety and product functionality. We used a U-shaped brush from the market and bio-compatible silicone tubing with interconnects for our initial prototype. To ensure user safety, we also used medical-grade Loctite glue for all joints of the elements that could interact within the user's mouth. Since some parts of the product come into direct contact with the mouth, the chosen materials must be non-toxic and hypoallergenic to minimise the risk of adverse reactions. Additionally, water resistance is crucial to maintain its longevity since the product is exposed to moisture. Lastly, chemical stability is also essential, as the materials must withstand exposure to oral care products without compromising their structural and chemical integrity.

Assembly Processes

To improve the feasibility and efficiency of our prototype for future production, we need to focus on streamlining the assembly process. The current prototype has a complex assembly with nearly a hundred fasteners and multiple potential points of failure, which poses challenges. Therefore, we need to adopt a redesign strategy that prioritises simplifying the assembly process by reducing the number of fasteners and consolidating components to minimise the points of failure.

Our prototype uses glue to fuse multiple elements due to the water resistance constraint, and it was not possible to implement a modular design with an o-ring and screw for maintenance within the short timeframe of this course. For example, the vibration motor is encapsulated in glue and plastic because of its short proximity to the user, and we need to guarantee water resistance and electrical safety for the user.

We should incorporate user-friendly features such as colour-coded or modular elements to facilitate a smoother assembly process. This will enhance the overall quality of our future product and contribute significantly to increased efficiency during mass production and ease maintenance on future stations if required.

Upgraded Electronic Components

As we move from prototype to market production, we must redesign and adapt the electronics to ensure optimal performance and reliability. We also need to redesign and test the circuit for compliance with various electrical regulations, including safety standards like IEC (International Electrotechnical Commission) or UL (Underwriters Laboratories), EMC (Electromagnetic Compatibility) Compliance, Environmental Regulations such as RoHS (Restriction of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment) directives, and certification like CE marking for the European Union or FCC (Federal Communications Commission) for the United States.

We'll implement the electronics on a printed circuit board to automate production and testing. Since washrooms can be moist, we must protect the electronics from moisture and protect users from electrical shock. We'll either encapsulate the electronics in a fully isolated plastic enclosure with epoxy or conformally coat the circuits if exposed to the air.

Our product is intended for use in washrooms, where electrical safety standards and legal regulations are strict, so we must prioritise user safety. Most of our products are plastic-encapsulated, but as our product requires main power, we must choose a good quality switch mode power supply that offers better user protection. If any metal is exposed to users, we must implement ground fault circuit protection to ensure their safety.

User Interface Refinement

The current prototype interface is minimalist and requires significant improvement to allow for customisation and intuitive design for the user. Moreover, we must refine the caretaker interface to cater to this market segment. Our main selling point is time optimisation for caretakers; therefore, we must ensure that maintenance, such as cleaning, toothpaste refilling and descaling, is easy.

2.4.3 Quality analysis and control

Collaborating with healthcare professionals and dentists for comprehensive testing provides valuable insights into the efficacy of oral hygiene products and the user experience. A thorough analysis of user feedback is conducted to evaluate the usability of the toothbrushing station, ensuring that it meets the needs of consumers. Evaluations by dentists provide expert opinions on brushing quality. This iterative and collaborative approach to testing addresses usability concerns and enhances functionality, ensuring that the product consistently meets established dental care standards.

To protect electronic components, rigorous testing protocols for water resistance must be implemented. Moreover, stringent verification processes are in place to confirm compliance with industry standards, encompassing aspects such as electrical safety and material adherence. Obtaining quality certifications from regulatory bodies adds credibility, reassuring consumers that the product strictly adheres to established benchmarks.

At the same time, a robust quality control system is established throughout the production process to ensure that each toothbrush station meets the highest standards. Regular inspections and testing at various production stages identify and rectify potential defects or deviations from specifications. Continuous improvement initiatives are seamlessly integrated into the production workflow, using insights from quality control processes and consumer experiences. This proactive approach guarantees the consistent delivery of high-quality products and fosters continuous innovation and enhancement. Our unwavering commitment to quality control and ongoing improvement underscores our dedication to providing consumers with top-tier oral care solutions.

3 Intellectual property

3.1 Prior art search

In the early stages of our concept development, we analysed the market to see if our idea was new or if there were already similar offerings on the market. Brush'it's competition is explained in more detail in section 4, but it is clear that there is definitely room for a patent because Brush'it is so unique as an all-in-one toothbrushing station.

3.2 Patent search

The analysis of Brush'it focused on the concept as a whole and its sub-functions for patent potential. The examination encompassed the U-shaped toothbrush, the toothpaste dispensing mechanism, and features like the self-cleaning mechanism, wall-mount capability, connection to the water supply, drainage, and fully automatic hands-free operation. This section presents the existing state of the art, and the determination is made regarding the novelty of Brush'it.

3.2.1 U-shaped toothbrush

Several products and patents in the market cover U-shaped toothbrushes, available in both manual and electric variations, with single or dual-sided designs allowing simultaneous brushing of the upper and lower teeth. These products claim construction characteristics, bristles, and brush operation innovations. Figure 2 illustrates a representative example of an existing patent for a U-shaped toothbrush. As the U-shaped brush in our project relies on existing research and is sourced as a commercially available part (Y-brush) for the prototype, no novel contributions are made to the existing art.

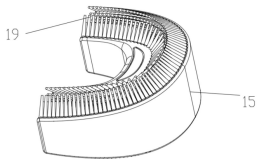


Figure 2: Drawing of patent CN211933032U Integrated U-shaped toothbrush

3.2.2 Toothpaste dispensing mechanism through slits

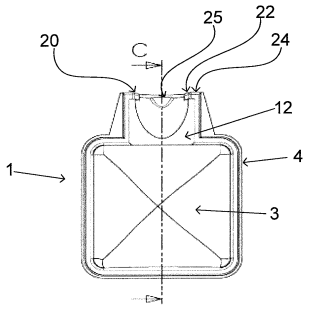


Figure 3: Drawing of patent WO2014051495A1 Dispensing mechanism for fluids

As the mouthpiece for the prototype is not manufactured in-house, the toothpaste dispensing mechanism through the slits is exclusively intended for the product. Through research into existing solutions, it was found that valve systems with an extended cross-section in the positive direction of fluid flow have already been patented, as depicted in Figure 3.

3.2.3 Combination of features results in novelty

Some features of Brush'it are found in existing products and are also patented. However, the novelty lies in combining these features, enabling a fully hands-free and automatic toothbrushing process, including toothpaste dispensing and toothbrush cleaning. The following patents protect properties that the Brush'it also has but are never exactly the same. See annexe 7.4 with figures 28/29, 30/31, 32 and 33 for an illustration of the considered patents.

- Patent CN203969615U Needle cylinder type portable travelling tooth set: It protects an automatic toothpaste dispensing mechanism similar to Brush'it's, but not for a U-shaped brush.
- Patent WO2019103701A1 Automatic Tooth Cleaning Device: This is an automatic U-shaped toothbrush with automatic cleaning fluid dispense but it can not be wall- or table-mounted.
- Patent CN209574940U Wall-mounted electric toothbrush: It's wall-mounted but not with a U-shaped mouthpiece nor automatic toothpaste dispensing or automatic rinsing of the brush.
- Patent AU2018331426A1 Electric toothbrush with fluid streaming capability: It is connected to a water source but not wall-mounted and does not have automatic toothpaste dispensing.

3.3 IP strategy

3.3.1 Patentable mechanisms

In pursuing comprehensive IP protection, the goal is to patent the harmonised system mechanisms of the toothbrushing station. This involves the integrated operation of multiple components, such as the syringe propeller for toothpaste refilling, the code governing controlled toothpaste dispensing through the sink mechanism with strategically positioned slits, and the lift ensuring precise positioning of the toothbrush. Seeking a patent for the entire system ensures exclusive rights to the coordination and interaction of these elements. It is noteworthy that, as of now, there is no actual product in existence embodying this system.

3.3.2 Main claim of Brush'it's patent

In view of the existing patents and the novelty that Brush'it brings, the first draft of the main claim could read as follows:

"The present invention relates to an automatic and hands-free tooth brushing station, in which the only user input is the push of a button. The station can be set up on a wall or a table and has a basin with nozzles for toothpaste and water, which holds a U-shaped brush when not in use. This brush is attached to the lift by a horizontal arm. When the button is pressed, the brush is raised so that it is at the optimum height for the user during brushing. The invention furthermore relates to automation also, including dosing the toothpaste and rinsing the toothbrush after brushing."

3.3.3 Design protection

Figure 4: Design render of Brush'It concept

Considering the originality of the toothbrushing station—especially its small, hands-free design connected to a water supply—pursuing a design patent can be a wise course of action. The design is distinctive and easily identifiable because of its unique characteristics, including its hands-free functioning, self-activation, auto-washing and display of toothpaste, wall-mounted, and suitability for use in healthcare and senior living facilities. A design patent could safeguard distinctive features that enhance the station's visual appeal.

3.3.4 Trademarks and branding

Getting a representative logo registered as a trademark is essential to building a solid brand identification for the product. The trademark ensures exclusive rights to the visual representation, reinforcing the station's unique attributes and differentiating it from competitors. This preserves the brand while simultaneously fostering consumer recognition and trust. It is an invaluable resource that enhances the entire branding strategy and establishes the toothbrushing station as an identifiable product in the marketplace.

Brush'It

SIMPLIFYING SMILES,
EMPOWERING LIVES

Figure 5: Brush'It logo

4 Aspects of a pre-Business plan

4.1 Market

Brush'it addresses the oral care challenges of individuals with limited hand mobility, serving an ageing population and those with disabilities. The product targets individuals facing difficulties in fine motor skills due to age, disability, or illness. Additionally, Brush'it aims to streamline oral care in healthcare facilities like hospitals and nursing homes, alleviating the workload for care staff.

Switzerland's health system, boasting 37,970 hospital beds and accommodating 100,354 individuals in nursing homes, presents a significant market potential [6]. Approximately 13.6% of those aged 80 and above utilise institutional accommodation, while 32.4% benefit from in-home care support [6]. Adding up the available places in hospitals and care homes and the people who need home care, assuming that half of these people need Brush'it and then 10% actually buy it, we would sell about 11,700 products. See Appendix 7.4 for a detailed market assessment. Furthermore, about 18% of Switzerland's population, approximately 1.57 million individuals, lives with some form of disability, suggesting a potential market of around 157,000 individuals facing hand-related challenges [8]. Moreover, a considerable portion of the 166 million disabled individuals in Europe experience gum health issues due to oral care struggles [5].

Switzerland's favourable environment for startups, especially in the MedTech sector, is noteworthy, with the Swiss MedTech sector generating over CHF 17.9 billion in revenue in 2021 [1]. Brush'it plans expansion into key European markets with similar demographics and a focus on accessibility. With 4.6 million hospital beds across Europe, expanding definitely promises success[10].

Figure 6: Toothbrush from Y-Brush

Competitors in the oral care industry include first of all the ordinary toothbrush and traditional brands like Oral-B and Philips Sonicare, offering adaptive products. Contemporary alternatives like Sonic Brush® [3], Amabrush [2] and Y-Brush [12], resembling a mouthguard, as can be seen on figure 6 share similarities with Brush'it's concept.

Nevertheless Brush'it stands out. A comparison is shown on figure 7. It can be seen that Brush'it's fully automatic, hands-free setting distinguishes it as a unique selling proposition. Market trends indicate a growing demand for inclusive products, aligning with Brush'it's objectives, while technology integration in personal care products emerges as a notable industry shift [9].

Figure 7: Comparison between Brush'It and its competitors

4.2 Strategy towards commercialization

The path into commercialisation is based on a comprehensive approach that emphasises as main points product functionality and commitment to inclusive design. Targeted marketing campaigns will specifically reach individuals with hand disabilities and their caregivers.

An impactful online presence featuring a dynamic website and active social media engagement forms crucial touchpoints. Collaborations with influencers and advocates in the accessibility and disability community will amplify our message. Communication efforts include educational campaigns and user testimonials for authentic narratives, positioning the product as a solution. Establishing partnerships with healthcare professionals and institutions, like dentists, rehabilitation specialists, hospitals and nursing homes, and insurance companies advocates for adopting individualised toothbrushes, reducing workload and costs associated with communal oral care practices. This enhances product credibility and ensures recommendations within healthcare networks. Additionally, prioritising widely-used online sales channels like Amazon or Galaxus enhances accessibility, facilitating the product's availability and reach to a broader audience. The launch and initial rollout will focus on Switzerland, gradually expanding to key neighbouring European markets like Germany, France, and Austria.

Key performance indicators and feedback mechanisms will be established to measure the success of marketing campaigns, product adoption rates, and user satisfaction to inform adjustments to thecommercialisationn strategy.

4.3 Organization

At the core of Brush'it is a dynamic team of five individuals, each bringing a unique set of competencies, motivations, and expertise to the table.

Kelan leads with strong organizational skills, managing the team and contributing to both mechanical and coding domains. Joel exhibits a steady commitment, skillfully integrating

mechanical intricacies with electrical components. Maxence combines business strategy, technical expertise, sales acumen, and mechanical skills. Samira transitions seamlessly between mechanical, manufacturing, and marketing operations. Mehdi excels in brand communication and showcases flexibility in technical and manufacturing skills. Brush'it covers the entire spectrum of tech business, from idea conceptualization to practical fabrication, implementing effective marketing strategies. Embracing agility and collaboration, the flat organisational structure ensures active contributions from every team member and adaptability to startup needs.

4.4 Planning

The growth plan for Brush'it unfolds over several phases. Initially (Year 1-2), the focus is on executing a coordinated launch in Switzerland, emphasising targeted marketing, user feedback integration, and establishing partnerships with healthcare institutions.

Progressing into Years 3-5, the vision extends to European market entry, technological enhancements, and scalable production. Beyond Year 5, global expansion is pursued, exploring diverse markets and expanding the product line. Simultaneously, there is a commitment to R&D, corporate social responsibility, and strategic alliances for sustained impact. Organizational development remains pivotal, with a focus on team expansion, continuous training, and fostering an innovation-centric culture. Financial sustainability is maintained through profit reinvestment, diversification of revenue streams (exploring licensing agreements with dental tech companies), and collaborative ventures (joint initiatives with oral health NGOs).

4.5 SWOT analysis

The toothbrush designed for individuals with hand disabilities possesses several strengths that set it apart in the market. Its user-centric design and technological integration align with current market trends, providing a competitive edge. The company's strong commitment to inclusivity, reflected in strategic partnerships with healthcare institutions, enhances its market presence.

However, challenges include a limited initial market reach in Switzerland and potential manufacturing complexities. Dependency on technological trends may pose risks, and the niche focus on individuals with hand disabilities might limit broader market appeal. Opportunities lie in the growing ageing population globally, initiatives promoting accessibility, and the potential diversification of the product line. Strategic collaborations can amplify the product's social impact. However, threats, regulatory challenges, potential economic downturns affecting consumer spending, especially considering the target customers' reliance on state assistance or caregiver support, and risk of resistance to change among the target demographic, who may have already found adapted solutions. Addressing these challenges will require strategic navigation and innovative approaches in the dynamic market landscape.

4.6 Pricing analysis

The table below shows that our estimated price of around 180 CHF places Brush'it competitively, considering its uniqueness. This price includes a profit margin of around 30% on top of the production cost of 140 CHF to keep the business going and cover costs linked to the product launch. In Annexe 7.4, you can find the cost evolution from the prototype to the commercialised product.

Product	Brush'it	Ordinary	Electric	Waterpik®	Sonic Brush®	Y-Brush	Amabrush
Price (CHF)	180	2-5	50-200+	238	90	129	80-100

5 Project management

5.1 General strategy

A structured approach was implemented to organise the team effectively using communication tools and regular meetings. WhatsApp served as a primary platform for group discussions and organisational updates. Two weekly meetings were conducted, one internally among team members and another with the Teaching Assistant every Friday. Written minutes were diligently recorded during these sessions to document accomplishments, challenges faced, and the action plan for the upcoming week. Additionally, shared collaborative folders on Fusion 360 for the CAD, GitHub for the code and Google Drive for miscellaneous files facilitated seamless coordination, allowing team members to access and contribute to project files efficiently.

5.2 Work breakdown structure

An important tool for this project is the work breakdown structure displayed in a reduced format in Figure 8 and in full in the Annexe 7.4 Figure 38. This diagram has changed a lot throughout our project. We can compare the difference between our final WBS and the original one in Annexe 7.4 Figure 39. It is interesting to note the substantial differences in the mechanical structure.

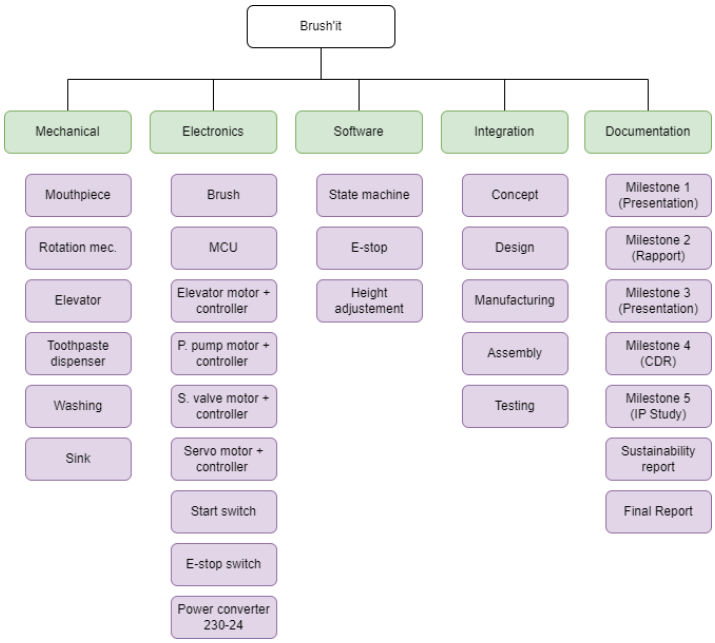


Figure 8: Brush'it's Current WBS (reduced)

5.3 Interface Diagram

To not miss any critical interfaces and to make collaboration as smooth as possible, we used an interface diagram as seen in Annexe 7.4 Figure 37. This allowed us to divide work efficiently, ensuring that nothing would be overlooked.

5.4 Stakeholder analysis

In this stakeholder analysis, we'll explore the diverse interests of key parties involved in our dental care device project, including end users, families and caregivers, and government or social security entities. Understanding their unique needs is essential for meeting regulatory compliance, enhancing user autonomy, and ensuring effective dental care.

For End Users:	For Family/Caregivers:	For Government/Social Security
Hands-free operation of the device	Knowledge of toothpaste quantity	Compliance with existing legislation
Suitability for individuals of all sizes	Access to usage history	Cost savings by enhancing the independence of individuals with disabilities
Ability to adapt the device for each user condition	Ease of recharging and maintenance	Feedback on results
Notification when brushing is complete	Easy to install and setup	
Effective teeth cleaning		
Long time with no maintenance		

Table 1: Needs for the 3 most important Stakeholders

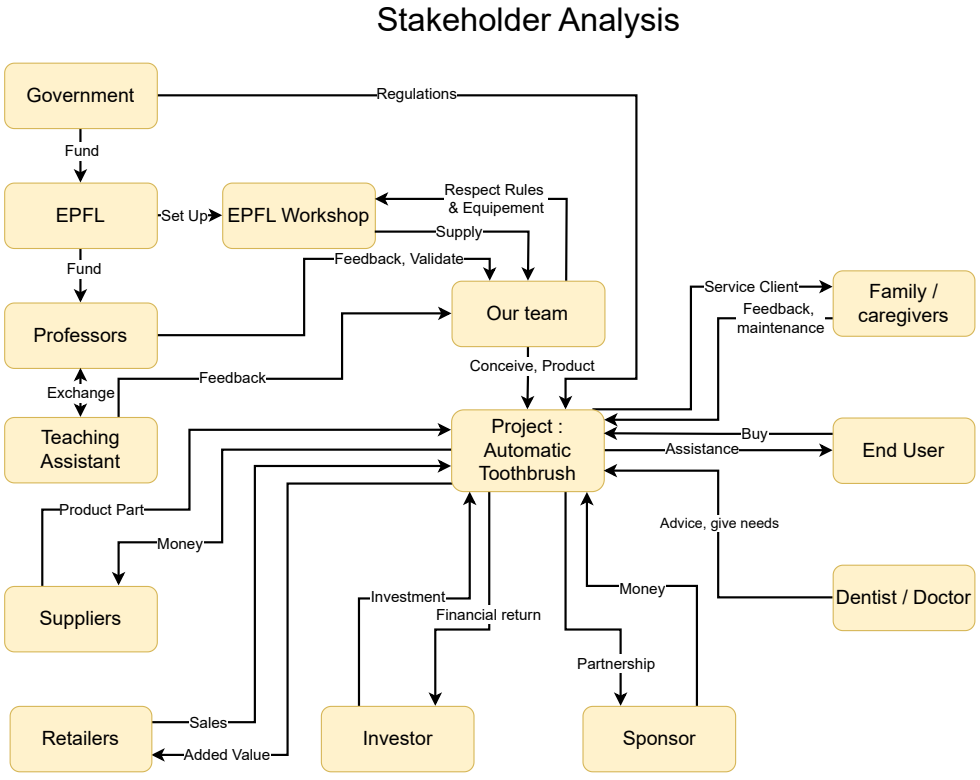


Figure 9: Stakeholder Diagram of the project

5.5 Gantt chart

5.5.1 Initial plan

The initial Gantt chart, detailed in Annex 7.4, guided the research and conceptualisation phase, focusing on adaptive toothbrush designs and the U-shaped concept, concluding by October 26. Subsequent design efforts covered U-Brush features and the development of a hot swap mechanism. Fluid injection exploration included gland cable, silicon moulding, and peristaltic pump applications. Critical rotation, vibration, and elevator mechanisms underwent extensive research until the first week of December. The electronics integration phase, targeting completion by December 21, involved activation sensor research, integration with brushing mechanisms, and Arduino coding. A dedicated two-week user testing and feedback period followed for comprehensive refinement based on real-world usage.

5.5.2 Deviation from the original planning

The U-Brush component posed unexpected challenges in manufacturing due to complexities in brush incorporation, silicon moulding, and prototype iterations. To address time constraints and intricacies, a strategic decision was made to purchase a U-Brush, simplifying the process but incurring additional costs. Similarly, choosing a peristaltic pump for toothpaste injection deviated from the plan. Practical implementation revealed insufficient pressure, leading to a return to brainstorming for an alternative method (syringe pump). This adjustment consumed additional time and caused delays in other project aspects, such as sink manufacturing. Numerous prototyping adjustments involving extensive 3D printing and laser cutting further consumed valuable time. These changes impacted both the assembly and feedback phases, resulting in suboptimal outcomes, including not realising the planned water supply.

5.5.3 Reflections

The challenge of building and conceptualising a product from A to Z within a limited timeframe provided an interesting learning experience. While initially envisioning a linear progression through each step, the realization was that theory does not always align with reality. A valuable lesson learned was the importance of relying more on rapid prototyping. Instead of committing extensive time to creating CAD models for all components and attempting a comprehensive assembly, submodulating larger parts to test mechanisms quickly and using basic materials to evaluate whether they worked would have saved significant time and costs and streamlined the project development process.

5.6 Division of tasks

Joel: Took care of the design, fabrication and component choice of the electronics

Samira: Worked on the design of the horizontal mechanism and the production of 3D-printed and laser-cut parts. She was also involved in conducting market and IP analyses and preparing presentations.

Kelan: Was in charge of the software, including the automation as a finite-state machine. He also designed and manufactured the toothpaste extruding mechanism.

Maxence: Worked on the elevator, the elevator casing and to make the whole system splashproof.

Mehdi: focused on the marketing and communication aspects of the project. Additionally, he contributed to the mechanical designs, including CAD conceptualization and hands-on tasks such as manufacturing through laser cutting and 3D printing of pieces. Also, he played a role in assembling, report writing, and creating presentation slides for the project.

6 Conclusions

6.1 Assessment of specifications

The needs and optional features that we wanted Brush'It to have were listed in section 2. Now, we will analyse if we achieved these specifications and discuss what would have to be different for the final product. The specifications written in italics refer to the optional features.

Specification	**Achieved?**
1. Effective cleaning of the upper and lower teeth arcades	To an extent
2. Swappable brush head	Yes
3. Hands-free flipping of the brush	Yes
4. Automatic vertical lift for the brush at the user-specified height	Yes
5. Toothpaste should be dispensed automatically when the device is initialised	To an extent
6. After use, the brush will be cleaned automatically	To an extent
7. Ensure compatibility with both the tap and greywater systems	Yes
8. Reliable electronic, software and user input control	Yes
9. Ensure the safety of the user, both electrically and mechanically	Yes
10. Emergency stop input for the user	*Yes*
11. Customisable user input to accommodate different types of disabilities	*To an extent*
12. Configurable brush height and brush time	*No*
13. Rinsing of the entire sink with tap water	*No*
14. Companion app for configuration, either via Bluetooth or wifi	*No*
15. Descaling process to ensure the longevity of the device	*No*

Remarks

1. Because of the mechanical connections between the vibrator and the mouthpiece, a lot of vibration is lost.
2. The mouthpiece connector allows for a hot swap of the mouthpiece.
3. The servomotor allows for a 180-degree rotation.
4. The mouthpiece is raised automatically after the toothpaste has been dispensed.

5. The toothpaste mechanism with the syringe works very well. The stepper motor can dispense toothpaste through the tubes without problems. Nevertheless, as implemented in the prototype, the toothpaste does not stick to the brush perfectly. Therefore, in the product where the brush head would be made of silicon, we would implement the dispensing through slits such that the toothpaste stays on the mouthpiece.

6. Whilst the principle of our rinsing mechanism is reasonable and works, more pressure is needed to rinse and properly clean the mouthpiece to ensure hygiene effectively. Therefore, a pump instead of the solenoid valve would control the water flow in the product.

7. The device can easily be connected to a water supply and greywater systems.

8. The user input consisting of pressing the big black button is very easy and can be done hands-free. Electronics and software work well.

9. The safety is assured by the security belt preventing anything from getting caught in the elevator and the emergency button taking care of whatever we may not have considered.

10. The emergency button had to be implemented to ensure safety. It became a need and not only an option.

11. The height can be configured to the user's needs when installing the device. Nevertheless, once installed, the height can not be changed anymore. As for the buttons, they allow for a lot of flexibility in their positioning and use (hand, foot, knee,...).

12. As of now, the sink is not rinsed. This is to develop the product.

13. No app was configured to control the height of the mouthpiece once Brush'It is mounted on the wall or a table. This would be a very nice feature for the final product, especially if the app has speech control as the user may not have hands and therefore, may not be able to type on an interface.

14. To ensure longevity, a descaling process has to be implemented in the final product.

6.2 Thoughts on the technical aspects

Overall, we're very satisfied with the end result of our project. We feel that our mechanism is creatively designed and meets a need that the current market does not satisfy. However, there are some points that we would do differently next time.

We are proud that we managed to fulfil all our needs, even if some of them only to a certain extent. In the future, we will test important mechanisms such as rinsing the brush earlier to ensure we can optimise them in the prototype. Producing the mouthpiece from silicone for our product would involve working with researchers and dental facilities to ensure that the teeth are well, without damaging gums or enamel. It is a complex topic on which much research has been done. Therefore, we think that making the mouthpiece ourselves is something that we could only have achieved in a period of more than one semester. Nevertheless, it would definitely be the optimal solution for the final product as the silicone material would also allow for the toothpaste dispensing through slits solving the problem of adhesion that we had with the prototype.

6.3 Thoughts on the management aspects

In terms of the organisation and running of the project, the group work was a great experience. We were a highly motivated group, and it was encouraging to see everyone contributing to the progress of the project. It was interesting to see how different people find different solutions to problems. Comparing ideas and weighing up the pros and cons allowed us to practise our communication and ability to work in a group.

The decision for the group members to work on different functions of the mechanism, for example, elevator, horizontal arm or toothpaste dispensing, instead of dividing the work according to mechanical or electronic aspects, was a good way of designing the mechanism in an efficient way because the design was done in parallel. On the other hand, it left the electronics to the end. Fortunately, we didn't have any major problems, but we will plan a bit more time for this stage next time.

The frequency of our meetings (twice a week and obviously more towards the end of the semester) was necessary and enabled us to keep up to date with the progress of our respective tasks. The Gantt chart helped us keep deadlines in mind. In addition to the Gantt chart, we also created an Excel document where we listed all the parts and tasks that needed to be done with the name of the person who had to deal with them and the current status: to do, in progress, to be reviewed, done. This enabled us to manage the work well. Next time, we would add binding deadlines to speed up the work.

Linking the development of a project with its management aspects, market analysis, and intellectual property was very interesting and gave us a good overview of what product development looks like in companies.

6.4 Outlook

We think Brush'it is worth investing in. However, a lot of work remains to be done in order to make it ready for sale, especially improvements linked to the mouthpiece. If we were to optimise Brush'it further, we would also implement more optional specifications like a descaling process and configuring the brush height and time. However, it is still unclear whether one of our group members wants to pursue the idea further. But if Brush'it were on the market eventually, it could give back a little bit of autonomy to thousands of people in Switzerland and on the globe and hence contribute to their mental well-being.

7 Annexes

7.1 The initial project idea

Figure 10: Early Render of Project Idea in Fusion 360

7.2 Technical drawings

7.2.1 Kitbashed Ender 3 3D Printer

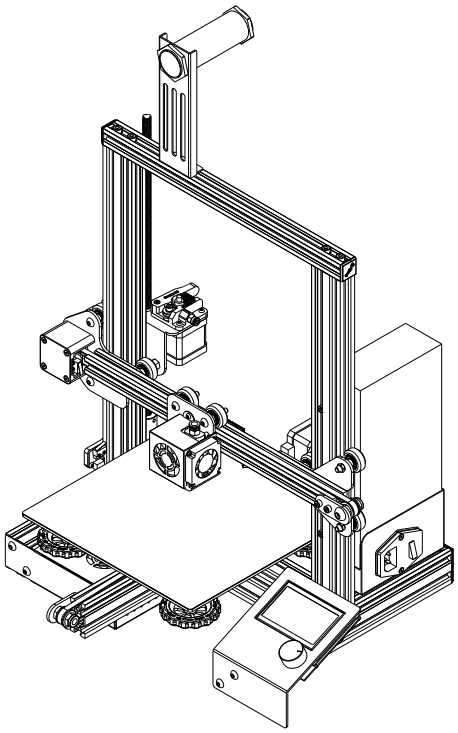


Figure 11: Original Ender 3 3D Printer

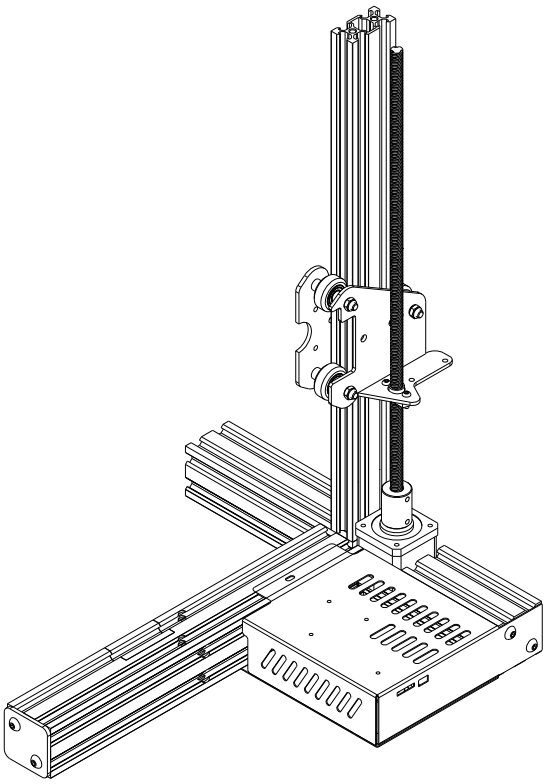


Figure 12: Elevator Implementation Utilizing Authentic Components Derived from the Ender 3 3D Printer

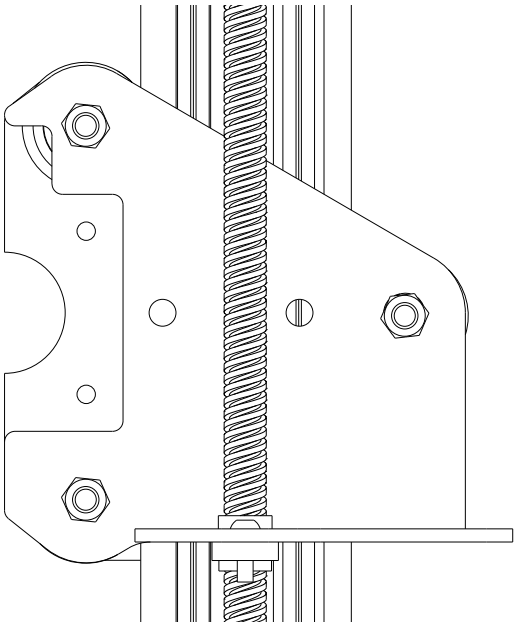


Figure 13: Modified Three-Wheel Aluminum Extrusion Roller Assembly Driven by a Lead Screw

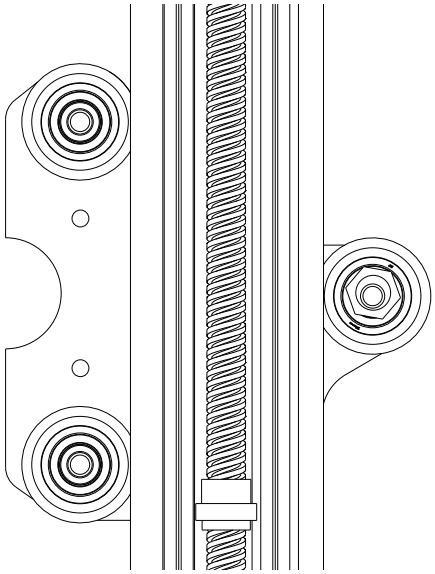


Figure 14: Aluminum Extrusion Roller with Three Wheels: The Third Wheel (on the right) is Adjustable via Off-Axis Nut Rotation for Optimal Friction Adjustment

7.2.2 Front-End Assembly

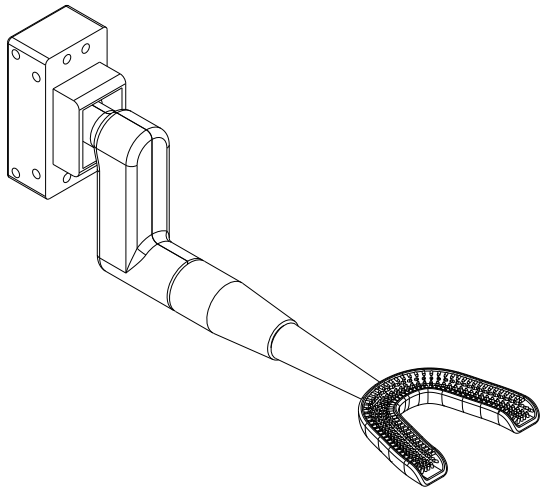


Figure 15: Front-End Assembly: Off-Axis Transmission, U-Shaped Brush Mounted

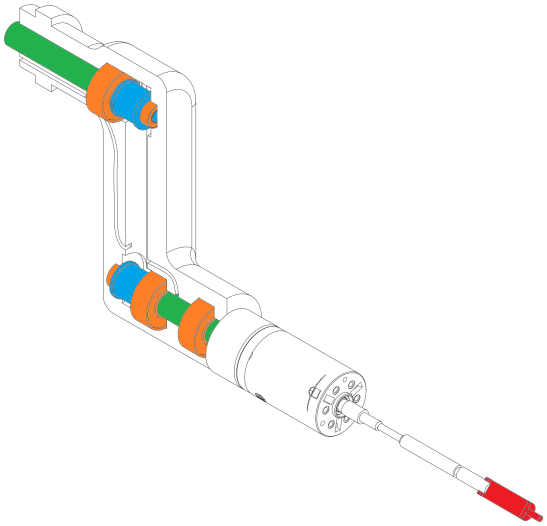


Figure 16: Front-End Internals: Off-Axis Transmission for the Half-Turn Rotating Axis (Green) with Two Timing Belt Pulleys (Blue), Ball-Bearings (Orange), and a Maxon Motor with an Eccentric Rotating Mass (Red)

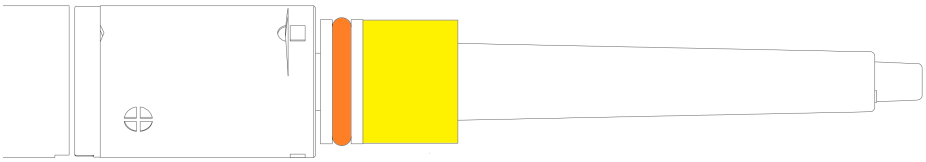


Figure 17: U-Shaped Brush Mounting Point: Orange O-Ring for Water Protection, Yellow Silicon Bushing for Vibration Damping and Structural Reinforcement

7.2.3 Toothpaste Dispenser Pump

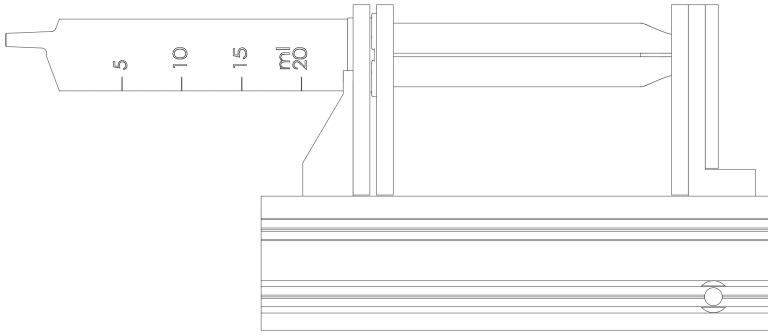


Figure 18: 3D Printed Mount for Toothpaste Tank Syringe: Lead Screw with Maxon DC Motor and Gearbox for Mechanism Drive, Aluminum Profiles for Linear Guidance of Seringue Sliding Pusher

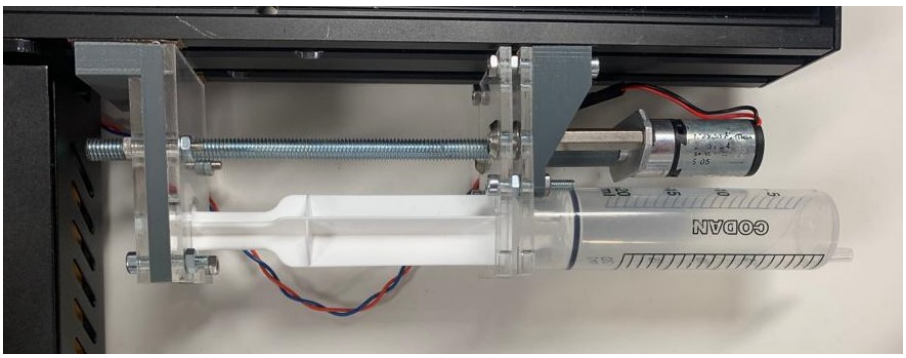


Figure 19: Final Seringue Toothpaste Pump

7.2.4 Full Assembly

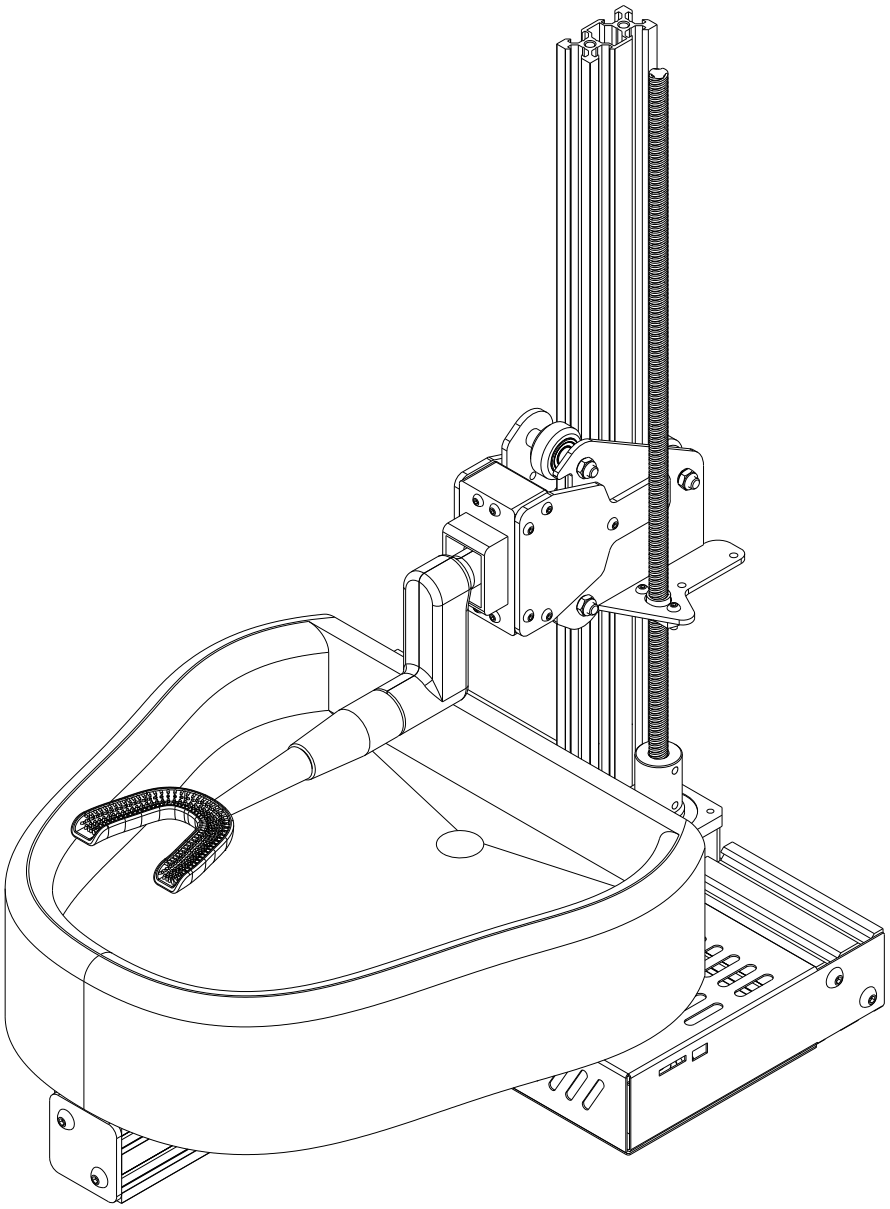


Figure 20: Assembly without Protective Wall and Ingress Protection Belt

Figure 21: Garden Hose Connection (Right) and Washing Machine Gray Exhaust Connector (Left)

Figure 22: Final Prototype

7.2.5 Electronics Prototype

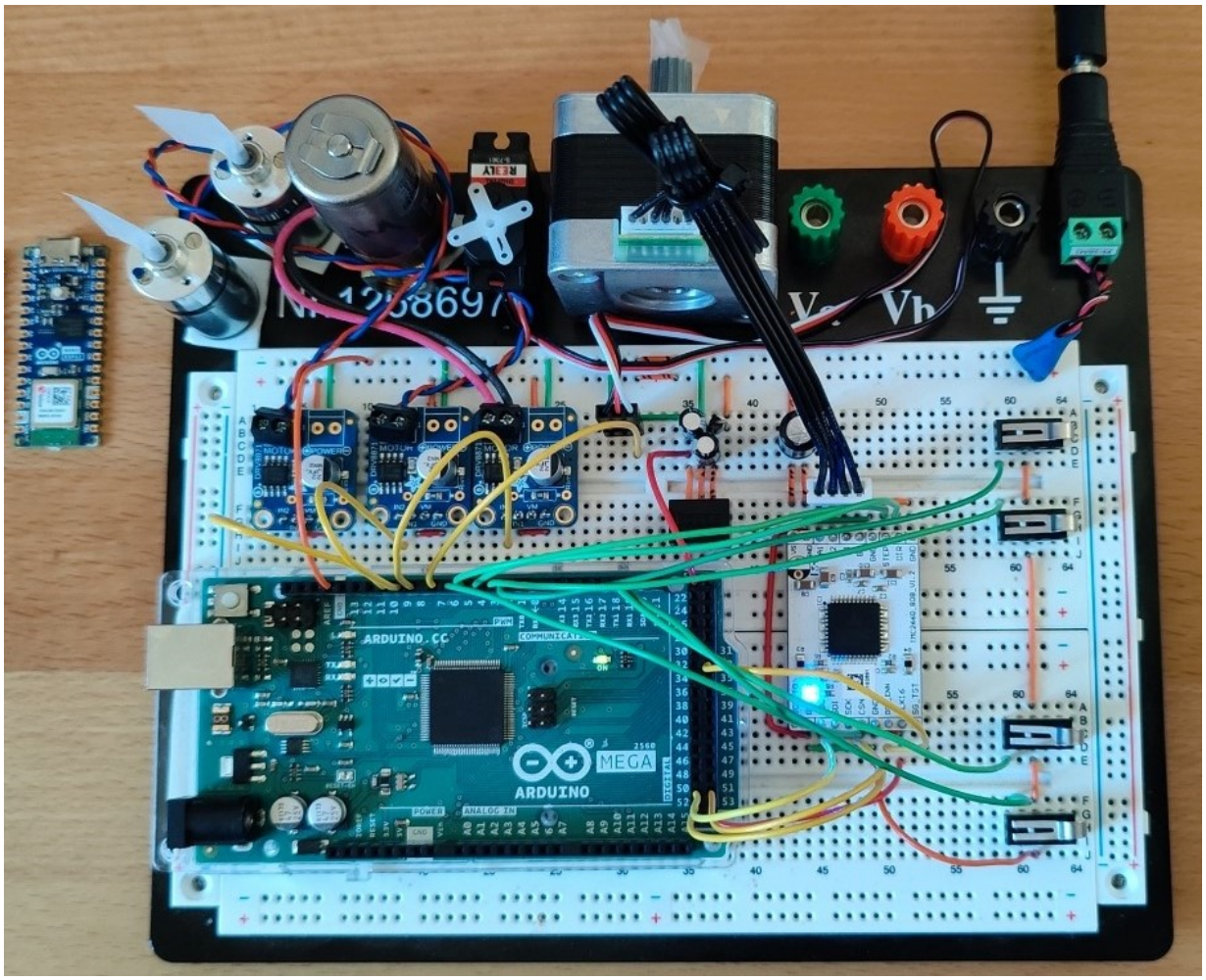


Figure 23: Early-Stage Electronic Prototype on Breadboard: Initial Power Rails Wired with Jumping Wires, Signals Connected to Arduino Mega

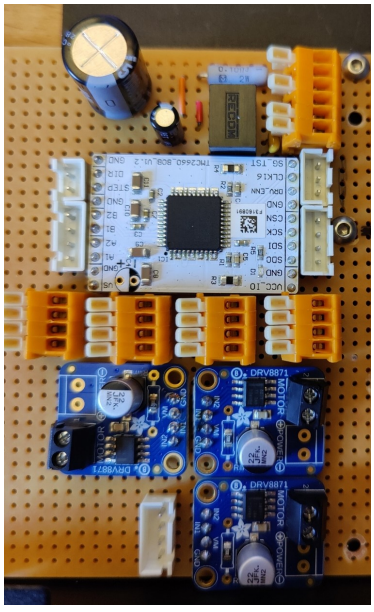


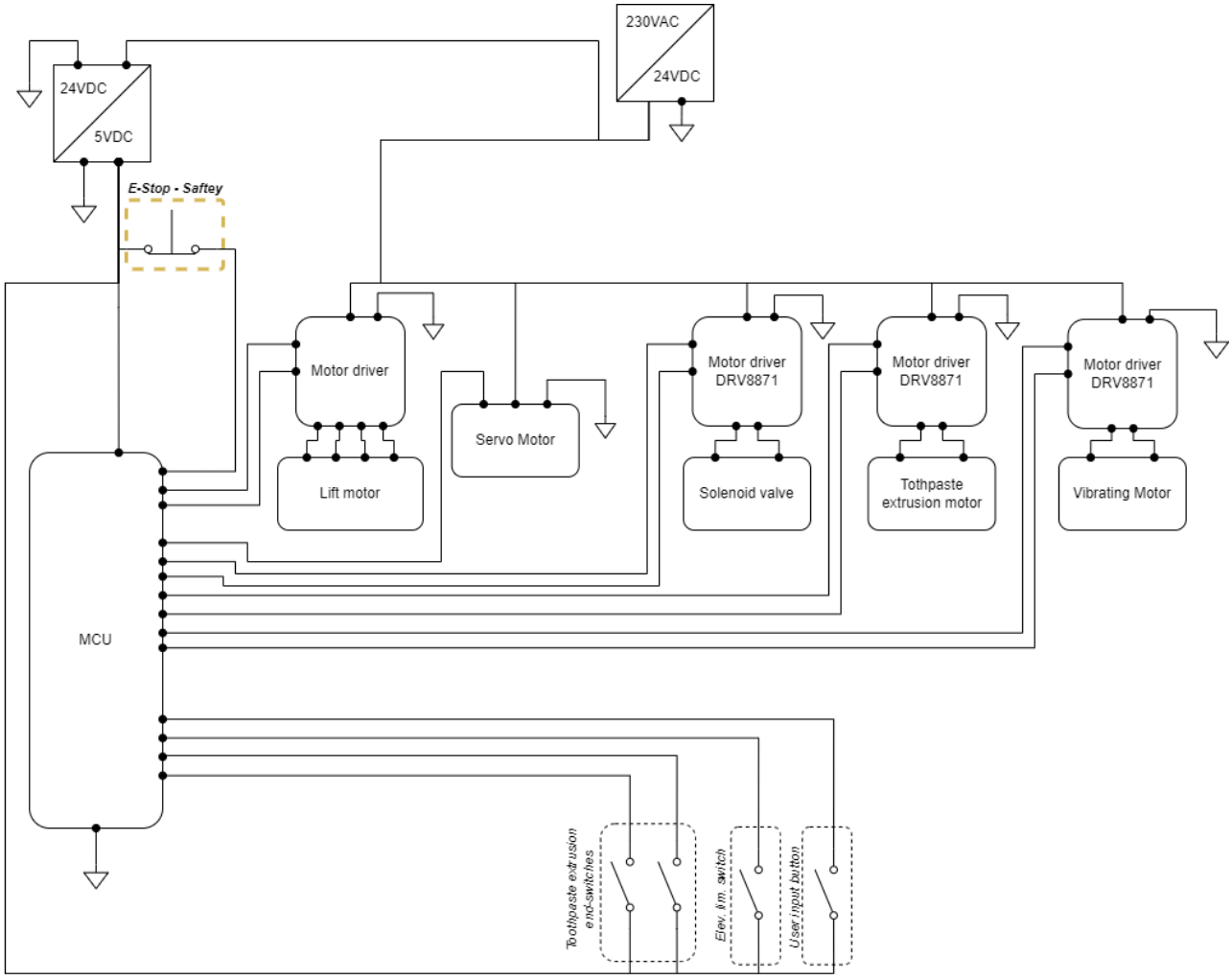
Figure 24: Electronics Soldered on Prototyping Board

The board is powered by a MeanWell power supply that provides 24 volts. The board uses a DC-to-DC converter to convert the 24 volts to 5 volts for the Arduino board. The Arduino board derives 3.3 volts internally through an LDO regulator from the 5V.

The TMC2660-BOB comes equipped with a Molex connector for easy connection to the Arduino and the stepper motor phases.

The orange wire connectors are quick-release on push-type, making it easy to wire the various limit switches and user buttons in a robust manner.

7.3 Circuit diagrams



7.4 Additional Documents

Design phase: Toothpaste dispensing mechanism

The following figures illustrate the design of the toothpaste mechanism. Figure 27 and figure 26 shows how the toothpaste will be dispensed through slits in the silicone mouthpiece in the final product. This mechanism is not implemented in the prototype. Figure 25 shows the initial idea of how the tubes will link toothpaste and basin. We then made a few changes, especially replacing the peristaltic pump with a syringe driven by a stepper motor.

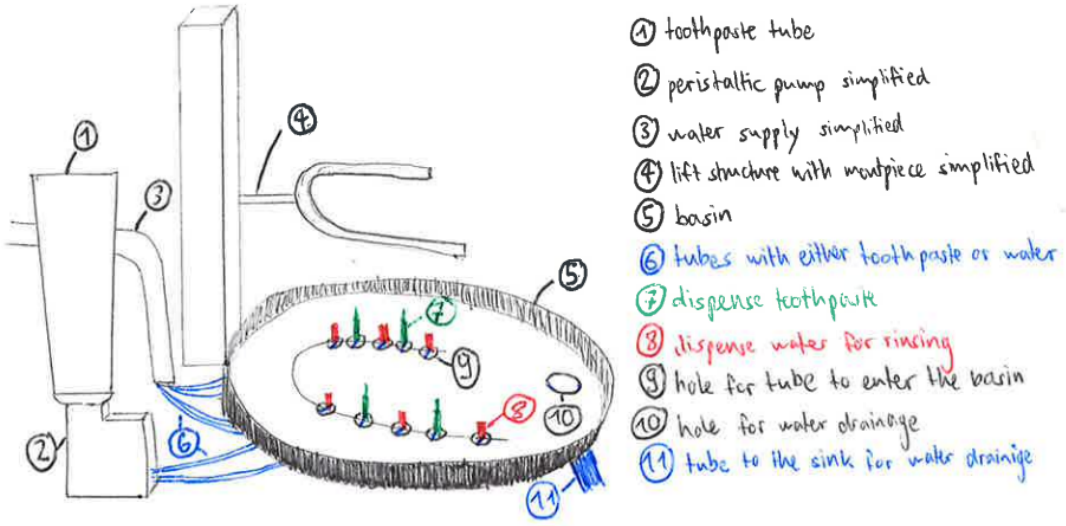


Figure 25: Drawing depicting the Schematic Overview of Toothpaste and Rinsing Mechanism in the Initial Phase

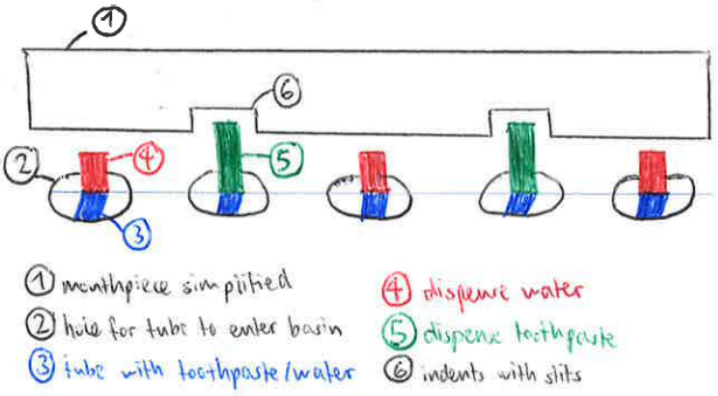


Figure 26: Close-Up Drawing Depicting the Placement of Water and Toothpaste Nozzles

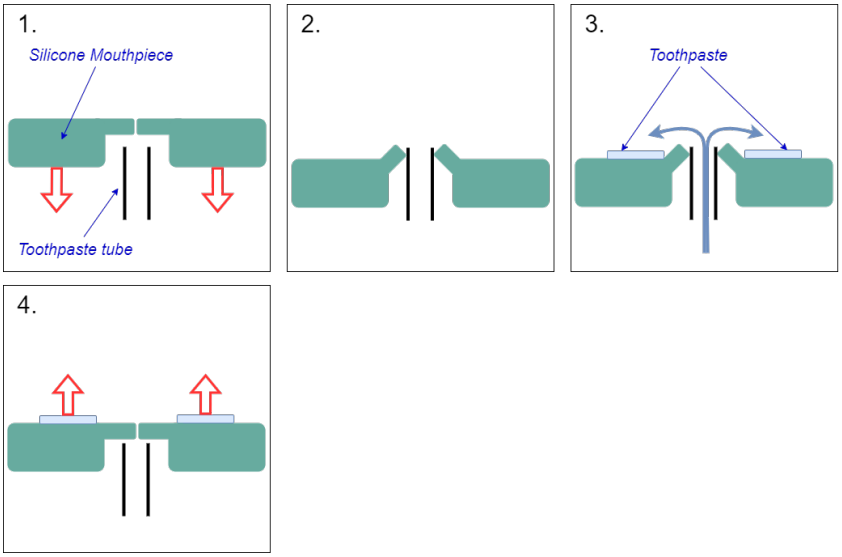


Figure 27: Concept Idea for One-Way Valve in Toothpaste Dispensing for Toothbrush

Patents for different features of Brush'it

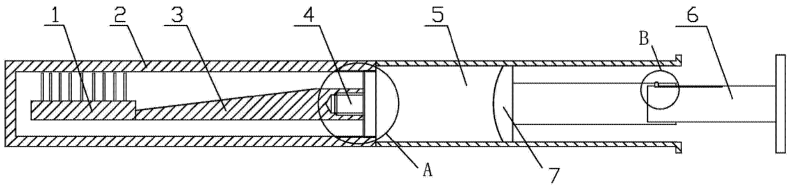


Figure 28: Drawing of patent CN203969615U Needle cylinder type portable travelling tooth set

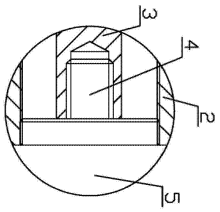


Figure 29: Enlarged drawing CN203969615U

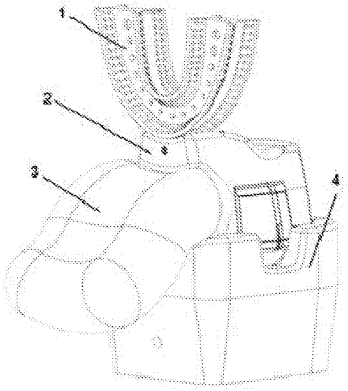


Figure 30: Drawing of patent WO2019103701A1 Automatic Tooth Cleaning Device

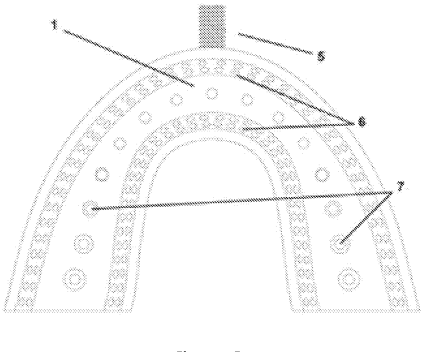


Figure 31: Top view WO2019103701A1

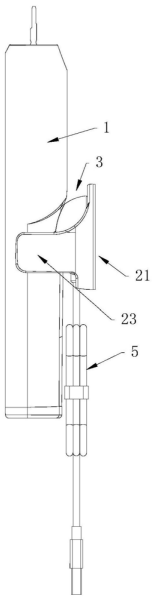


Figure 32: Drawing of patent CN209574940U Wall-mounted electric toothbrush

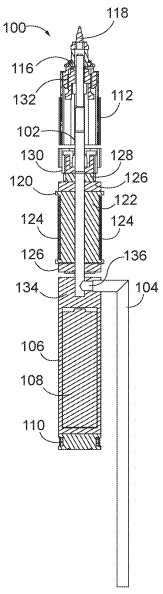


Figure 33: Drawing of patent AU2018331426A1 Electric toothbrush with fluid streaming capability

Market analysis

Figure 34 shows a visualisation of the market analysis for Switzerland. The estimation is based on data of the Federal statistical office[6][7][11].

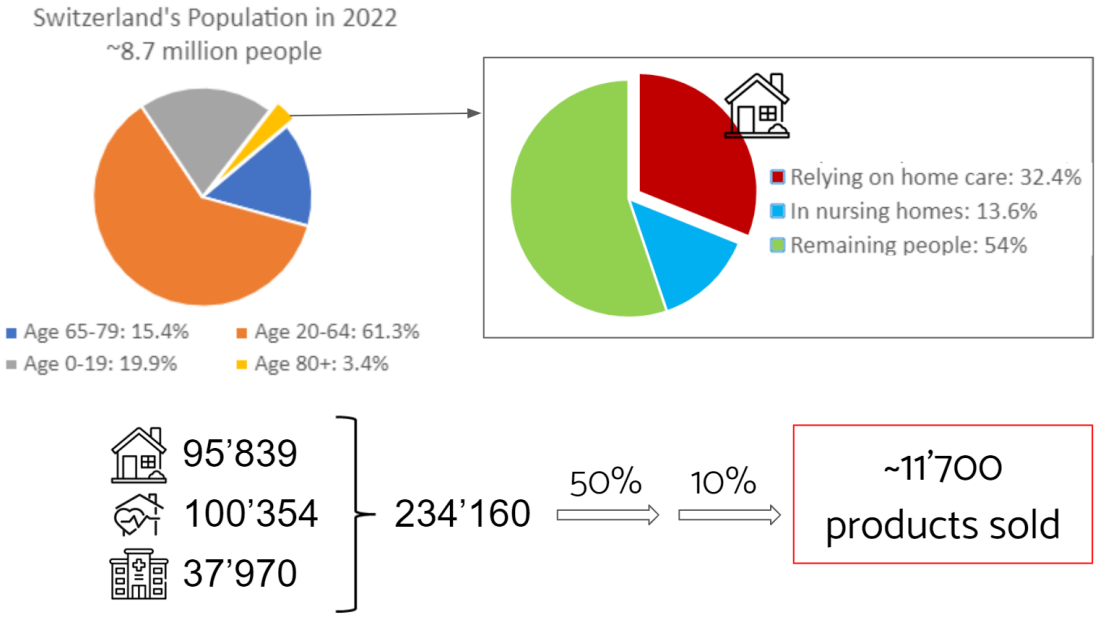


Figure 34: Swiss demographics for market assessment

Figure 35 shows an alternative approach for market estimation - numbers cannot be added due to the risk of double counting. The calculations are based on data of the Federal Statistical office [8][7].If we assume that a quarter of them have impaired dexterity and again 10% buy our product, we get a similar result as above.

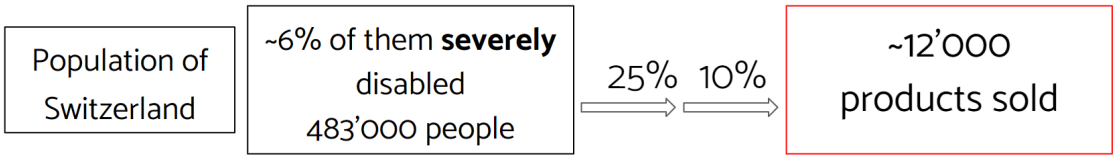


Figure 35: Disabilities in Switzerland for market assessment

Pricing Analysis for Commercialisation

Prototype	Mouthpiece: Y-Brush	Alu frame & plexi casing	3D printed sink	Toothpaste & water dispensing: 1 spot	Miscellaneous	
Cost CHF	35	40	40	10	290	415

Better Quality
Lighter
Cheaper: - 65 %

Product	Mouthpiece: PIM	Full plastic casing	Sink: PIM	Dispensing more sophisticated	Miscellaneous	
Cost CHF	25	15	15	5	80	140

Figure 36: Production cost for prototyping and commercialization

Risk analysis

Risk Analysis

Likelihood	Consequence: Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Fig 1: *Risk assessment matrix*

Category	***Risk***	***Risk level***
Electrical	*The user can be electrocuted*	
	Control malfunction (linear stage)	
	Control malfunction (Break itself)	
	Control malfunction (Limit switch not correctly debounced)	
	Solenoid valve malfunction	
	Peristaltic malfunction	
Mechanical	*The user gets hurt by putting their finger in the elevator*	
	User's hair gets stuck in the mechanism	
	Mouthpiece rotates while brushing	
Device abuse	*The user breaks the product*	
Misinterpretation	*The user activates the station not on purpose*	

Interface Diagram

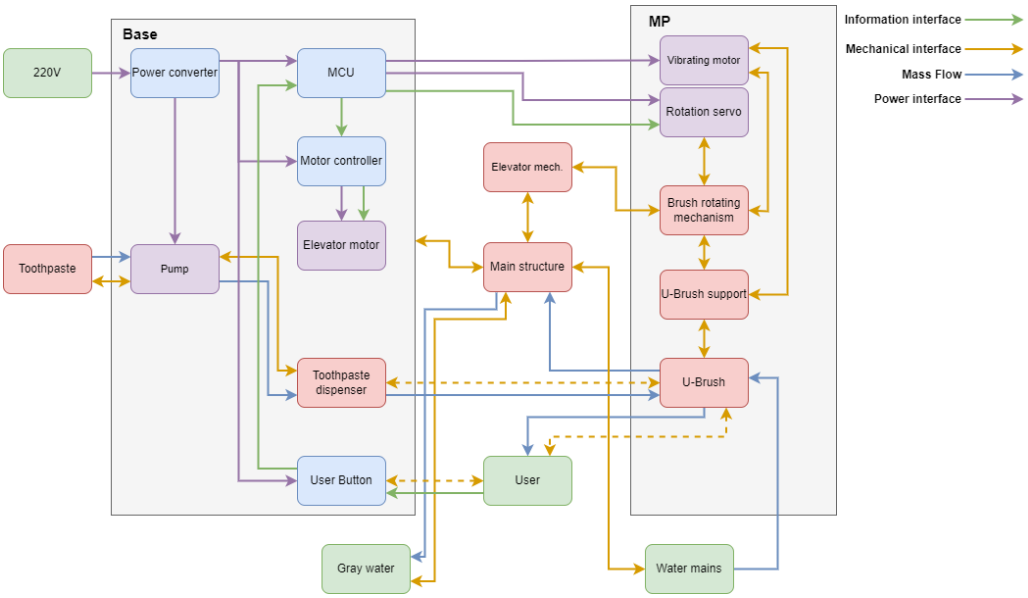


Figure 37: *Brush'it*'s Interface Diagram

WBS

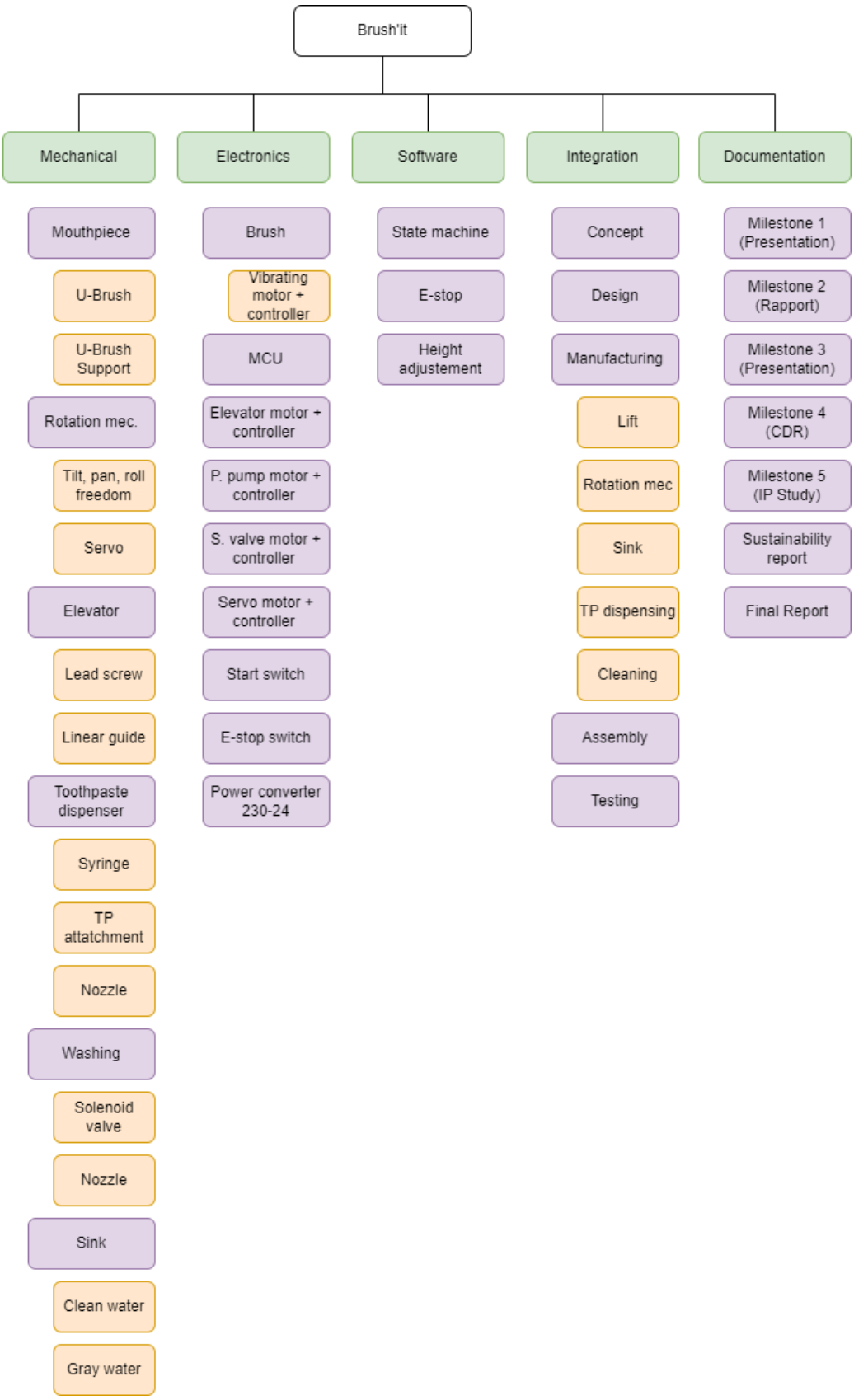


Figure 38: *Brush'it*'s Current WBS

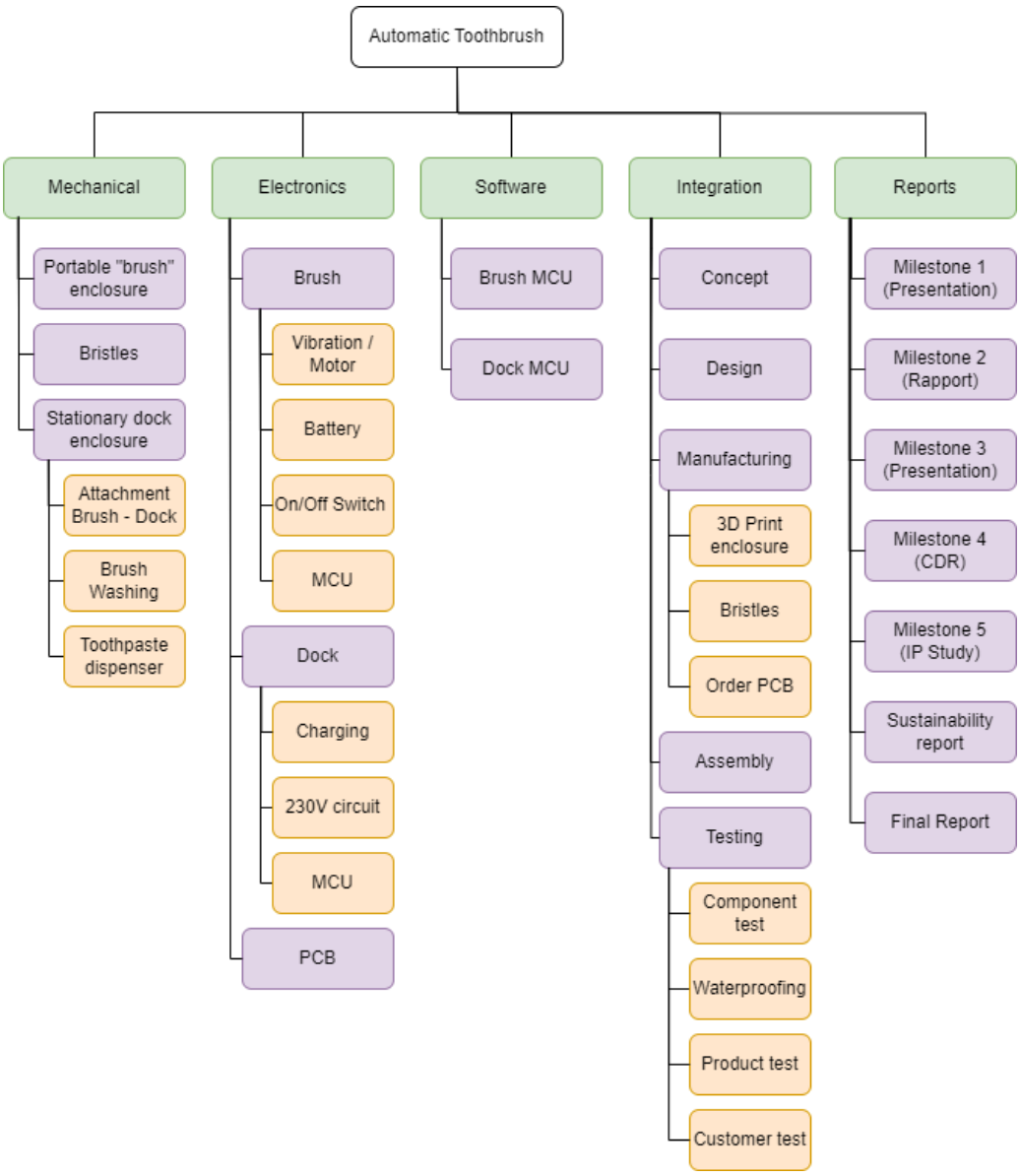


Figure 39: *Brush'it*'s First WBS

Gantt chart


ID
Name
Sep, 2023
Oct, 2023
Nov, 2023
Dec, 2023
1...
17 Sep
24 Sep
01 Oct
08 Oct
15 Oct
22 Oct
29 Oct
05 Nov
12 Nov
19 Nov
26 Nov
03 Dec
10 Dec
17 Dec
24 ...
1 Research and Conceptualization
5 Research adaptive toothbrush designs
6 Brainstorm and conceptualize the U-shaped ...
7 Define features, dimensions, and materials
2 Design phase
8 U-Brush
16 Brainstorm hot swap mechanism for tooth...
17 Design clip mechanism and test it
18 Design the mold for the silicon toothbrush
19 Fabricate the silicon TB and test it
20 Integrate nozzle injection mechanism
21 Assemble parts together
9 Rotation and vibration mechanism
22 Brainstorm best rotating mechanism
23 Find an adequate servo-motor and implem...
24 Brainstorm best vibrating mechanism
25 Incorporate the vibrating motor with the ot...
10 Fluid injection
12 Try gland cable option for toothpaste tube
13 Try silicon option for toothpaste tube
14 Brainstorm which pump is most optimal for...
15 Brainstorm injection in toothpaste mechani...
11 Elevator
26 Brainstorm elevator mechanism
34 Brainstorm how to make it safe
35 Design aluminum profiles depending on th...
36 Design the incorporation of components/c...
3 Electronics integration
27 Research and select the activation sensor
28 Integrate the sensor with the brushing mech...
29 Connect electronically different components
33 Code the Arduino for wanted applications
4 Prototype Assembly
30 Assemble all prototype components
31 Test functionality and make adjustments
32 User Testing and Feedback

8 References

References

[1] URL: https://www.swiss-medtech.ch/sites/default/files/2020-09/SMTI_2020_EN_low.pdf.

[2] Amabrush. 2019. URL: https://www.amabrush.com/.

[3] Sonic Brush. *Official Website*. 2024. URL: https://sonic-brush.net/.

[4] Robyn A. Cree & Catherine A. Okoro & Matthew M. Zack & Eric Carbone. *Frequent Mental Distress Among Adults, by Disability Status, Disability Type, and Selected Characteristics*. 2020. URL: https://www.cdc.gov/mmwr/volumes/69/wr/mm6936a2.htm?s_cid=mm6936a2_w.

[5] *Electric Toothbrushes, Floss, & Dental Health*. URL: https://www.oralb.co.uk/en-gb/big-rethink.

[6] Federal Statistical Office. *Health system*. URL: https://www.bfs.admin.ch/bfs/en/home/statistics/health/health-system.html.

[7] Federal Statistical Office. *National Projections*. 2023. URL: https://www.bfs.admin.ch/bfs/en/home/statistics/population/population-projections/national-projections.html.

[8] Federal Statistical Office. *Persons with disabilities*. URL: https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/equality-people-disabilities/disabilities.html.

[9] Mukesh Ram, Pimcoremkt, and yash.mehta262. *Technology trends in the Personal Care Market*. Mar. 2023. URL: https://datafloq.com/read/technology-trends-personal-care-market/.

[10] Statista. *Topic: Hospitals in Europe*. 2023. URL: https://www.statista.com/topics/8361/hospitals-in-europe/#topicOverview.

[11] Bundesamt für Statistik. *Demografisches Porträt der schweiz - Bestand, Struktur und Entwicklung der Bevölkerung im jahr 2020: Publikation*. Mar. 2022. URL: https://www.bfs.admin.ch/asset/de/479-2000.

[12] *Y-Brush : The 10 seconds toothbrush*. URL: https://y-brush.com/en.