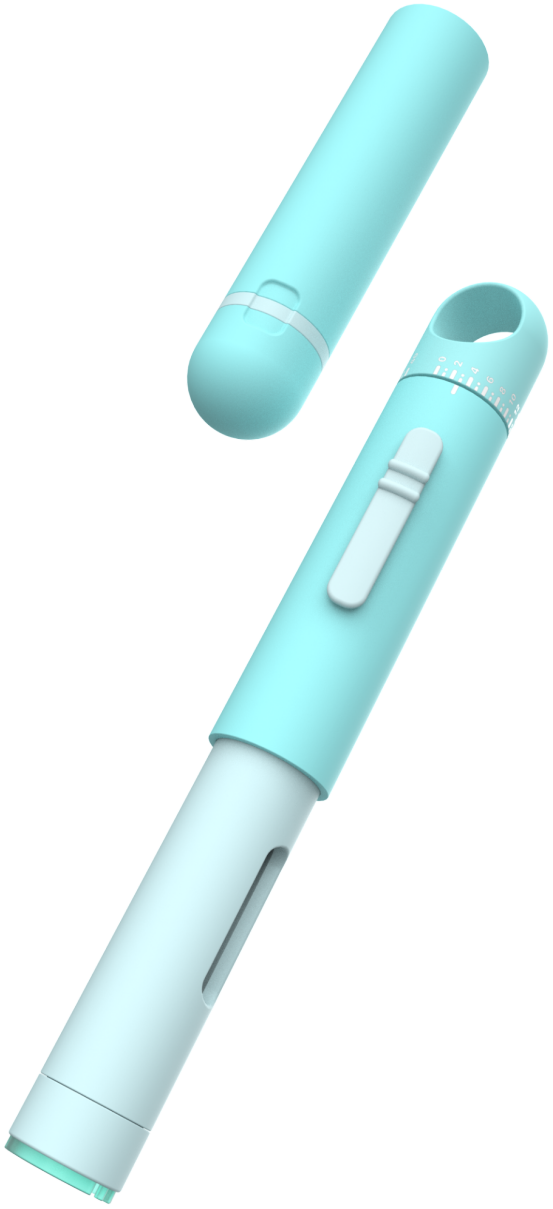
IDC School of Design
अभिकल्प विद्यालय
Indian Institute of Technology Bombay

Design Project - 1 | Autumn 2021

Redesign of an Insulin Pen for Adolescent Type 1 Diabetics



Zaid Khuram | 18U130030

Guided by **Prof. Purba Joshi**

Declaration

I declare that this written submission represents my ideas in my own words, and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated, or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been appropriately cited or from whom proper permission has not been taken when needed.

Zaid Khuram

18U130030

IDC School of Design IIT Bombay

26 Nov 2021

Approval Sheet

This B.Des Design Project titled **“Insulin Pen Redesign for Adolescent Type 1 Diabetics”** by Zaid Khuram, Roll Number 18U130030 is approved, in partial fulfilment of the B.Des Degree at the IDC School of Design, Indian Institute of Technology Bombay.

Digital Signature
Purba Joshi Joshi (i09042)
21-Jul-23 02:10:59 PM

Guide: Prof. Purba Joshi

Acknowledgements

I would firstly like to thank my guide, Prof. Purba Joshi for her constant guidance and support, and going above and beyond in steering me in the right direction. I also want to thank my jury – Prof. Chakravarthy, Prof. Kums Kumaresan and Prof. Sandesh, for all their valuable feedback. I would also like to thank all of the users who took time out of their schedule to participate in my research. I am most grateful to my family and friends at IIT Bombay for their support without which this project would not have been possible.

Project Abstract

This project is an attempt to redesign the insulin pen for adolescent diabetic users. The initial part of the project included literature review of existing research done in the area of insulin delivery methods to validate the project area and understand the existing usability and design problems faced in this product category. I reflected on my own experiences growing up as a diabetic, as well as conducted user interviews to get a deeper understanding of the contextual problems. An iterative ideation process was adopted to work on solving the difficulties of a stable grip, controlled injection and injection site tracking. Concepts were created and evaluated before the detailing and development of the final design.

Contents

Motivation and Project Area

At the end of my first semester here at IDC, my classmates and I did our first design project on problem identification. Titled the “Mumbai Project,” the project involved all of us stepping outside the campus to experience the different ways of life in the city and document our experiences.

Since then, as a design student, I have looked beyond myself to define a problem, while attempting to empathise with experiences. This allowed me to broaden my understanding of people’s priorities, culture, and work and undoubtedly help me grow as a person.

Since the start of my life at IDC, we were expected to express ourselves. In the last few years, I’ve been on a journey to find myself and understand what I like and who I am. Only recently did I discover a side of me that I’ve been living with for the past 10 years that has been experiencing life disconnected from the conscious me.

I was diagnosed with type 1 diabetes almost 10 years ago, in 2011. It's been an experience that presents a unique set of challenges everyday. Finding myself and thinking about my experiences as being a part of me was a huge step forward.

I felt determined to work on a project in an area I’ve been understanding and learning about everyday. My experiences through adolescence with diabetes motivated me to work specifically for that age group in the realm of **Insulin Delivery Devices.**

Introduction

WHAT IS DIABETES?

Diabetes is a chronic disease that occurs when the pancreas is no longer able to make insulin, or when the body cannot make good use of the insulin it produces.

Insulin is a hormone made by the pancreas. It acts like a key to let glucose from the food we eat pass from the bloodstream into the cells to produce energy. All carbohydrate foods are broken down into glucose in the blood. Insulin helps glucose get into the cells.

Not being able to produce insulin or use it effectively leads to raised glucose levels in the blood (known as hyperglycaemia). Over the long-term, high glucose levels are associated with damage to the body and failure of various organs and tissues. (IDF)

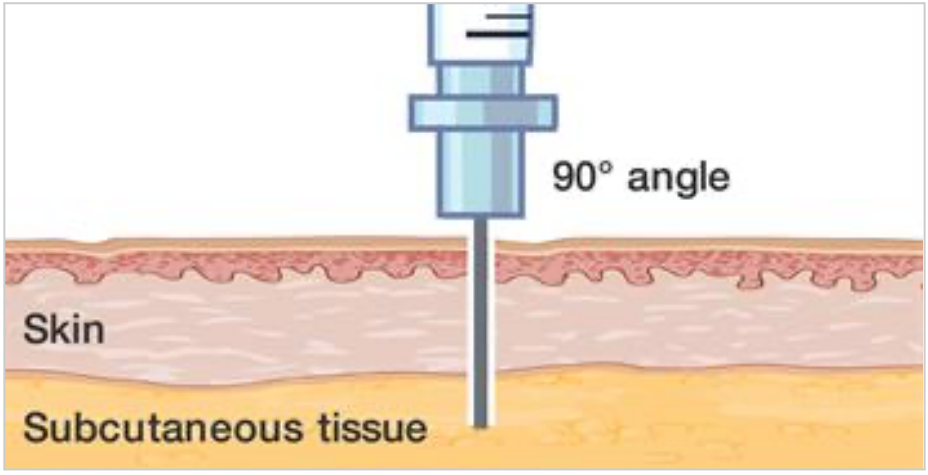
When one has type 1 diabetes, the body produces very little or no insulin, which means that one needs external doses of insulin everyday to manage their glucose levels. (IDF)

Type 1 Diabetes can develop at any age, but occurs most frequently in children and adolescents. It is one of the most common pediatric endocrine illnesses in the world. Over half of the type 1 diabetics live in developing nations, with India being home to an estimated 97, 700 children with type 1 diabetes. (Kumar, 2015)

INSULIN AND ITS DELIVERY METHODS

Insulin is a peptide hormone, therefore, destroyed by gastric acid if taken orally. Intradermal absorption (through the skin) of insulin is not reliable, and it cannot mimic physiological insulin secretion. In addition, intradermal, intramuscular and intravenous therapy is not suitable for self-administration daily. (Shah et al., 2016)

The subcutaneous route of administration is a widely preferred method for administration of insulin because of the ease of self-administration. However, it does have limitations like pain at injection site, lipodystrophy (complications with the way one's body uses and stores fat), noncompliance by the patient, etc.



https://www.aboutkidshealth.ca/injectenoxaparin

Insulin can be administered subcutaneously via various methods such as vial and syringe, insulin pen and continuous subcutaneous insulin infusion (CSII).

The vial and syringe is the most commonly used method because of its relatively low cost and ability to mix insulins and in turn reduce the number of injections. However, it is very inconvenient and tedious to draw and measure the insulin making it highly unsuitable for children and adolescents to use independently.

https://www.diabetesselfmanagement.com/education/insulin-injection-technique-tips-and-tricks/

Insulin pens are mechanically primed devices that allow for easy and accurate dialling of the dosage making it more convenient to use. Recently developed pen needles are also shorter and thinner, less painful and require less thumb force and time to inject insulin resulting in improved patient satisfaction. (Hirsch, 2012)

https://www.medicaldevice-network.com/comment/smart-insulin-pens-gain-ground/

Both these methods of administration require Multiple Daily Injections (MDI) to manage blood glucose levels. However, they do not mimic the secretion from the pancreatic cells leading to higher glycemic variability (i.e., hyperglycemia and hypoglycemia).

The mode of delivery using an insulin pump is a form of Continuous Subcutaneous Insulin Infusion (CSII) that stays connected to the patient's body and allows for the continuous delivery of insulin.

Clinical trials have demonstrated the effectiveness of CSII over MDI therapy in achieving glycemic goals (~0.5% A1c reduction), reduction in insulin dosage (~14%), reduction of hypoglycemia and glycemic variability and improved patient satisfaction and quality of life. (Retnakaran et al., 2004) However, the massively higher cost compared to MDI makes it a very rare choice in the Indian context. The

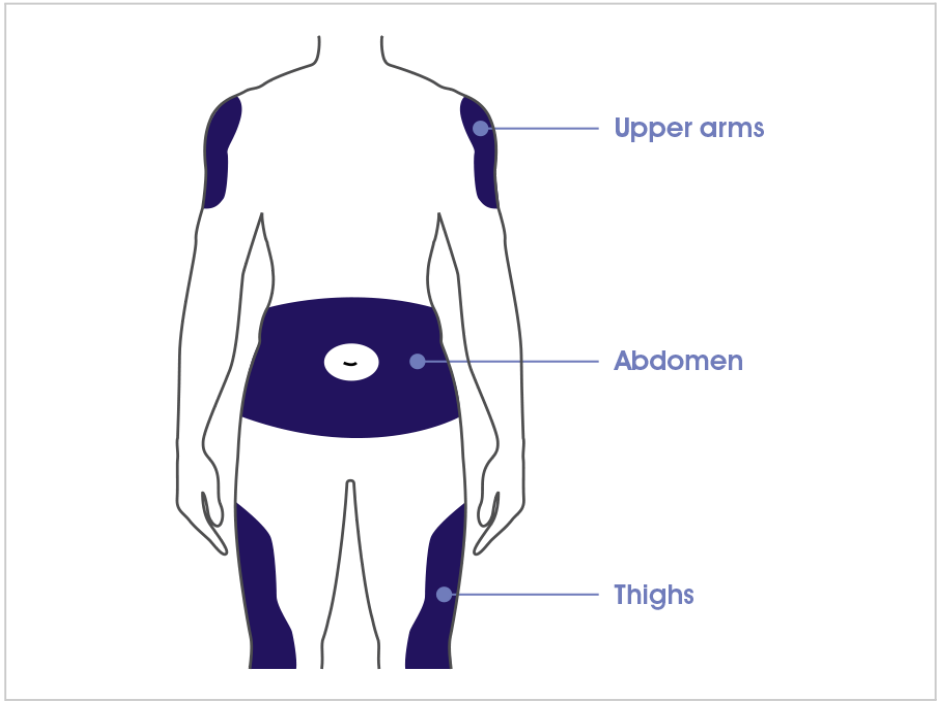
inconvenience of being attached to a device also makes it an unlikely choice for children and adolescents with active and exploratory lifestyles.

https://www.faulhaber.com/en/markets/medical-laboratory-equipment/insulin-pump/

For the storage of insulin, all manufacturers recommend storing it in the refrigerator to make sure the insulin keeps its potency until the expiration date. However, injecting cold insulin can be more painful. Therefore, most healthcare providers recommend keeping the case of insulin one is currently using at room temperature. Insulin kept at room temperature will last approximately one month. (ADA)

AREAS ON THE BODY TO INJECT INSULIN

It is recommended to inject insulin into a region of the body with subcutaneous fat. The most common areas of insulin injection are the abdomen and thighs, mainly due to it being so easily accessible for injecting yourself. The upper arms, lower back and buttocks are also areas recommended by health care providers but are not preferred, at least by me, because of the difficulty in reaching these areas.



https://www.lantus.com/hcp/dosing-injection/injection-guide

Personal Experiences

Living with diabetes is not easy. Doing the job of an organ, and living your life at the same can take up heavy amounts of mental space. While injecting insulin is the part I study heavily in this project, it absolutely does not end there. I strongly feel there is a conversation that needs to be had about how design affects a users' personal and social choices.

Insulin, in the simplest of terms, is the hormone injected to bring one's blood glucose down. Before that, however, one is required to continuously monitor, and constantly analyse the changes that occur. A diabetic is required to understand how each activity, each food item, and even one's own mental state, could affect blood glucose levels. Taking insulin is the easy part that follows.

Since my project is focused on adolescent diabetic users, I would like to recall my own experiences of very nuanced problems I faced because of my lifestyle at that age.

Being in school, food and snacks are everywhere. Insulin is required for any item that has any calories in them, so that involved keeping my insulin pen on me at all times. However, the size and weight of the pen never allowed me to keep it hidden in my pocket, which just ended up with me leaving it in my bag and taking insulin at inappropriate times. It had a very bad effect on my glucose levels.

Going out with friends was another scenario that may seem easy to work around. Carrying an insulin pen in public catches attention and answering strangers' questions about your condition is never easy. Moreover, taking an insulin injection is not a very quick task.

Most people would empathise with such difficulties but assume that the child would work through it. Looking back however, I feel such an assumption is too optimistic. Adolescent users are more likely to avoid the problem rather than look for solutions or methods to face it. This ends up in the mismanagement of their blood glucose which, in the long run, could result in serious complications.

This experience is obviously not a blanket statement. The age and maturity of the user heavily influences the way they deal with such issues, but it is important to recognise that design can so heavily contribute to the perception and usage of such products.

Even today, at 21 years of age, I experience so many of the same problems that I recognise adolescent users dealing with in this project. The portability of the insulin pen can make everyday events stressful. The tracking of injection sites only increases in importance as time goes on and the long term effects start to show up.

Understanding Insulin Pens

HOW DOES AN INSULIN PEN WORK?

The function of an insulin pen is to allow the user to inject insulin. The user is required to set the dosage of insulin they want using the dial on the outside of the pen and then inject themselves. (Healthwise)

The insulin pen is available in both reusable and disposable variants. The disposable pens have a set amount of insulin prefilled in them and would be thrown away when it runs out. The user would need to buy a new pen if they need more insulin. Disposable pens are also often built with cheaper materials to reduce cost and are therefore less durable.

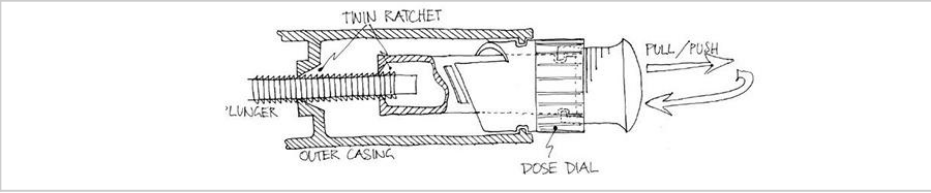
Reusable pens on the other hand do not need to be disposed of. Once empty, the penfill (or cartridge) is removed and replaced with a new one. Reusable pens are made of sturdier materials and designed to last much longer. I continue to use the same reusable insulin pen I started using when I was diagnosed about 10 years ago.

Both types of insulin pens require a new needle with each shot. Needles are purchased separately and need to be screwed onto the top of the pen. The needles come in different lengths and widths. Shorter needles will prevent injecting into the muscle, especially in children or people who are lean. Thinner-width needles reduce the pricking sensation. (Healthwise)

INJECTING MECHANISM

There are numerous mechanisms that have been developed in the realm of injections. From a usability standpoint however, there are only two types of interactions that are used to inject the insulin itself.

The first one is the most commonly used, and has been heavily improved upon over the last decade. The dial works as an input as well as a pull back mechanism that then pushes the syringe downwards. The force required to push the plunger is directly from the user pushing the dial downwards.

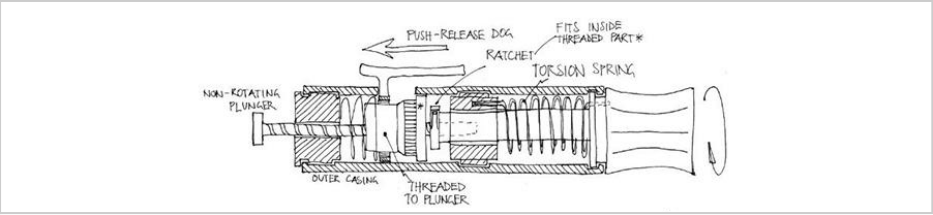


https://www.idc.uk.com/medical/case-studies/dispo-pen-and-pen-royale/

The point to keep in mind here is the dial is located at the opposite end of the pen from the needle and requires a substantial downward force. Most reusable and disposable pens use a version of this mechanism today.

http://flipbooks.leedsth.nhs.uk/LN004629.pdf

The second, and relatively less common, mechanism that exists is one that uses a torsion spring to minimise the force required by the user in pushing the plunger. The turning of the dial to input the dosage also primes the torsion spring, which is then released and pushes the plunger downwards using a slider on the side of the product.



https://www.idc.uk.com/medical/case-studies/dispo-pen-and-pen-royale/

The AutoPen 24, a product that uses this mechanism, boasts its ease of use, especially for children and people with reduced physical ability in their hands which includes senior patients.

https://wchh.onlinelibrary.wiley.com/doi/pdf/10.1002/pdi.877

THE DIFFERENT PARTS OF THE PEN

I will outline the different areas of the insulin pen. These are terms that I have coined and used throughout this project to reference my findings and ideas. I will use an existing insulin pen for this, and define any new parts or ideas as I go along.

The first two parts that separate are the *pen cap* and the *body*. The pen cap is primarily for the protection of the components while the body of the pen comprises all of the functional parts of the insulin pen.

From the body of the pen, two subparts can be disassembled. These are the *penfill* itself, along with the *penfill case* that holds the penfill in place. The needle that sits on the penfill is a separate part. It is purchased separately and is required to be replaced after each use.

The remaining part of the body houses the very accurate mechanism that pushes the *plunger*. At the far end of the body lies a *dial* that is used to input the number of units of insulin for injection.

Literature Review

Development of the SoloSTAR® Insulin Pen Device: Design verification and validation

This paper shares the insights of the design team that worked on the SoloSTAR insulin pen. The author goes through the factors and problems that shaped the direction of its development, along with its iterative design process and evaluation of the product with the users.

I have outlined my main takeaways from this paper below.

- Users of the insulin pen are not limited to just the patients. They include doctors, nurses, and pharmacists who advise/train the patients on the use of the pen.
- Multiple unmet needs were identified during the research phase of this project.
    a. Other competing insulin pens in the market would only allow the user to take a maximum of 60 units per shot. The user would be required to take a second shot if they required more than 60 units at one time.
    b. Hand function and injecting force were two important factors taken into account in this design. The team aimed to have the pen require minimum force for injection and a very short dial extension.
    c. All type 1 diabetics are required to take a minimum of two different types of insulin. The differentiation of types of insulin based on colour was added to the design brief based on research to reduce confusion and risk of hypoglycemia.

The rest of the paper included design specifications and choices made for the product and was not relevant to include at this stage of my project. The findings highlighted a small increase in comfort from the reduced injection force requirement and shorter dial extension.

Perceptions of Usability and Design for Prefilled Insulin Delivery Devices for Patients With Type 2 Diabetes

This paper presented the findings of a study conducted on how patients with type 2 diabetes perceive different 'prefilled insulin delivery devices' based on the usability and design features. I have listed the findings that I found insightful to my project below.

- Disposable pens are common and are generally more convenient for patients than reusable pens.
- The only statistically significant difference between non-naive and naive patients was in being able to hear the clicks when they dialed the dose; experienced pen users did not rate this feature to be as important as naive patients.
- Design Features in general are considered less important than usability features with exceptions
    - How well it can be gripped while using
    - Pen robustness and durability
    - How it feels in the hand while using
- Female patients prioritised the discreteness of the insulin pen in storage and usage over their male counterparts.
- Highest importance placed on 3 main features

    - Knowing that the entire dose has been injected
    - Reading the dose correctly
    - Correcting the dose if over-dialled
- A previous study found that patients considered insulin pens to be more socially acceptable than vials and syringes. This study confirms that patients feel aspects of social acceptability are an important design feature of insulin pens.
- Potential **bias** as more than 50% ranked their own pen as their preferred choice. Might not be very willing to change what works.
- The study focused on patients with type 2 diabetes and was limited to the delivery of prandial insulin. Therefore, the results are not generalizable to patients with type 1 diabetes (recent research has highlighted the need to improve and refine the functionality of insulin pen devices for use in children and adolescents45), to other types of insulin regimens (e.g., basal insulin or premixed insulin), or reusable pens.

This research was focused on type 2 diabetics who can have different treatment plans and methods of control compared to type 1 diabetics. However, the insights on the usability preferences are still useful and relevant to my project.

Insulin delivery by injection in children and adolescents with diabetes

This paper presented a qualitative study conducted on insulin delivery in children and adolescents. The author pointed out how the age of diagnosis plays a massive role in the successful management of the condition. “Children diagnosed at an older age have been reported to have more success with self-care.” Other key findings from the study conducted are highlighted below.

- Insulin pens are the most commonly used and most ideal for children. The risk of other forms of insulin therapy include the increased chances of hypoglycemia by not monitoring closely or overdosing on insulin.
- “CSII (Continuous subcutaneous insulin infusion) is not the preferred solution for all children; success with a (insulin) pump requires proactivity, commitment, and motivation which may be lacking in this patient group and their support structure.”
- The demands for insulin pens that are ‘simple, accurate and tailored for the pediatric population will increase.’
- Insulin pens offer freedom and flexibility over other forms of insulin delivery like the vial and syringe.
- Memory function or the ability to download user data is likely to improve the long-term management of diabetes.

This research study very succinctly validates my project area. The author talks about how the insulin pen is the ideal insulin delivery method for children and how the product needs to be developed further to cater specifically to the needs of the user group.

Market Study

There is a range of insulin pens in the market today, with varying designs and different injecting mechanisms. In this section however, I will focus mainly on interesting products and mechanisms that help solve a particular set of issues while keeping the standard use case of the insulin pen the same.

I-PORT ADVANCE™ INJECTION PORT

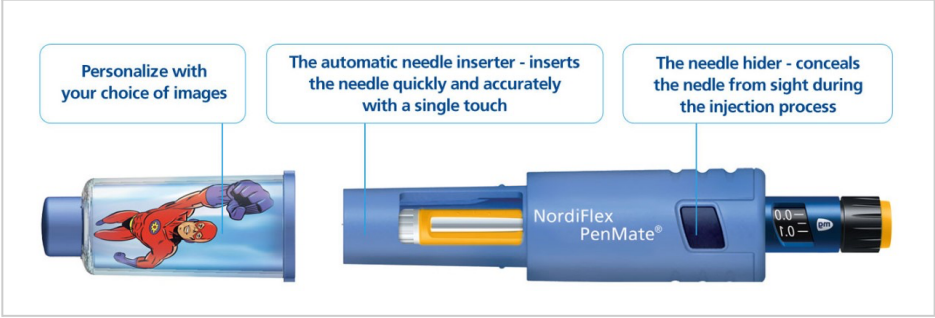
The i-Port Advance is a supplementary product to the insulin pen that is aimed at solving the issue of the number of times a diabetic patient is required to puncture their skin to inject insulin.

https://www.medtronicdiabetes.com/products/i-port-advance

The product itself has a coin sized plastic body with an adhesive attached to allow for it to stick to the skin. Once applied, using the built-in inserter, a soft flexible tube known as the cannula, stays underneath the skin. The user can then just inject their insulin (still using the insulin pen) through the port instead of puncturing the skin.

The product is described as a small and discreet patch. It stays attached to the user's body for upto 3 days, after which it would need to be replaced.

NORDIFLEX PENMATE®



https://www.novonordisk.com/our-products/pens-and-needles/NordiFlex.html

The NordiFlex PenMate is designed to work specifically with Norditropin NordiFlex which is a prefilled growth hormone injection pen. While the use case is different, the task of injecting is exactly the same. The product is also designed primarily for a younger age group and aims to address specific issues.

The PenMate product itself is an attachment that sits on top of the Norditropin pen. When attached, the form of the PenMate hides the needle from sight to reduce the perception of pain.

The product also has the function of automatic injection, which pushes the needle downwards without the user having to apply any downward force. A button is located on the side of the PenMate that when pushed, inserts the needle 'quickly and accurately with a single touch.'

HUMAPEN MEMOIR

https://www.mims.co.uk/humapen-memoir-insulin-pen-discontinued/diabetes/article/1338643

The HumaPen Memoir is a reusable insulin pen with a very unique feature. It is a digital pen that records the dosage of the last 16 doses taken by the user.

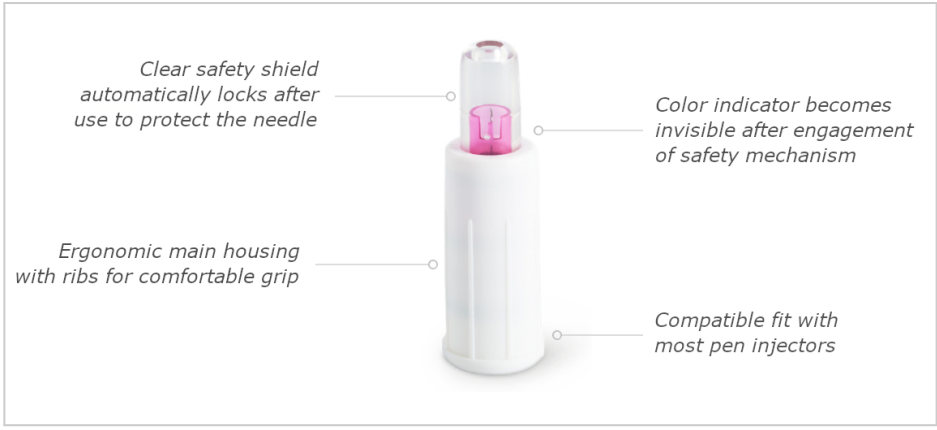
This addresses, and to an extent, solves two problems. Users take insulin and forget whether they have or have not taken it. This is common when the user is busy with work, or in a social situation, where it could slip their mind. There can also be situations where users also forget the amount of insulin they have injected in. The HumaPen Memoir keeps track of the amount of insulin taken as well.

MEDIVENA ONE-CARE SAFETY PEN NEEDLES

ONE-CARE Safety Pen Needles is an alternative pen needle design. This product aims to solve the problem of new users getting injured or hurt by needles.

The design has a casing on top of the needle that hides the needle to help with the visual discomfort, as well as protects users from injuries. The plastic casing springs back while injecting, and covers it back once the user is done injecting.

The product also has a visual indicator that pops out once the needle has been used. In the setting of a hospital, this would prevent healthcare workers or users from reusing needles, which could be a cause for the spreading of infection.



https://www.one-care.com/safety-pen-needles

Task Analysis

There are two main tasks carried out by users of the insulin pen. I was the user for this study, and recorded and analysed my own actions.

These tasks were carried out in my home in Bangalore. I recorded a video of myself and analysed it after. I have listed the sub-tasks along with the time taken for each of them below.

TASK 1: INJECTING INSULIN

The task of injecting insulin is the primary task of the insulin pen. It is carried out multiple times a day by most users. The user is required to input the dosage on the dial before injecting themselves.

The sub-tasks highlighted in blue have taken up a majority of the time taken to complete the whole task. I have explained the problems faced within each sub-task below.

Task - Injecting Insulin	**Time Taken**
Locating the Insulin Pen	12s
Calculating amount of Insulin	2s
Dialling the dosage on the pen	4s
Removing pen cap	1s
Removing needle cap	1s
Locating an injection site on the body	8s
Injecting insulin	28s
Locating and placing needle cap	7s
Locating and placing pen cap	2s

Locating the insulin pen *– 12 seconds*

The insulin pen was not easily visible to the user amongst items kept on the desk, which caused him to waste time looking for the pen elsewhere. It can also be noted that the user did not consider the pen portable enough to carry around comfortably all the time.

Locating and injection site on the body *– 8 seconds*

While the user was relatively quick to select an area of the body he was comfortable to inject in, he did not do the task immediately. The user was required to recall where specifically he had injected last time and to consciously choose another spot. The absence of any form of tracking except memory forces the user to spend time and mental capacity while performing the simplest of tasks.

Injecting insulin *– 28 seconds*

The user uses the needle to puncture the skin and slowly push down on the dial to inject the insulin. The user did not rush into it but made sure to puncture the skin in a controlled manner. It is also recommended to hold the needle in the skin for around 10 seconds after injecting to make sure the dosage is administered fully. The

method of puncturing the skin could be explored. The 28 seconds taken to complete the sub-task is understandable but not ideal.

Locating and placing the needle cap *– 7 seconds*

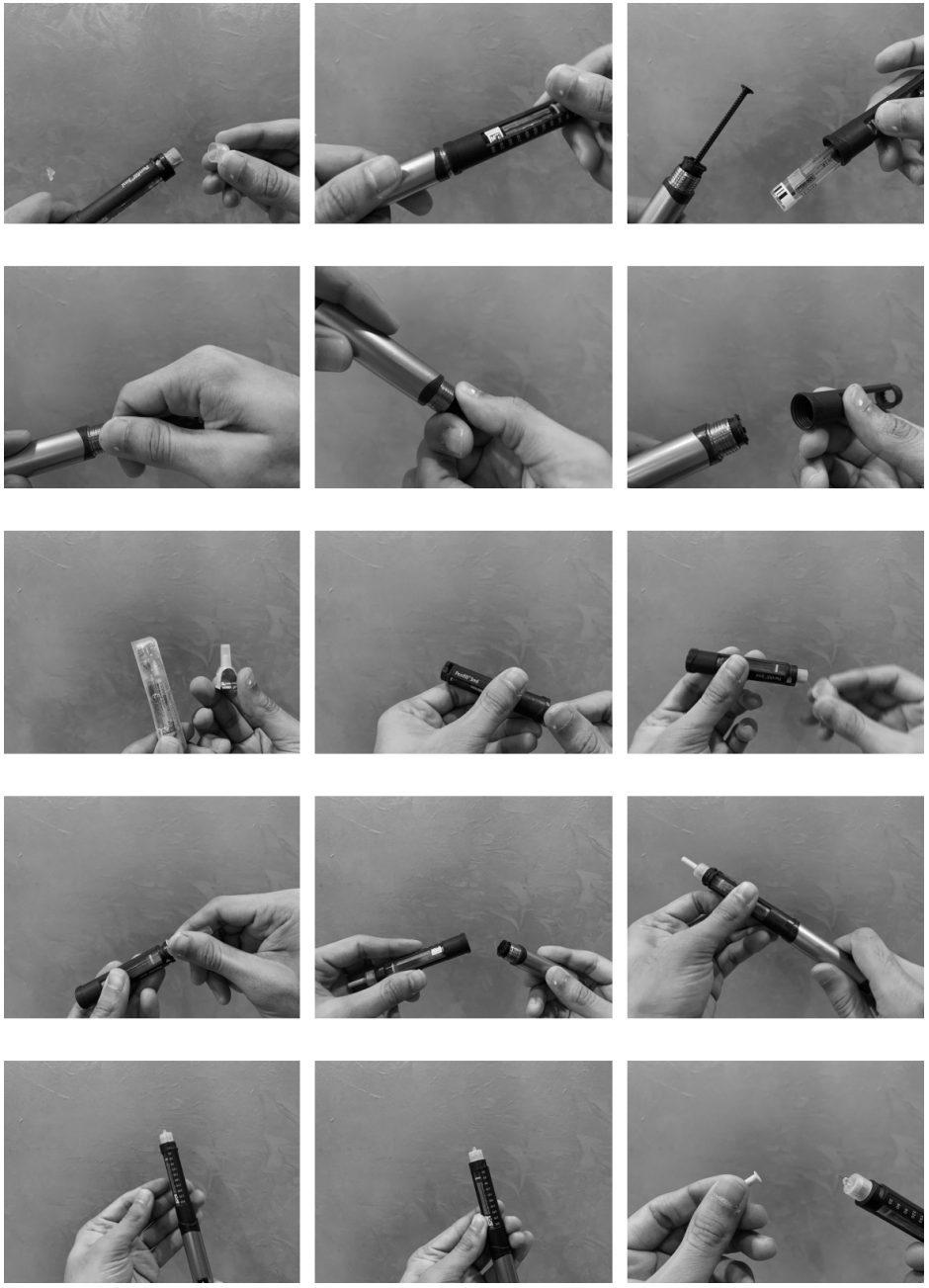
With the insulin injected into the body, and the needle pulled out, the user has completed the main part of the task. However, with the needle cap being so small and no designated area to store it, the user spends more time searching for it. The needle cap is also a very small piece and requires care when placing it back on which may contribute to the time taken as well.

TASK 2: REPLACING THE PENFILL

The task of replacing the penfill is secondary, since it is done only when the pen runs out of insulin. The frequency of this task can vary from less than a week to upto four weeks based on the dosage of the user.

The user is required to unscrew and open up the insulin pen to replace the penfill. Most users will also inherently replace the needle during this change as well since they are required to unscrew it as well. To understand the nuances of this multiple stepped task, I have taken images to record each step (show on the right).

Task - Replacing the Penfill	**Time Taken**



Retrieving the penfill from the refrigerator	16s
Removing the pen cap	1s
Unscrewing the needle	4s
Unscrewing the penfill case from the body	7s
Removing the penfill	1s
Rewinding the plunger	19s
Unpacking and placing the new penfill into the case	4s
Attaching the penfill case to the body of the pen	8s
Unpacking and screwing needle on	8s
Removing needle cap	1s
Priming the plunger to reach the penfill	18s
Locating and placing needle cap	8s
Locating and placing pen cap	4s

Rewinding the Plunger *– 19 seconds*

The user owned an insulin pen that was designed in 1992. To reset the plunger, the user was required to rotate it manually all the way back to its starting position. New designs allow for the user to press it back in one push which only takes about two seconds.

Priming the plunger to reach the penfill *– 18 seconds*

The starting position of the plunger is below the penfill. For the insulin pen to work, the plunger must be in contact with the rubber in the penfill to push out insulin through the needle. The user dials and pushes the plunger in small increments until the plunger reaches the rubber in the penfill.

Locating and placing needle cap *– 8 seconds*

For similar reasons as the previous task, the user takes more time to locate the small part i.e the needle cap and then carefully place it on the needle.

GRIPPING METHODS

In the task of injecting insulin itself, the way the pen is held can sometimes cause more or less pain. It is also likely that each user develops their own style and preferences of holding, or gripping the insulin pen over the course of their lives.

I looked back and studied the way I gripped the pen. I named the grips based on the style and have listed the challenges I face, as well as what I anticipate adolescent users may face. I have listed the positive points too.

Stab

While this grip may seem like the most natural to spectators, it is not very comfortable. New users will use this grip because of where the interaction point or the dosage dial is positioned, at the other end of

the pen. Hoping to reach the grip most easily with the thumb, the user will wrap their hand around the body of the pen.

Since the pen is being held so far away from the needle, the user has much less control over the exact point of penetration. Also, because the user has no support for the arm anywhere around the injection point, the force applied to push the needle in, is pivoted around the elbow or shoulder. This ‘stabbing’ action will usually cause users to overestimate the force required and end up causing them more pain.

Pencil

As the name suggests, this pen is held much closer to the tip of the needle. This allows for the user to very minutely control the exact point of penetration, which may be essential for patients with thinner builds. The user also has much more control over the force they apply. This allows for a controlled and painless penetration into the skin which is an ideal scenario for any user.

However, once the needle does penetrate the skin, reaching the dosage dial is very difficult. The user would need to shimmy their hand up the insulin pen and apply force on the dial. All of this would need to be done while the needle is inside the skin. These movements of the pen can not only cause pain but leave larger puncture wounds that may take longer to heal.

Stretch

The stretched grip is an unusual one. The pen is held in the middle of the body with the thumb and three fingers while the index finger is used to push down the dial. The index finger remains at full stretch to allow the pen to be gripped as low as possible to maintain greater stability while puncturing the skin.

While it may sound ideal, it cannot be done comfortably by everyone. Users with small hands, especially children and adolescents, would struggle to reach the top of the pen with their index finger while still gripping the pen as low as possible. If the pen is gripped any higher than the midpoint with the rest of the fingers, it would make this grip inefficient and unreasonable to use.

Images of the different grips: Stab, Pencil, Stretch (from left to right)

User Interviews

INTERVIEW STRUCTURE

Background

- How long have you been a diabetic?
- What method of insulin delivery are you currently using?
- How long have you been using this form of delivery?
- What do you think of other forms of insulin delivery?
- Have you ever used any alternative forms?
- What was your experience with other forms of delivery?

Day to day tasks and routine

- How often do you use this product in a day?
- Can you take me through the **step by step process** of using this form of insulin delivery?
- Have you ever felt any difficulties while using the product?
- Have you ever felt any discomfort while using the product?
- Have you ever felt confused while using the product?

Opinions and Thoughts

- What would you consider to be the best part about the product you use?
- Would you recommend the product to other diabetics?
- Any changes you would like to see in a newer version of the product?

BACKGROUND AND DEMOGRAPHIC

I struggled to make contact with too many type 1 diabetics. Many patients felt uncomfortable talking about their experience with the products and denied permission. I was able to successfully interview two users.

INSIGHTS

User 1 – 32 year old male

- Uses 3 different types of insulin on a daily basis.
- One of the three types of insulin uses vial and syringe, while insulin pens are used to deliver the other two types of insulin.
- Was very clear that insulin pens are much more convenient and easy to use.
- Would only use insulin pens while travelling. Vial and syringe not suitable.
- Has no particular pouch or bag to store the insulin pens, but tends to keep them together and in the same place.
- Explained his method of site rotation. He has specific regions of the body designated for different types of insulin to aid in keeping track of rotations.
- Would only use the vial and syringe on the thigh because of the needle length being larger.
- Still uncomfortable injecting himself in public or even in front of relatives.
- Mentions incidents of hiding in the office and taking insulin even though many of his co-workers know about his condition.

User 2 – Mother of 8 year old male

- Uses only insulin pens as the needles are smaller.
- Is still newly diagnosed so parents still administer the insulin for him.
- Parents allowed the child to try but felt too scared and intimidated by the process.
- Mother suggested that the insulin pen did not seem to be visually very pleasing or comfortable to use.
- Appreciated the metal body of the pen as she felt it retained temperature and kept the insulin cool for longer. Especially useful when going out for a meal.
- Also felt that the body kept the penfill inside from breaking too often.
- Was very irritated by the size of the needle cap.
- *"Very often I end up pricking myself while trying to close the needle cap."*
- Was aware of the requirement of the rotation of injection sites but had no clear method or idea to follow.
- Has identified areas of injection that the child is more comfortable with but fears that it could lead to swelling and other issues.
- Has designated areas for different types of insulin.
    - Short acting insulin on the abdomen
    - Long acting insulin on the buttocks

DISCUSSION

While both users have different levels of experience with the products, they both prefer using the insulin pen. The use of the pen by User 1 holds greater significance because he has also used other methods of delivery and chooses the insulin pen over the rest.

The selection of the insulin pen by User 2 gives us insight on the preference of new users. User 2 felt the insulin pen would hurt less because of the smaller needles and the relatively neutral form would make it seem less like a medical device.

Both users also mention the context of travelling outside the home and how the insulin pen is more suited for it. None of the users mentioned any difficulty in storage of the product or the size of the product.

Both users, with very different levels of experience, struggled with keeping track of their insulin sites. User 1, who had more experience, understood the significance of the difficulty much more than User 2, who was relatively new and probably didn't see the need to prioritise this problem.

It was interesting to note that both users did have some mental strategy to help decide areas to inject, but were still uncertain of how effective they were. This ambiguity may seem minor, but when coupled with all the things a diabetic patient needs to worry about constantly, it can add up. Not rotating injection sites can cause unwanted medical complications in the long run.

Final Design Objective

In my initial selection of the project area, I had already narrowed down my user group to diabetics under the age of 20. I chose to focus on insulin pens as a product.

During my research, I came across multiple case studies on the topics of usability and design for insulin pens. However, very few actually included a younger demographic and limited their research to type 2 diabetics. An older age group has very different priorities and a more mature attitude in dealing with medical complications.

The majority of type 1 diabetics are diagnosed below the age of 20 and are required to navigate and mature mentally while also managing their health. With the advantage of first hand experience, I felt it would be ideal for me to work on **redesigning an insulin pen for type 1 diabetics between the ages of 8 and 15.**

It was important to choose a more specific age group since the social needs of a child can vary widely within the span of 10 years. A parent of a patient I interviewed also mentioned that a child before the age of 8 would not feel comfortable injecting themselves. 8-15 year old diabetics would be using their first insulin pen independently which made for a very unique design brief.

I made sure to focus on the usability and design problems of the insulin pens rather than go too deep into its mechanisms and working.

Problem Areas

INJECTION SITE ROTATION

As mentioned in the interviews conducted, both users face difficulty in tracking their injection sites and being confident in their selection of sites on their body. I feel it would be highly beneficial to give users some method to track their injection sites without adding to their task flow.

SIZE AND PORTABILITY

While the product does take the form of a pen, and is relatively portable to other methods of insulin delivery, it is not easy to carry around. The product is much bigger than a standard pen. It would be uncomfortable for a grown person to carry it around in their pocket, and almost impossible for a child or adolescent user.

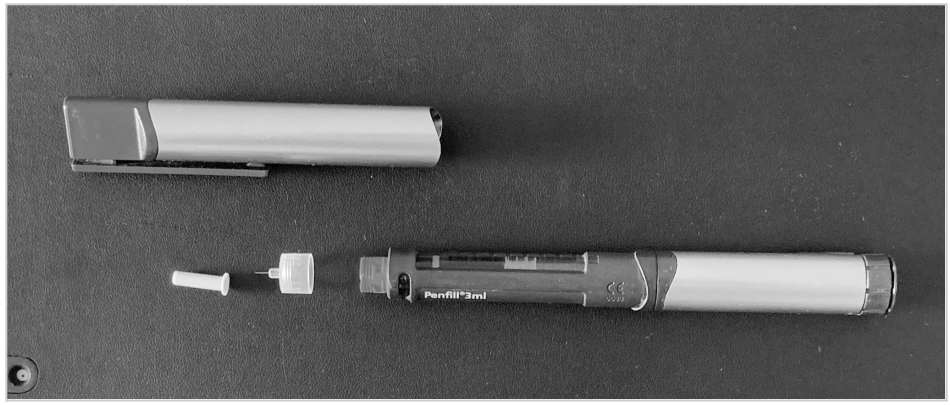
STABILITY AND GRIP

For diabetics, who very often have had no medical training, especially children, a more slow stable insulin shot would be preferred rather than a stab. This would be hard for children since they are still growing.

As seen in the user study, all of the common grips used with current pen designs have problems associated with it. Finding a solution to the most basic interaction between user and product would be imperative.

NUMBER OF PARTS

As seen in the task analysis, the user spends a lot of time removing the parts to carry out the primary function of the product. Placing it back on adds on to the time taken since the parts vary in sizes and can easily get misplaced during the task. There is no designated area to store the individual parts while open.



SOCIAL COMFORT

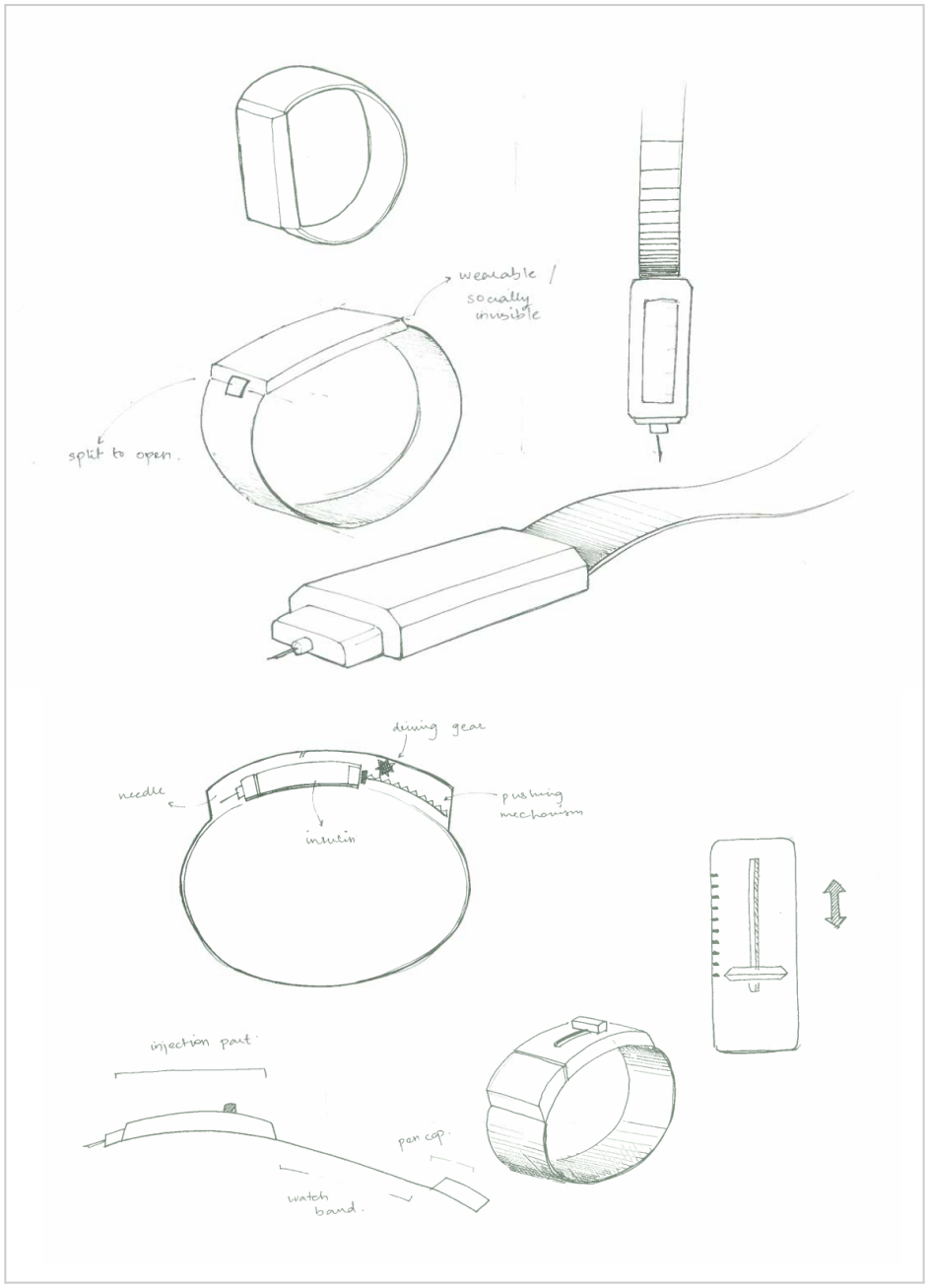
In designing for adolescent diabetics who are at stages in their lives where fitting into social norms takes priority. To use a pen that looks different may not always be comfortable. It would be more appropriate to design a product that fits in, rather than stand out while still serving its function as an insulin pen.

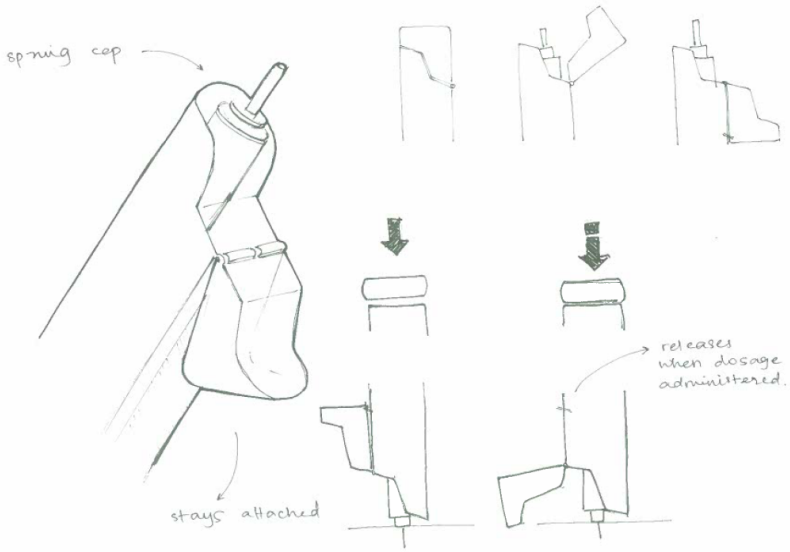
Initial Ideation

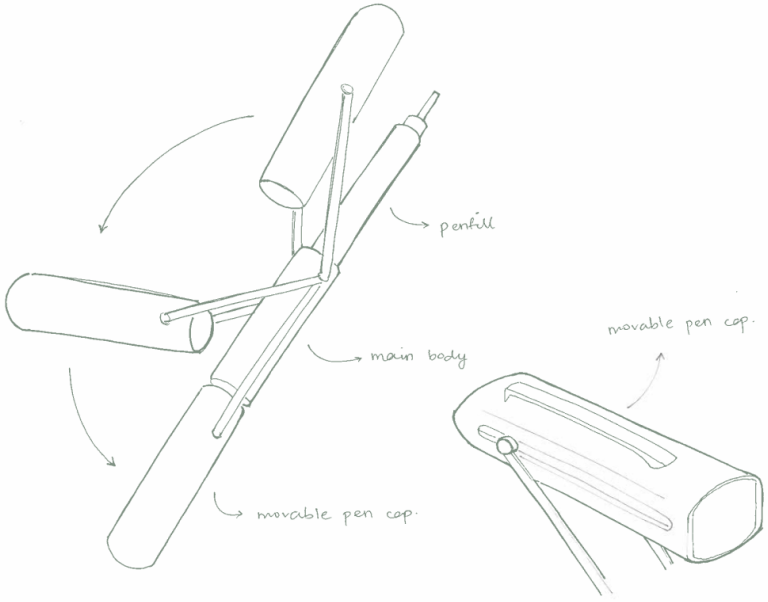
For this stage of the ideation process, I held back from limiting myself with the manufacturing, feasibility and possible acceptance of the product by the users. This allowed me to explore a wider range of unconventional forms and ideas.

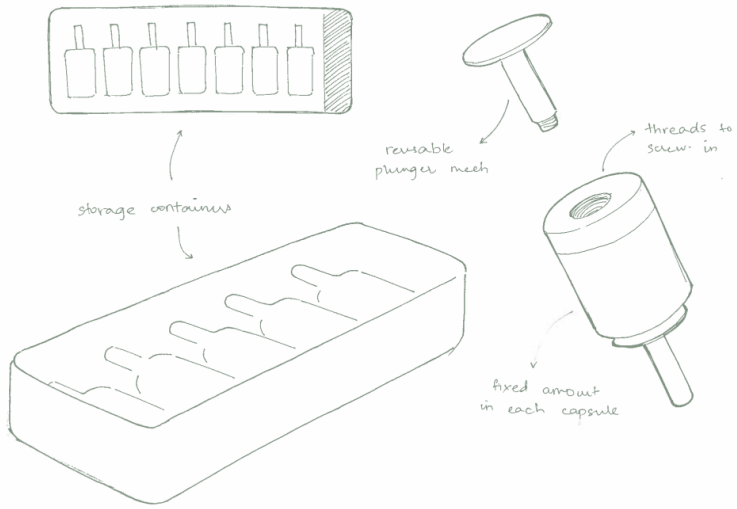
Another strategy I used to help in this process was random analogies. The first step was selecting any two random words, an animal and a thing, and listing out everything associated with them. After creating the list of words, I tried to recall my research and see if any of those qualities could fit into the product itself. This was not limited to just the form of the product but included mechanisms, storage, and all other aspects as well.

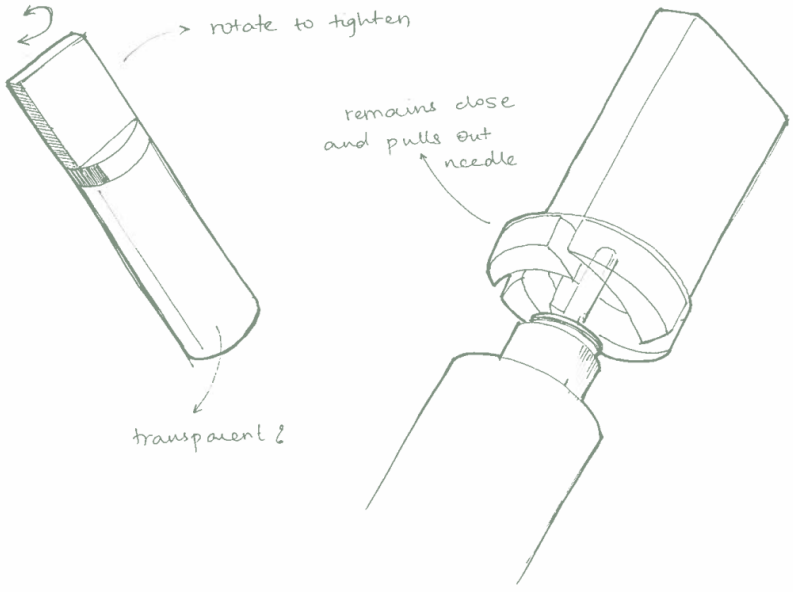
I feel that I was successful in coming up with a range of very wild ideas, as well as moving away from the conventional form of the pen, even if just in theory.

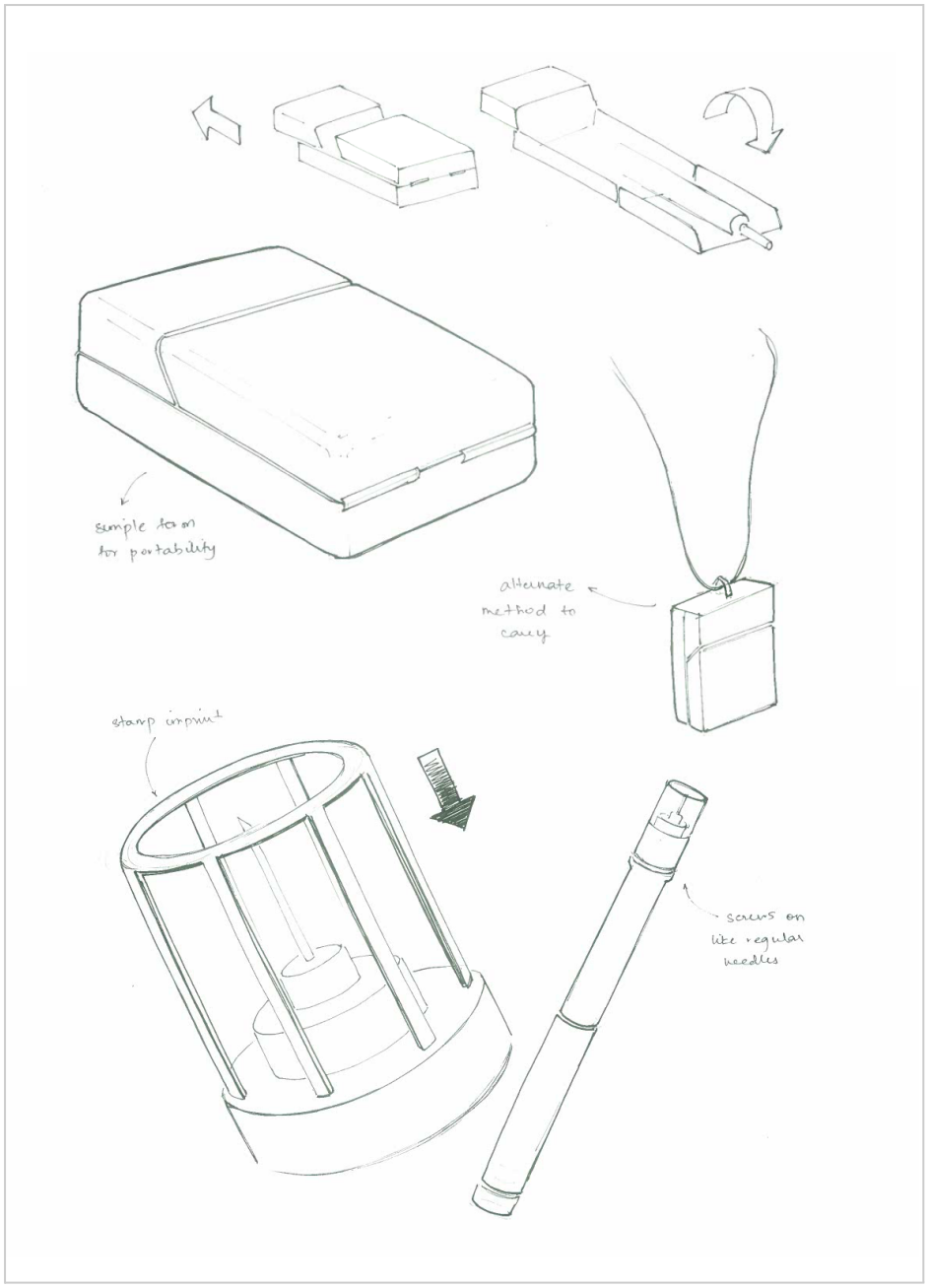


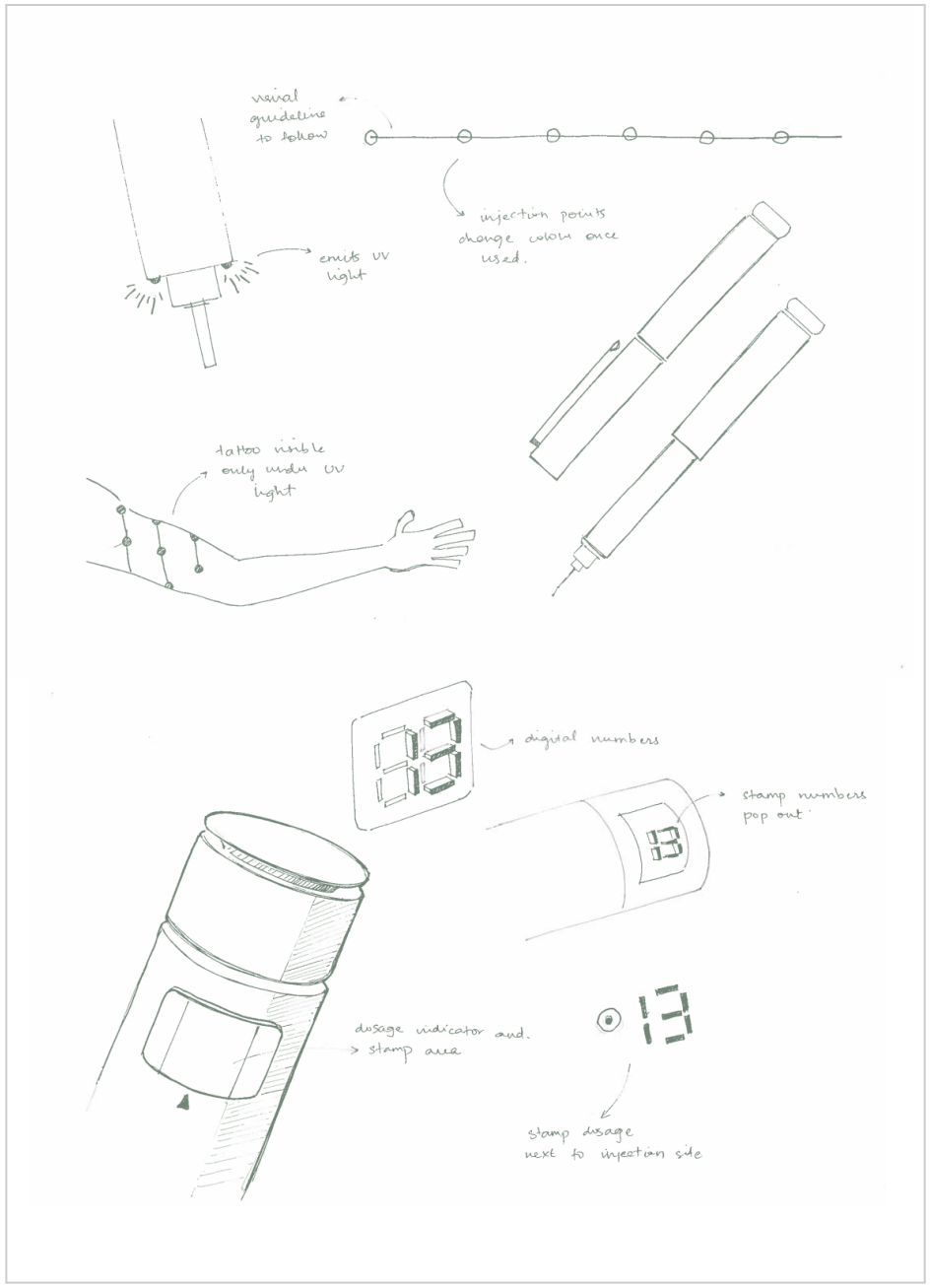

spring cap
releases when dosage administered.
stays attached


penfill
main body
movable pen cap.
movable pen cap.


storage container
reusable plunger mech
threads to screw in
fixed amount in each capsule


rotate to tighten
remains close and pulls out needle
transparent


simple foam for portability
alternate method to carry
stamp imprint
screws on like regular needles


visual guideline to follow
injection points change colour once used.
emits UV light
tattoo ink only under UV light
digital numbers
stamp numbers pop out
dosage indicator and stamp area
stamp dosage next to injection site

Design Brief

The design brief is a checklist that was developed through the research phase and altered through the course of the project. This was used as a guideline for my ideation process and kept my focus grounded in the research I had conducted.

The statements that were included defined an ideal product that would solve all the problems outlined through the research. The statements were added, removed and modified as my understanding of the problem grew.

I would later use these statements to evaluate my concepts and choose one that meets these requirements to the fullest.

1. The product must allow users to perform the basic task of injection in the least amount of time.
2. There must be enough room to firmly grip and open the needle cap without the risk of accidents.
3. The product must provide some sort of visual tracker to help users keep track of injection sites.
4. The product must be easy to store and portable.
5. Interactions must be intuitive and natural for people coming from older products in the category
6. The product must allow the user to refill the insulin penfill with minimum hassle
7. Movements required to do the task must be straightforward.

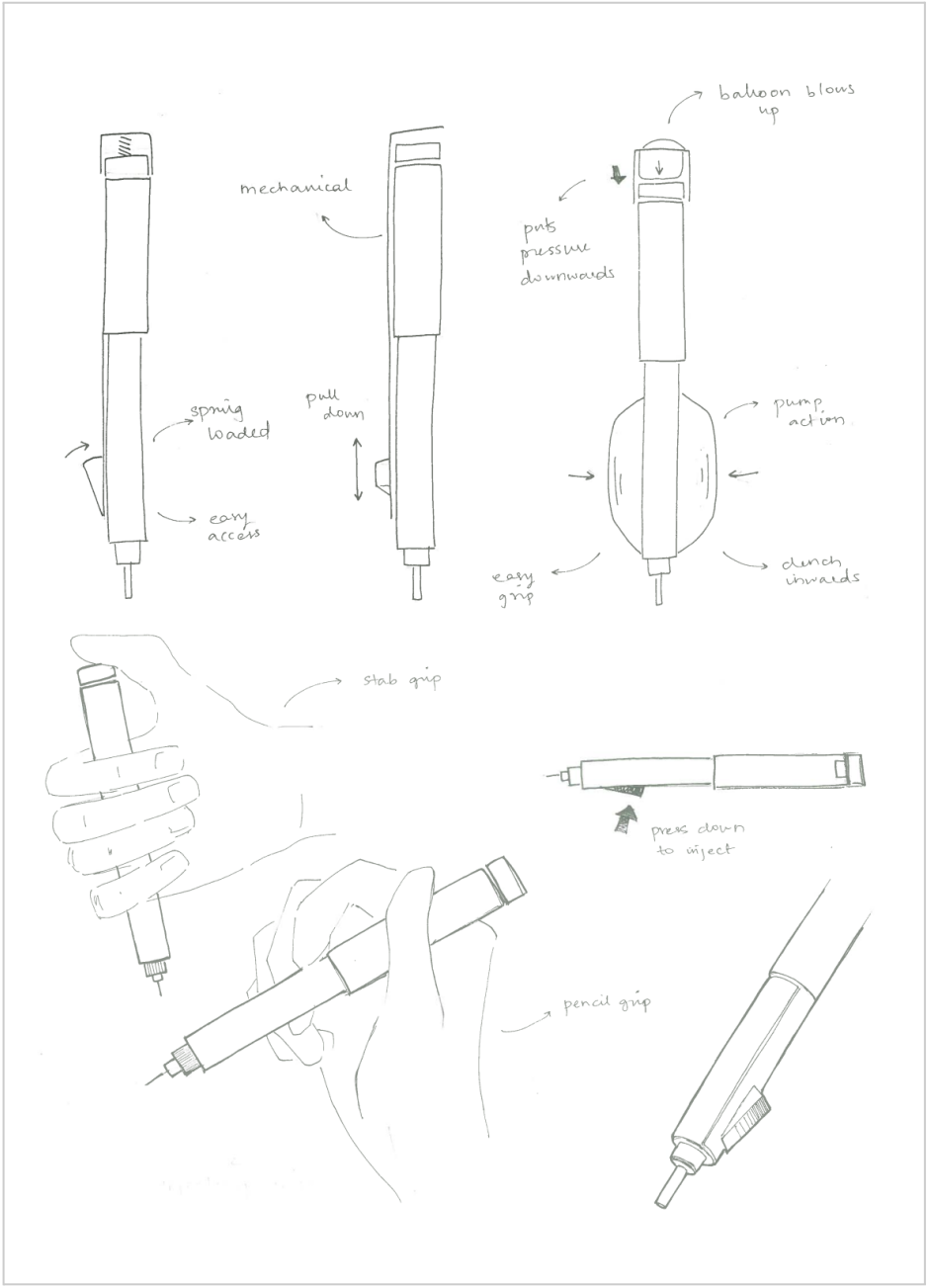
Ideation

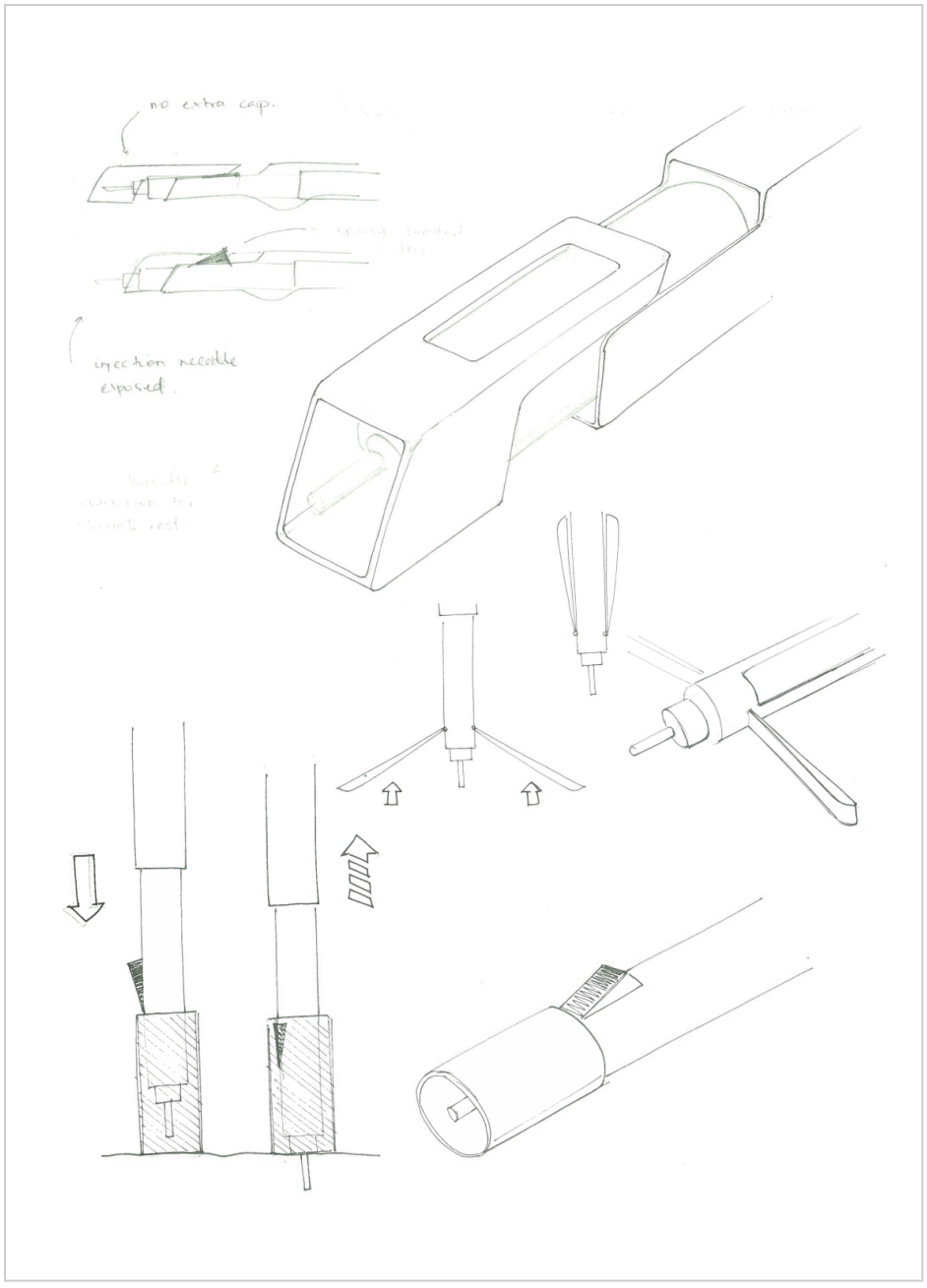
For this stage of ideation, I explored and ideated for each problem area separately. The problems areas I identified in the previous stage were not of equal importance. In the study conducted to understand the perception of prefilled insulin delivery devices by type 2 diabetics, the findings clearly pointed out that users prioritise usability features over design features.

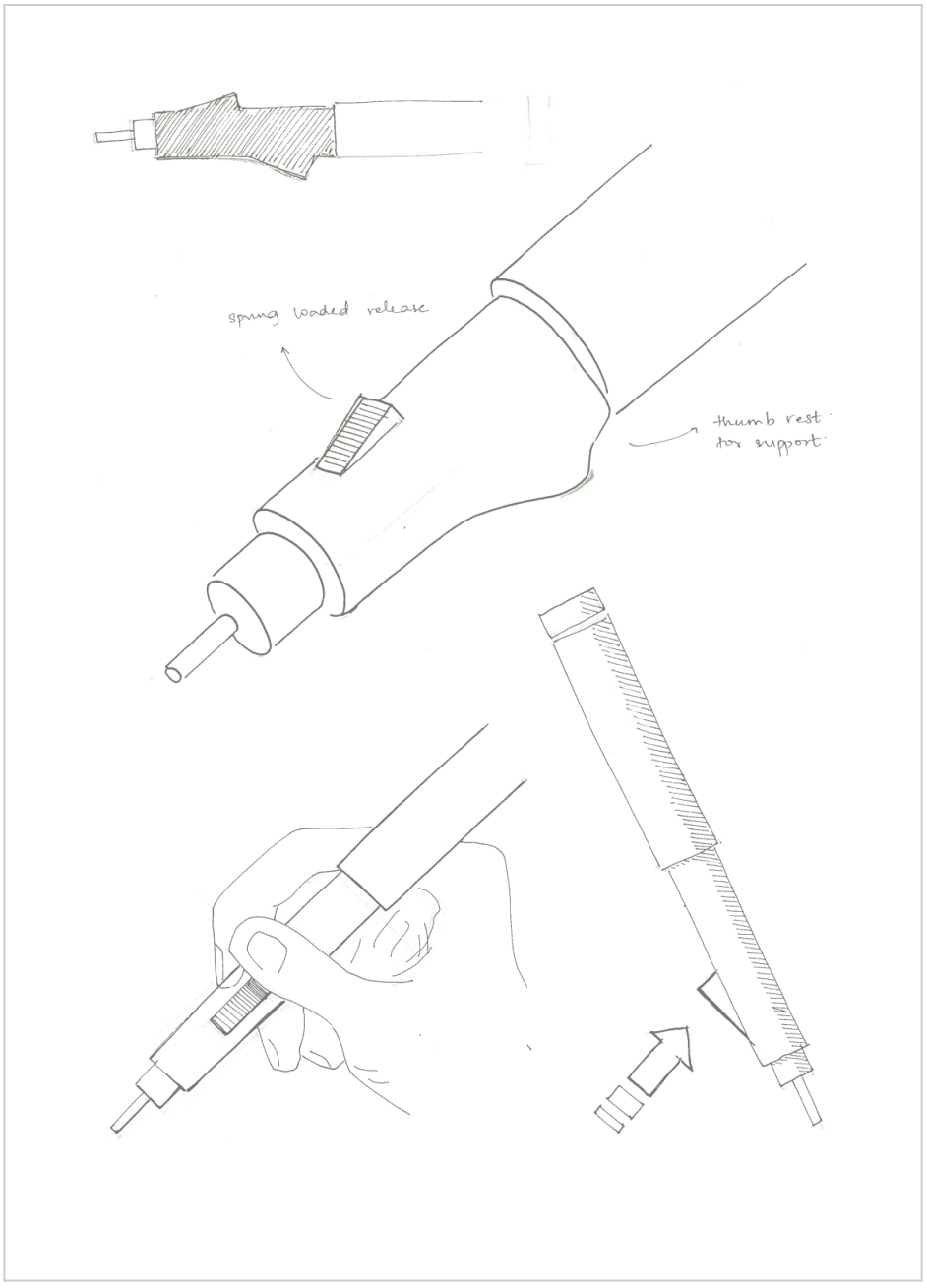
I started ideating on the problem areas of the ***stability*** of the pen while injecting and the ***grip*** of the product. I also explored different ***methods of interaction*** for the user with the injecting mechanism inside the pen.

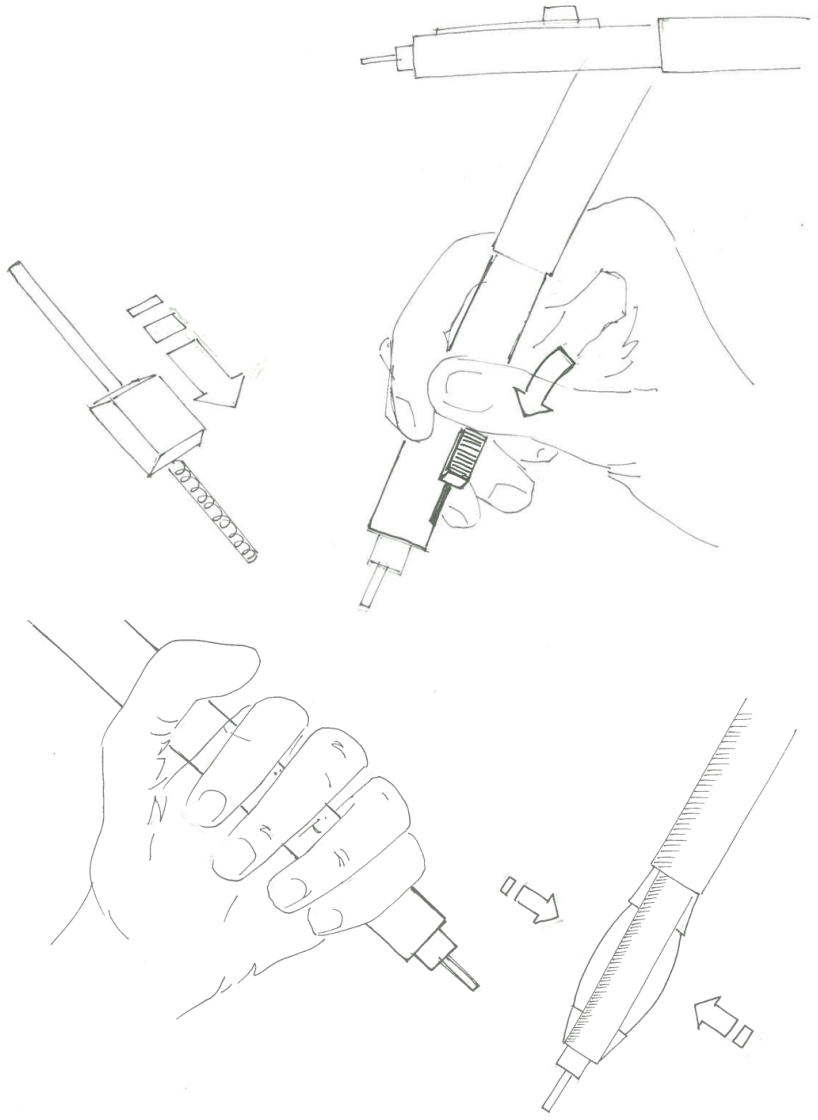
At the same time, other problem areas were not forgotten. For example, many ideas that were developed here revolved around the thought of using some sort of stamping tool to mark the skin. This would help users keep a visual track of previous injection sites and avoid them until the marker fades away.

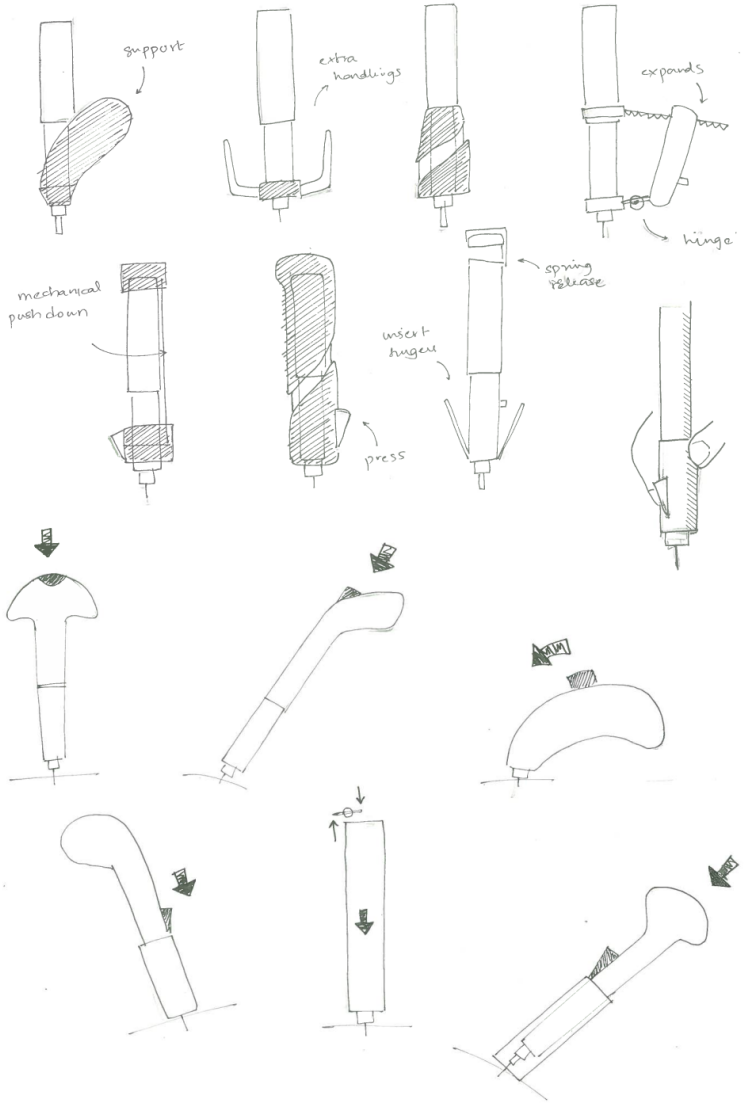
Throughout this stage, I was limited by the project area I had chosen. By choosing to build off existing injecting mechanisms, I was limited to the linear form of a pen. This mechanism was also required to be right above the penfill for it to work. I spent a lot of time looking for possible areas of intervention and then constantly validating the possibility of my idea working along with the existing design.

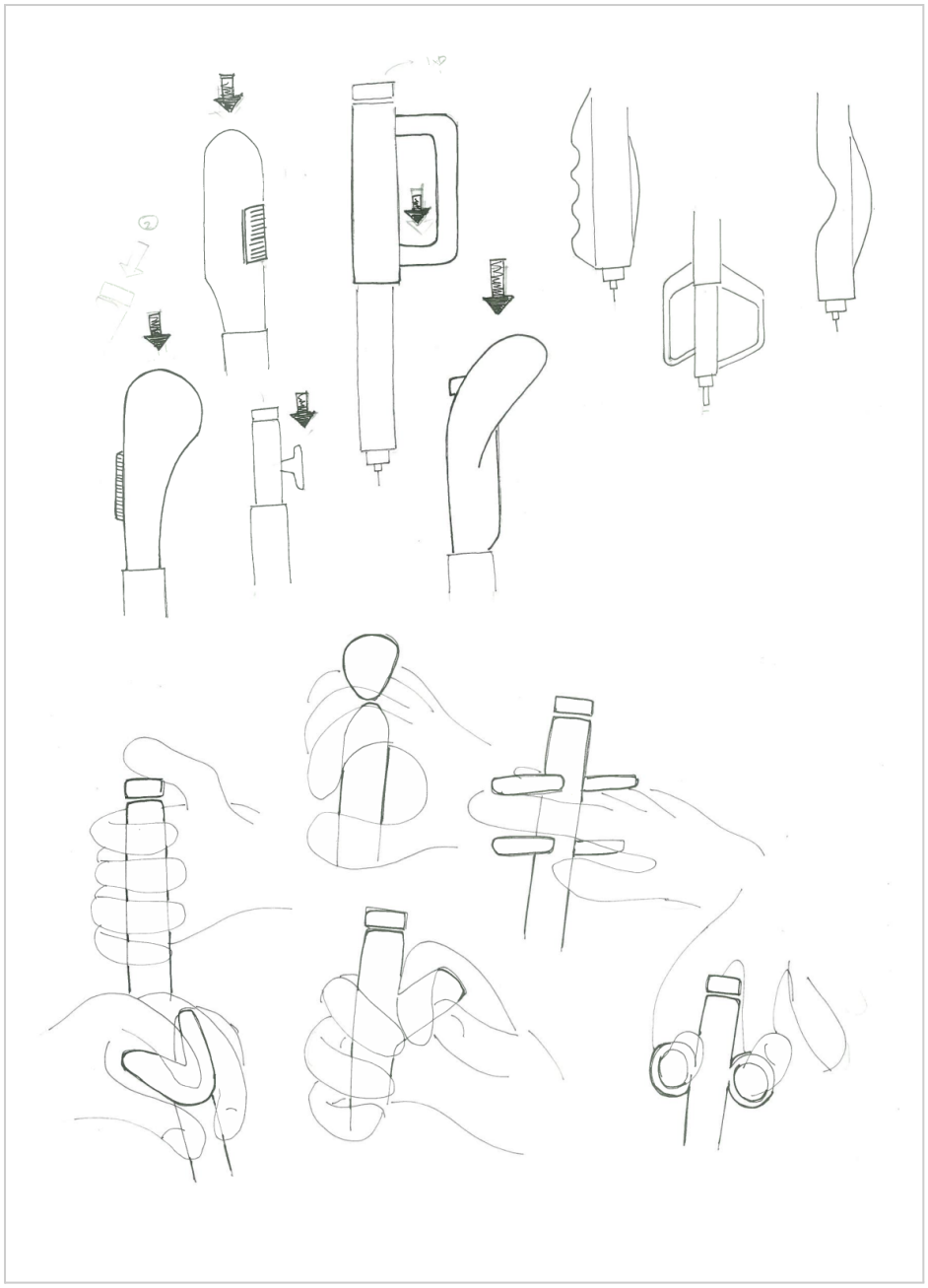


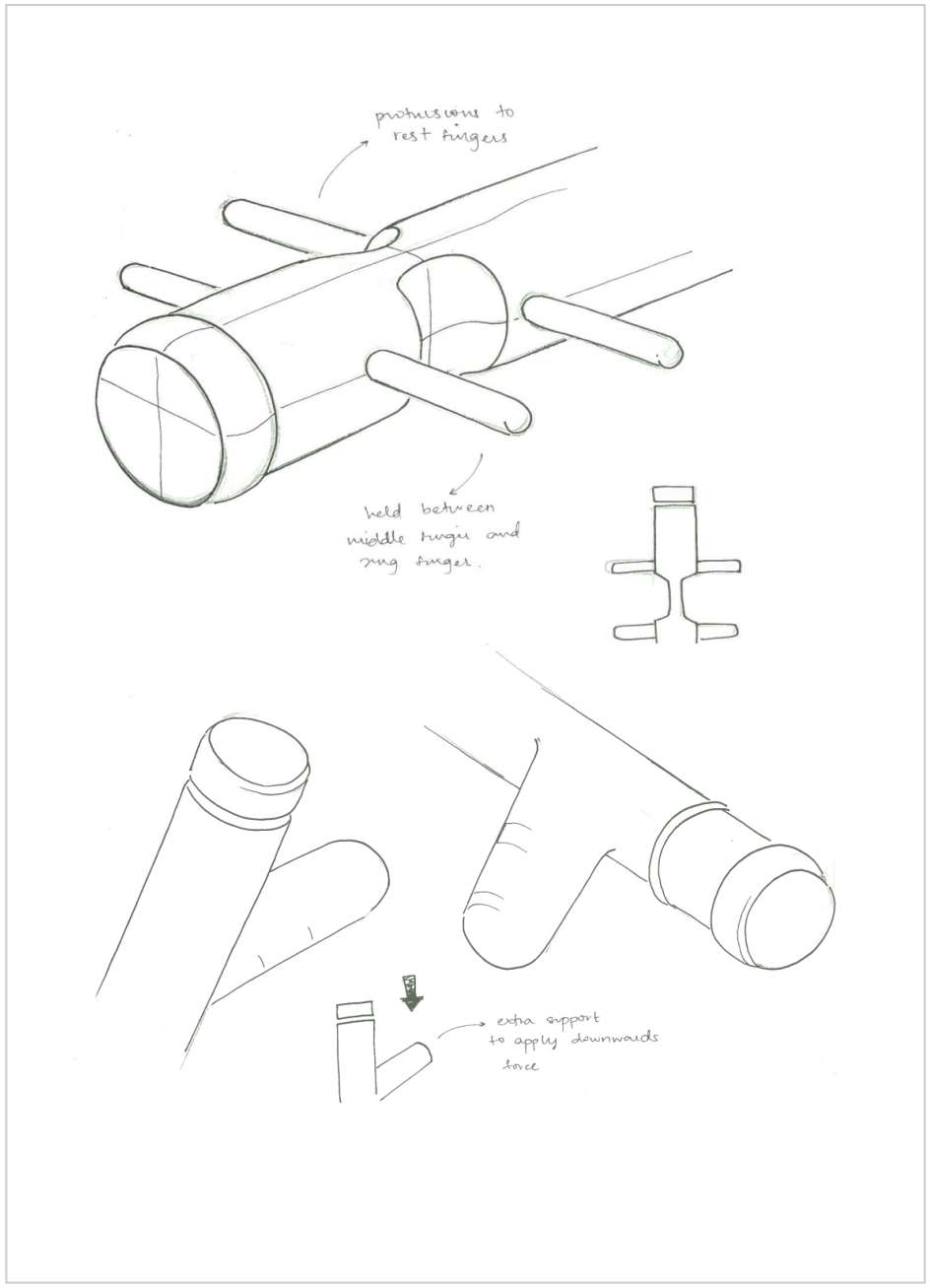

no extra cap.
injection needle exposed.

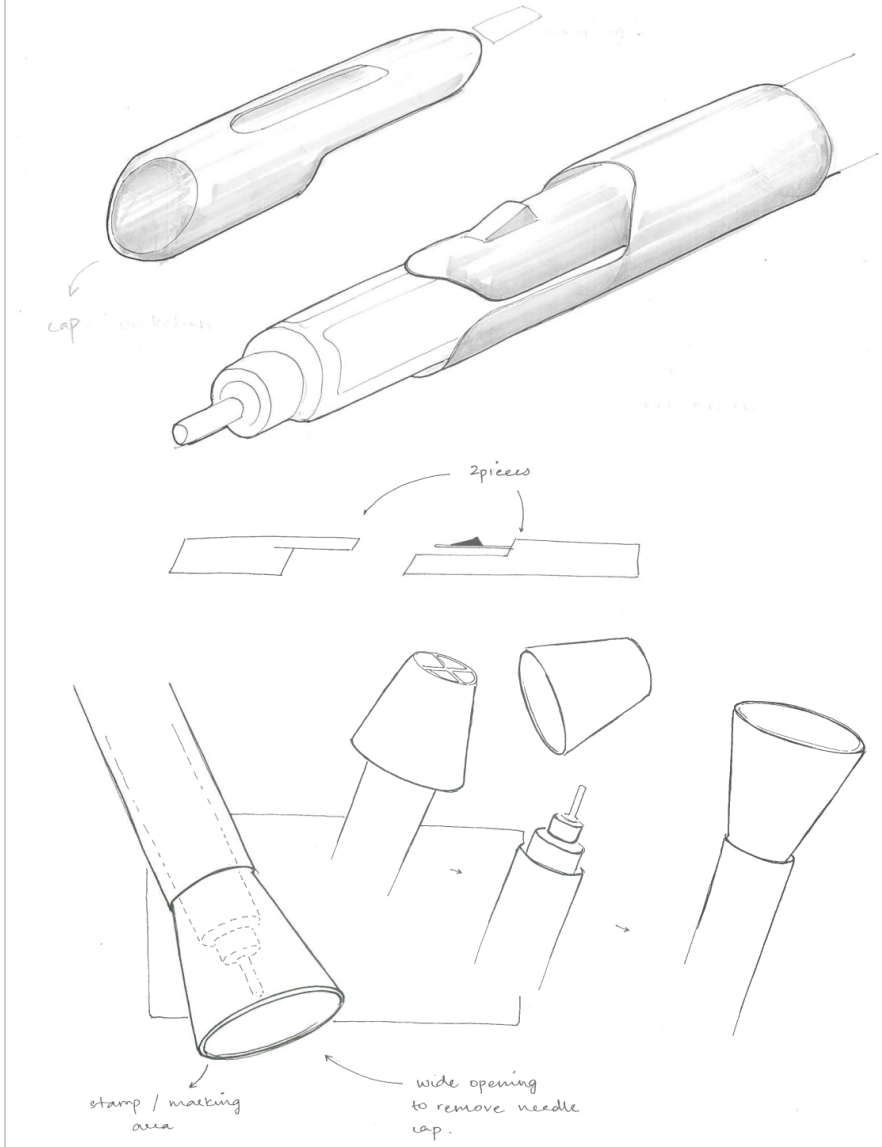

spring loaded release
thumb rest for support

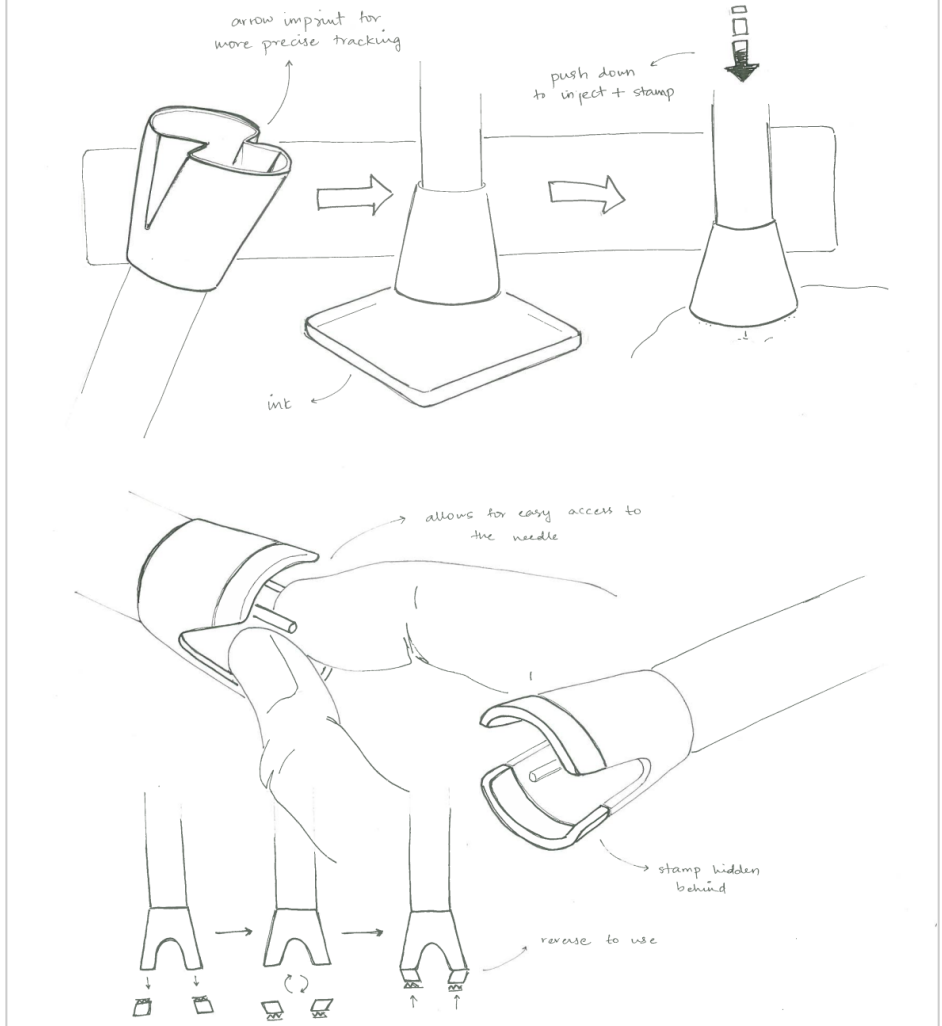


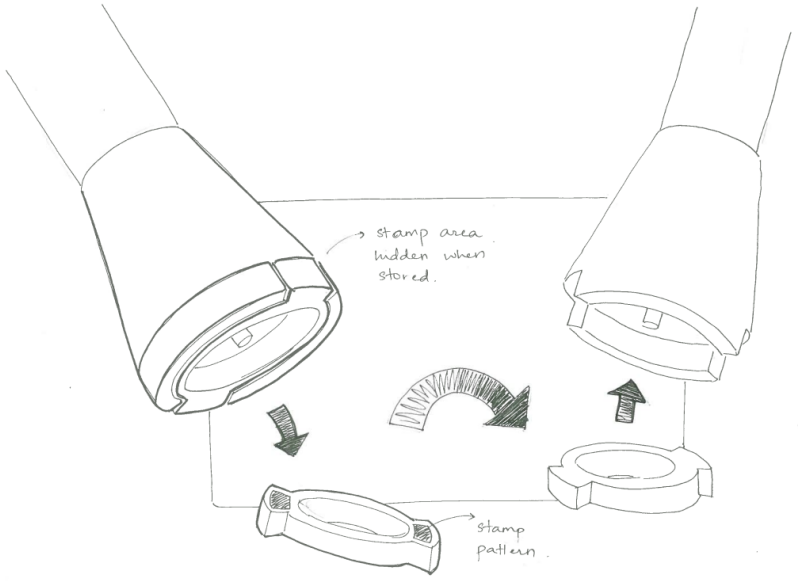

support
extra handlings
expands
hinge
mechanical push down
spring release
insert fingers
press

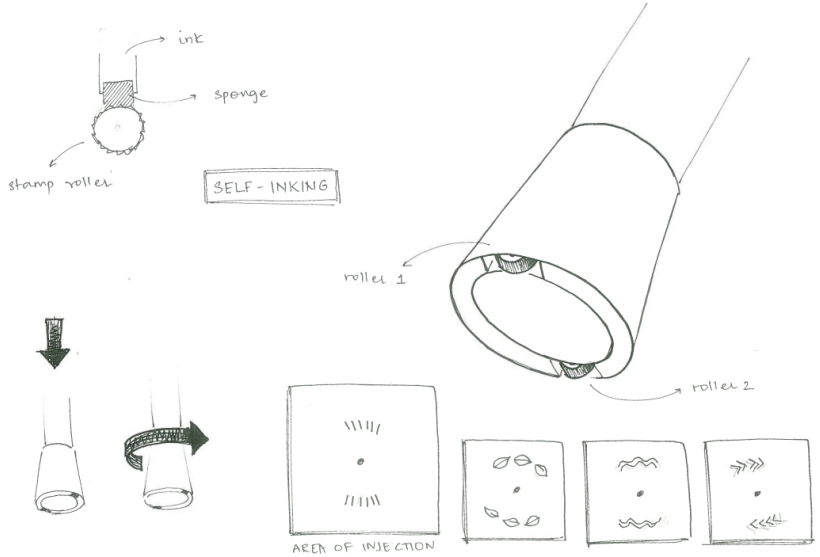


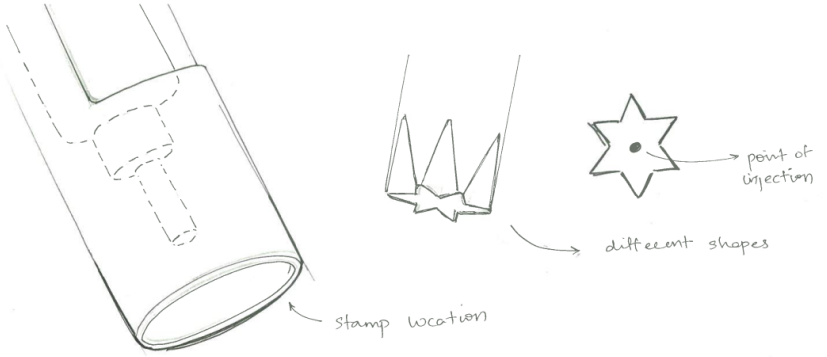

protrusions to rest fingers
held between middle finger and ring finger.
extra support to apply downwards force

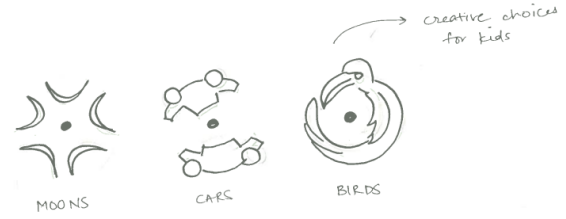

cap
2pieces
stamp / marking area
wide opening to remove needle cap.

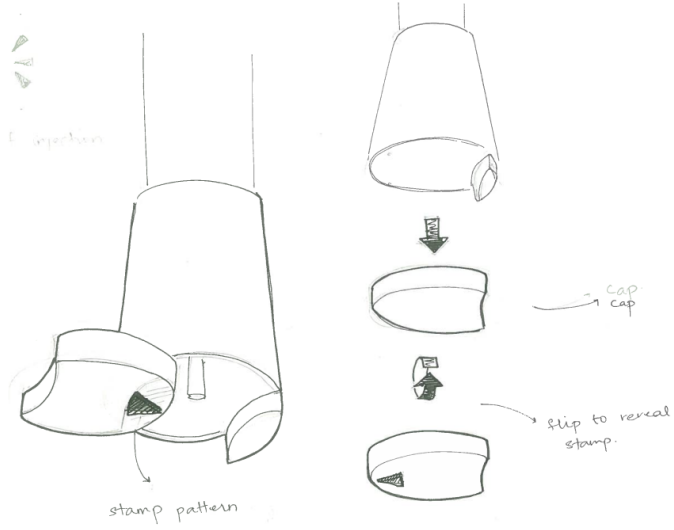

arrow imprint for more precise tracking
push down to inject + stamp
ink
allows for easy access to the needle
stamp hidden behind
reverse to use


stamp area hidden when stored.
stamp pattern


ink
sponge
stamp roller
SELF-INKING
roller 1
roller 2
AREA OF INJECTION


point of injection
different shapes
stamp location

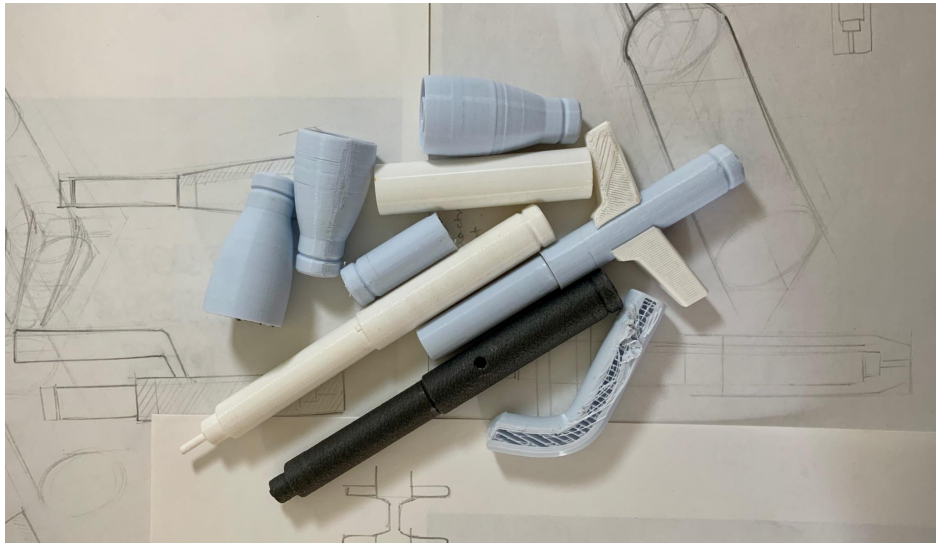

creative choices for kids
MOONS
CARS
BIRDS


cap
cap
slip to reveal stamp
stamp pattern

3D Printing Grips for Testing

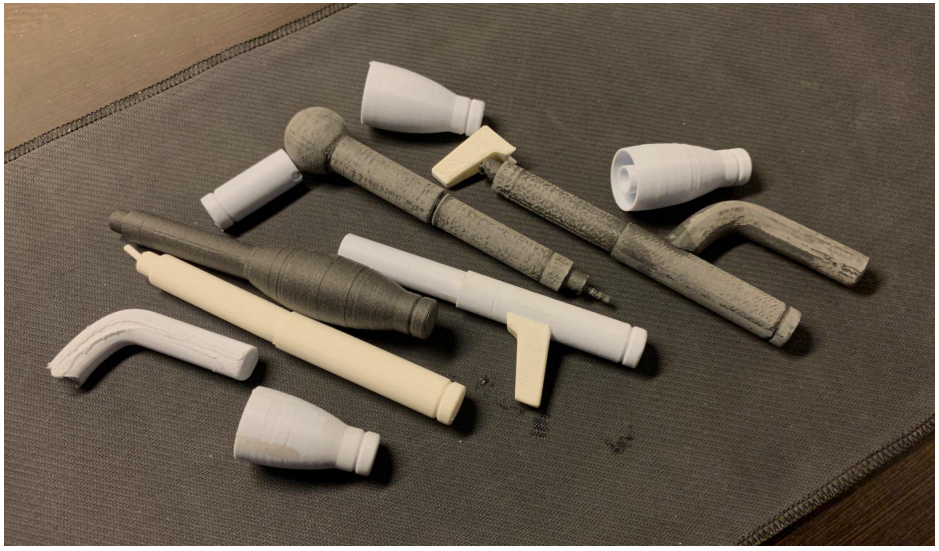
The handles and grip forms of the pen was an area I was very uncertain about. There was no way to evaluate my ideas without allowing users to physically hold and interact with the forms.

Modelling the forms and 3D printing them allowed me to give potential users a physical product to grip and critique.



Achieving the desired results with a prototyping technique I have not used before was difficult. Designing for the print was a new skill, and being efficient in the usage of the material was hard. I had multiple failed attempts. I have written some of my learnings below.

- When printing tall forms that do not require the middle to be hollow, use a solid model and allow the printer to add supports.
- Make sure your product has minimum overhangs. This will make anything that is printed above unstable.
- If the proportions of the product is relatively extreme, consider printing it horizontally to avoid the risk of it tipping over.



User Testing Grips

With the help of my guide, Prof. Purba Joshi, I was able to contact the parents of three children to test out my models. However, the children were not diabetic and had not used any form of injecting mechanism before.

Before beginning, I gave the children a brief introduction about diabetes as a condition and what the purpose of the pen is. The functional requirements of the pen were also explained to allow the child to mimic the actions and test the product accurately.

The test was conducted under the supervision of their parents. All three users were in the range of 10-12 years old.

TESTING NOTES

User 1

- Did not immediately settle on any one grip. Experimented holding the form with different fingers and at different angles.
- After a while, the child defaulted to the *stab* grip and tested all the products using it.
- The child chose the bulged handle as the most comfortable.
- Used the word ‘soft’ to describe the feeling when gripping the bulged grip form.

User 2

- Settled on the *stab* relatively quickly.
- Was very confused on how to grip the forms with protruding handles and after a while avoided picking them up.
- The child felt equally comfortable on the standard form and the bulged form.
- Expressed dislike towards the forms with any protrusions as it made it unnecessarily difficult to grip.

User 3

- Initially attempted to hold the form with the *pencil* grip but readjusted to the *stab* grip when reminded of the need to apply force at the top.
- Was also confused on how to grip the forms with protruding handles.
- The child was most comfortable with the standard form with no changes.
- Felt any of the changes were unnecessary and had seen the existing design work well before.

KEY INSIGHTS

All three users eventually felt most comfortable with the ‘stab’ grip. 2 out of the 3 users said it was natural to use the thumb to press downwards. Users also did not feel comfortable gripping forms with any protrusions. I am assuming that users were just not aware of how forms with protruding handles were meant to be held and so just avoided them altogether.

While one of the users did like the bulged grip’s ‘softness,’ the other two were very uncomfortable with the complexity of the form. I am assuming it felt alien in their hand and therefore unpredictable for them

Designing for Kids

USER EXPERIENCE RESEARCH

It was important to understand how kids or adolescents differ from adults in their choice of products. Through the span of 20 years, children go through many stages which can have different effects on their styles and preferences. Choosing a more specific age group was very helpful in understanding what the users may prefer.

Any user, especially kids, would highly benefit from instant feedback. This would give users a level of confidence in using the product and assurance that it is functioning correctly.

Adding a story or context to the product was something that would make kids more likely to enjoy the product. I planned to include this initially in the aesthetic of my product but realised later on that it was more specific to a younger audience than my specific user group. (Molnár, 2018)

PRODUCT RESEARCH

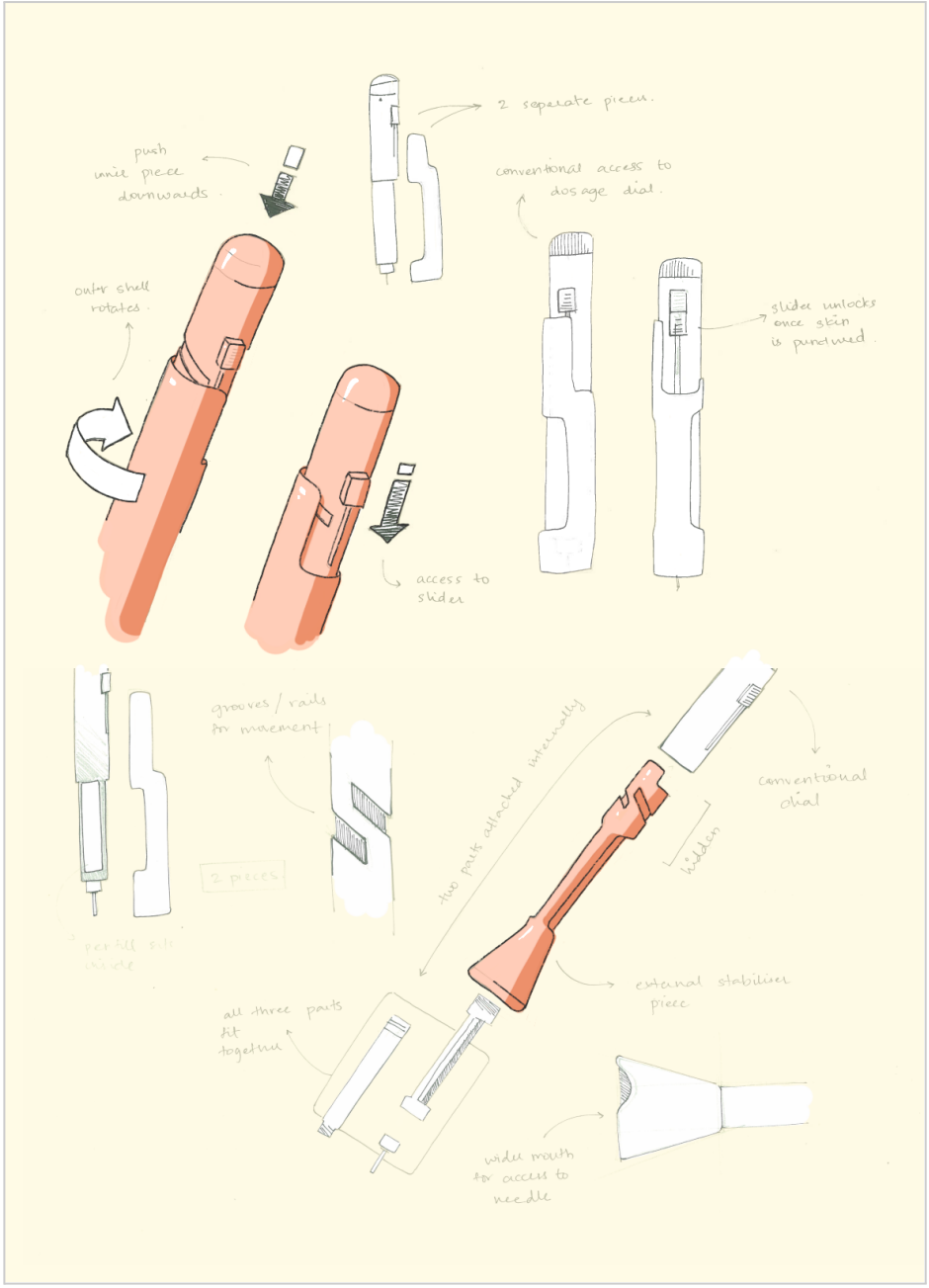
I looked up medical products designed specifically for adolescents and kids rather than generic products that included them. A colourful, happy and vibrant aesthetic was noted along with simple lines and geometry to keep the product looking clean.

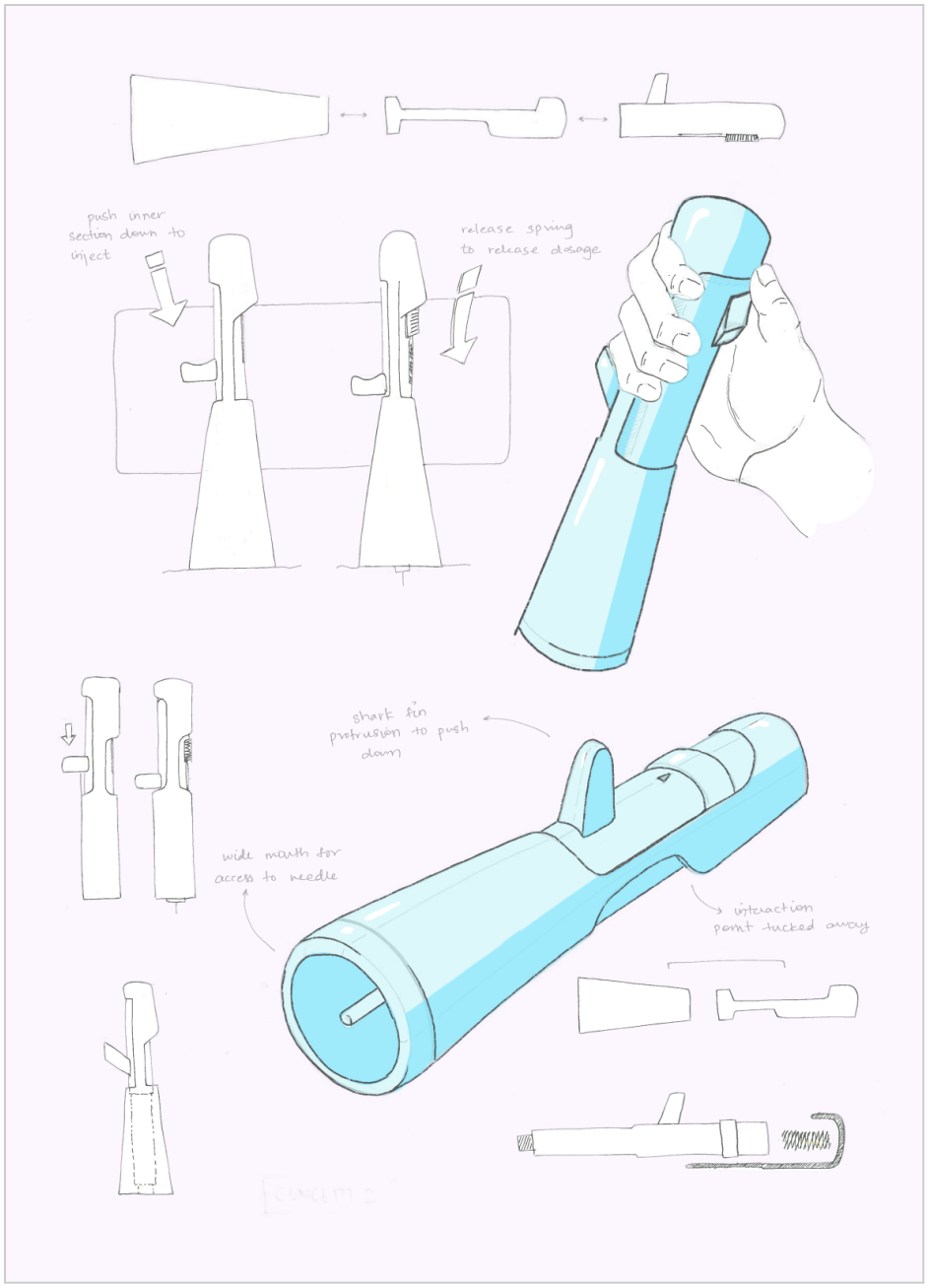
https://www.yankodesign.com/2018/08/22/the-bean-thermometer-for-children-is-equal-parts-playful-and-medical/

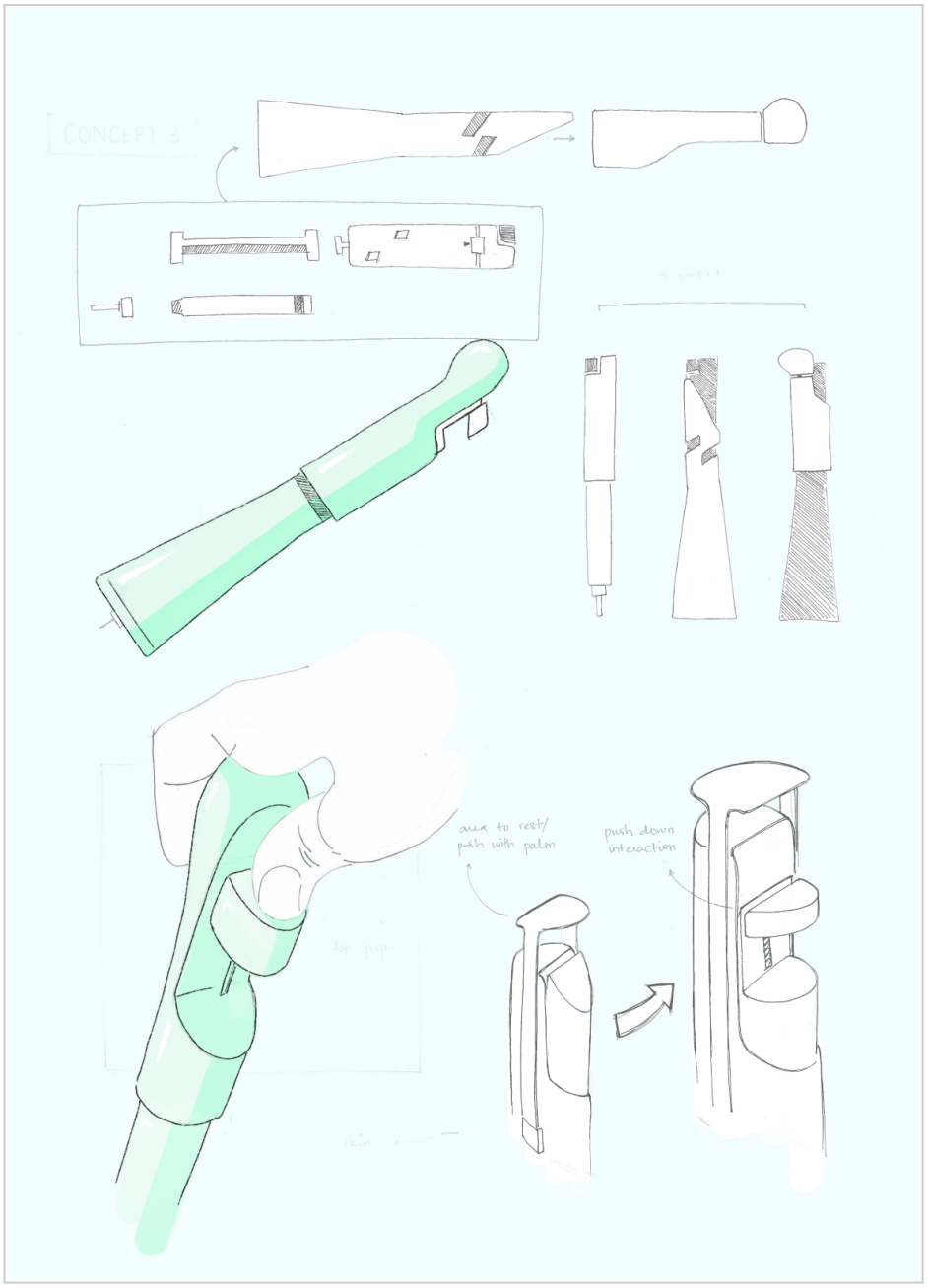
Final Concepts

The champion concepts were created by comparing previous ideas based on research and findings. The concepts were also heavily influenced by the insights from user testing.

In comparison to ideas, the final concepts were heavily detailed. The focus was on designing a functioning and coherent product from its parts and reducing the number of problems the user would encounter.




push inner section down to inject
release spring to release dosage
shark fin protrusion to push down
wide mouth for access to needle
interaction point tucked away
CONCEPT 2


CONCEPT 3
area to rest/ push with palm
push down interaction

Concept Evaluation

Concepts were evaluated against the design brief I had developed through the course of research, before I started my ideation. Each of the three concepts were then given a score of 0, 1, 3 or 9, depending on the design. This scoring method would allow for a more clear distinction when evaluating the final scores.

Brief	Concept **1**	Concept **2**	Concept **3**
1. Perform Basic Tasks	9	9	9
2. Easy Needle Access	9	9	9
3. Site Tracking Methods	9	9	9
4. Storage and Portability	9	1	3
5. Intuitive Interactions	9	3	1
6. Easily Refillable	3	1	3
7. Simple Movements	9	3	1
Total	57	35	35

Concept 1 scored significantly higher in the evaluation scoresheet than the other two concepts. The scores given to all three concepts for the first three statements remained high as ideas to solve those issues were finalised early on in the ideation process.

All the concepts scored relatively low in keeping the insulin pen easy to refill. The evaluation pointed out areas like this one that I overlooked during the detailing of concepts. I made sure to explore the concept in the final design of the product.

The evaluation technique does not accurately capture and compare the strengths of these concepts due to the iterative ideation process that I adopted. Nonetheless, it validated my preference in concepts and allowed me to move forward to create a feasible design.

Product Moodboard

UNDERSTANDING THE USER

This product is designed for users of the age group 10-16. Speaking only from personal experience, such users are at a stage in life where they would rather fit in than stand out, especially in regard to a medical illness. At the same time, users may want the freedom to customise the products they use and make it their own. A sense of freedom with an illness like diabetes that can feel very restrictive at times, would definitely have done me some good.

COMMUNICATING EMOTIONS

The product is one that would be used multiple times a day. The goal was to make the product fit into the product aesthetic that users of that age group would have. Key ideas like fun, playful and independent were identified.

The context and use case was an important aspect of these choices. The task of injecting is not a very pleasant experience, wherever or whoever they may be. While insulin injections are essential for type 1 diabetics to survive, I wanted to disconnect the insulin pen from other injections, disease and sickness. I looked for opposite emotions of health, safety and comfort to define my aesthetic.

https://www.yankodesign.com/2019/05/30/relay-gives-your-kids-the-benefits-of-a-smartphone-without-the-addictiveness/
https://www.behance.net/gallery/81529429/Baby-crying-monitor

Final Concept

DETAILING THE COMPONENTS

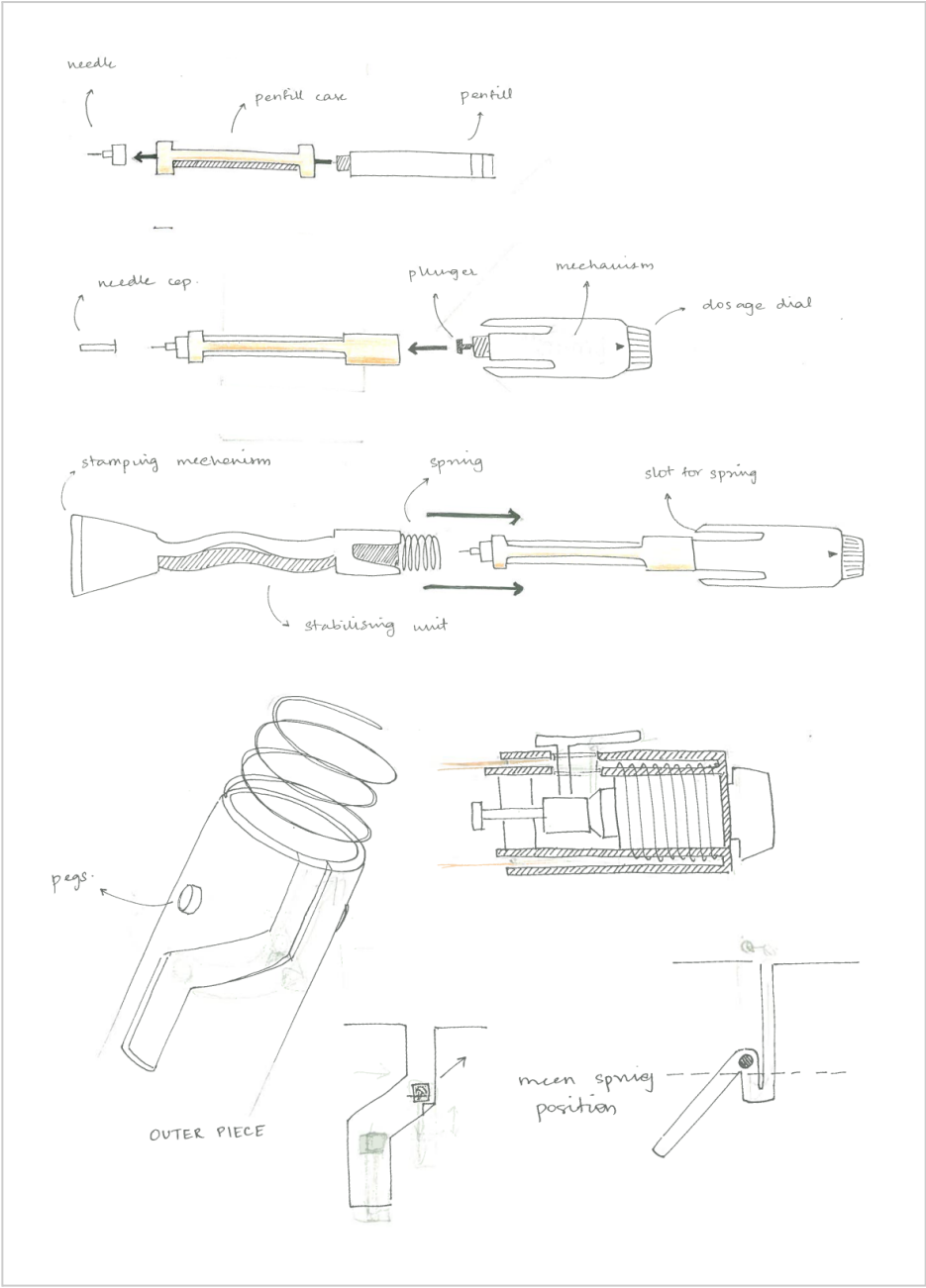
The final design of the product is relatively complex. A lot of time was spent in figuring out how each component would serve its purpose along with fitting in with the rest of the product.

Three components remained unchanged in my final design. The first of them is the needle, which is an industry standard. It is a disposable part of the product that screws onto the penfill. The penfill is the second standard part which is designed differently by different manufacturers. I based my design off the range of penfills designed by Novo Nordisk, a Danish pharmaceutical company.

The third component is the penfill case which holds the penfill. I didn't find the need to change this design as its purpose remains similar to the original design.

I have also used the existing torsion spring injecting mechanism that I detailed out earlier in this report. I did not attempt to ideate or explore alternative designs as it was out of the scope of my project.

Other parts of the design, the casing of the internal mechanism, the stabilisation unit, the dial, the cap, and the stamps were designed to measurement, keeping in mind the material and durability of the product.



MECHANISM DEVELOPMENT

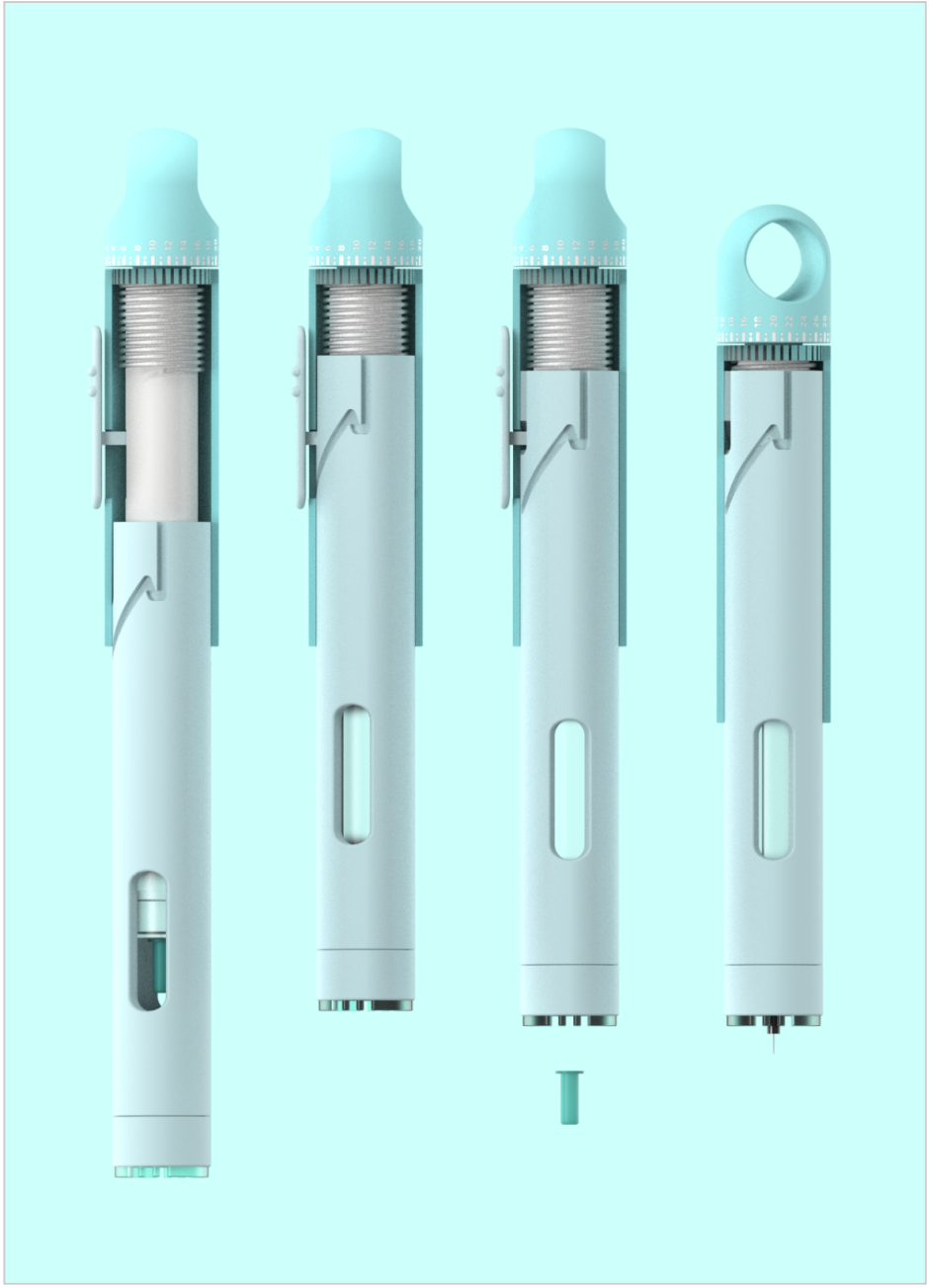
The process from selecting the concept to detailing the product was a long one. I started by detailing the functional aspects of the stabilising mechanism.

There were two main components that fit together so the mechanism would work. The first component is the *insulin pen* itself, with changes made to the body to accommodate for the interaction with the second component. The *stabilising piece* is the second component that would sit within the first component. A spring would be present between these two components to help with the stabilisation while injecting.

The illustration on the right shows the different steps involved. The user would lock in the stabilising component by pushing it against the spring, rotating about 20º and releasing. This would need to be done only after replacing the penfill.

The user can then pull out the needle cap right before injecting and place the pen on the surface of their skin. The user can comfortably push down the pen to allow the needle to slowly puncture the skin.

The concept I chose also included a locking mechanism to prevent any accidental presses of the slider to release the insulin without the needle even entering the skin. I included a stopper in the stabilising component that would stay hidden under the surface of the pen. This would prevent the slider from being released unless the insulin pen has been pushed downwards against the skin.

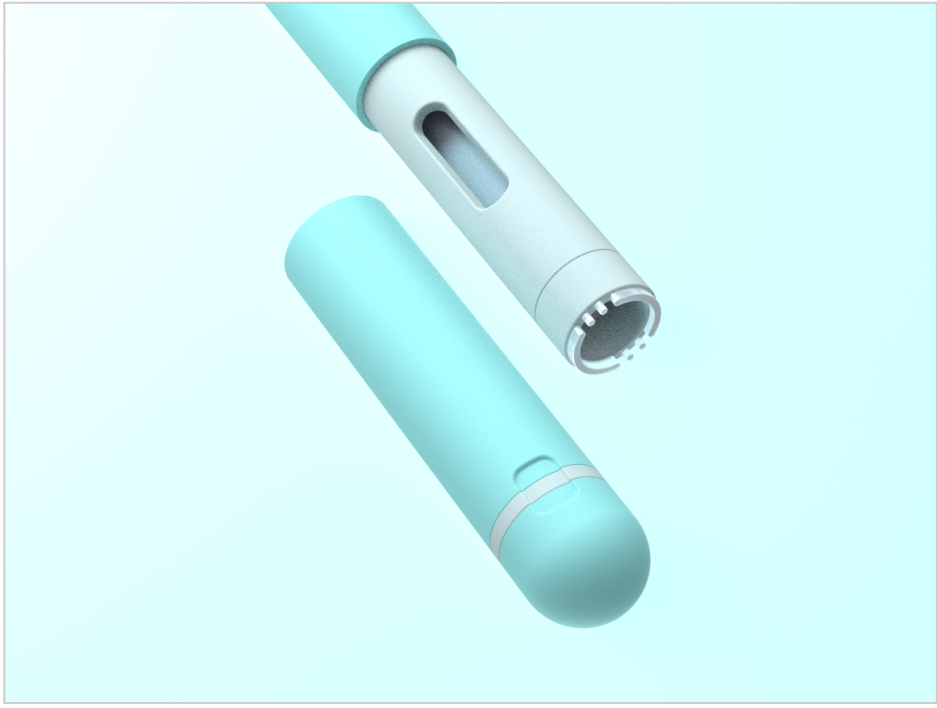


FORM DEVELOPMENT

Developing the form consisted of anticipating usage patterns for each component of the product and making the product easy and simple to use as a whole.

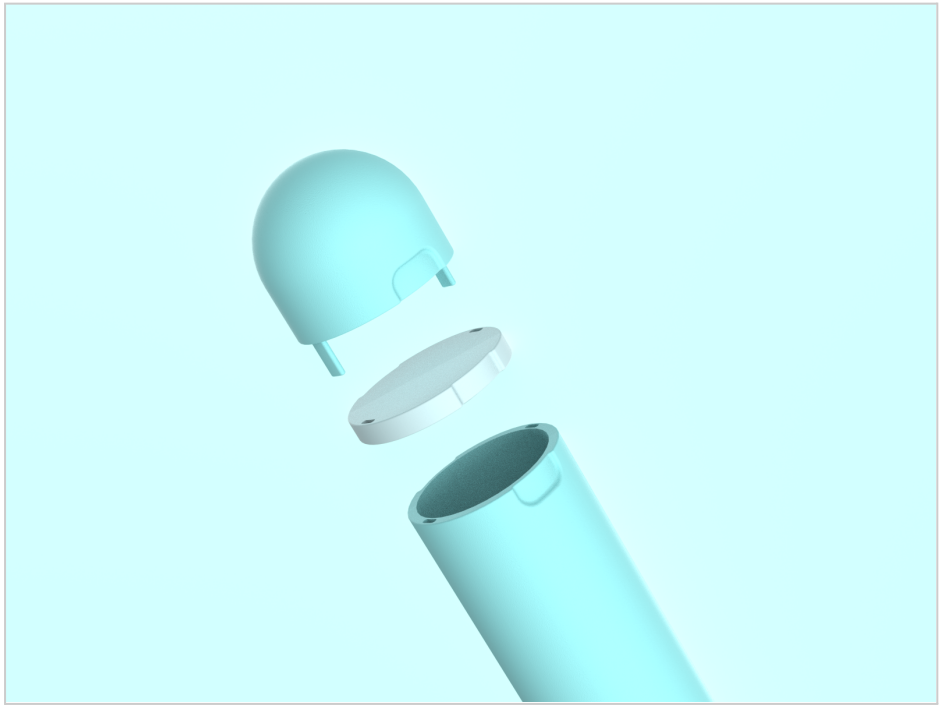
During concept development, I overlooked the need for a cap on the insulin pen. I only realised the importance after a discussion with my guide where the context was pointed out to me. The cap would not only serve as a capsule to protect the components inside from external force, but also protect it from the elements. Keeping parts such as the needle and insulin penfill sterile and clean was non-negotiable for a product with such a use case.

Initial explorations consisted of allowing the cap to be attached on the back of the pen (onto the dial), while in use. However, it would have made the task complex and reduced usability. A conventional full pen cap was used in the final form.



Including an ink pad or stamp pad into the pen cap was a challenge. The design required to allow the user to replace the ink pad with different colours of ink or a new one. Since the frequency of this task would be much lesser, the pen cap was separated in 3 parts. In the

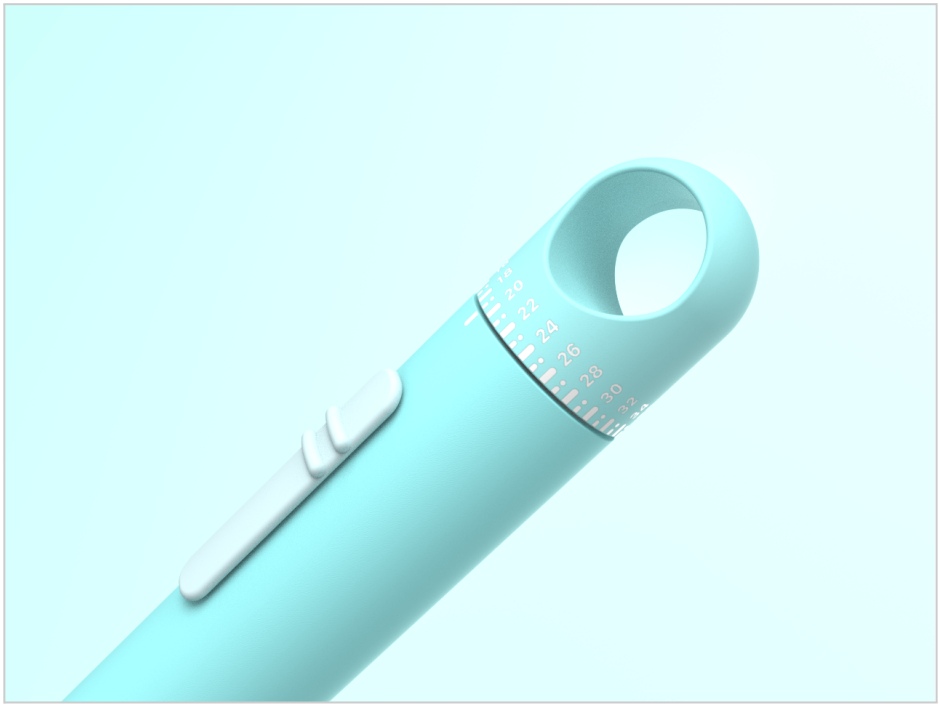
final design, the top and bottom parts of the cap would basically sandwich the replaceable plastic piece that held the ink pad.



The body of the pen in the final design was made taller to allow for a larger gripping surface. The length of the slider was increased to make it easier to reach with the thumb using a standard ‘stab’ grip.

The dosage dial is one of the two interaction points on the product. It is used to input the dosage for the injection. The numerical indicators on the dial needed to be readable. The design also needed to include a gripping element to allow the user to apply accurate force and rotate it comfortably.

A non-cylindrical element was added on top of the dial to increase the grip as well as add more surface area on the component. The hollow ring is not only an aesthetic feature but would also provide users with an alternative grip to rotate the dial or even just grip the product.

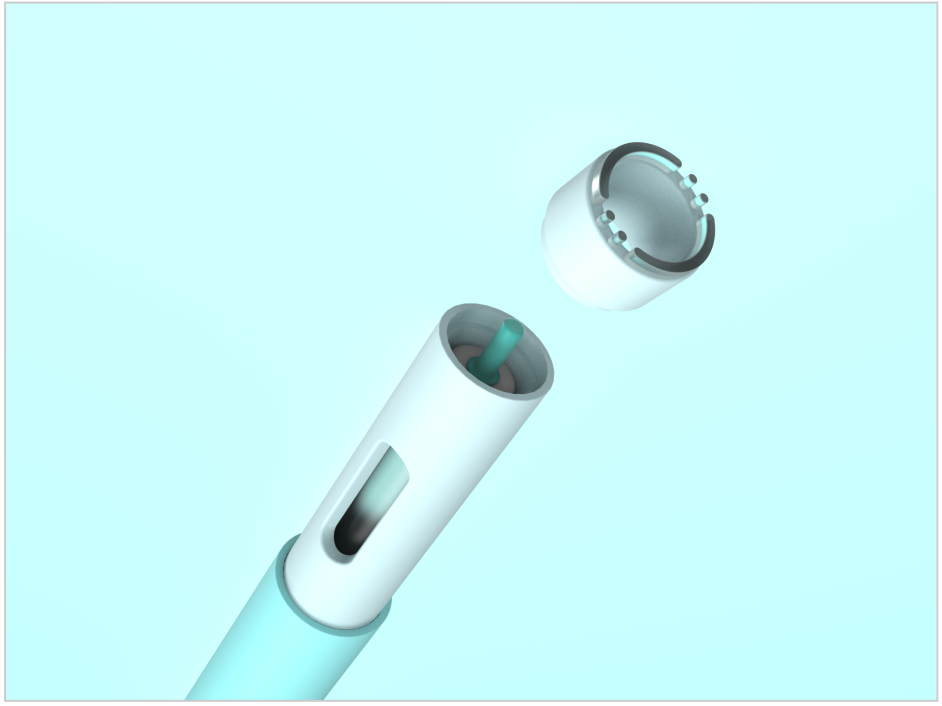


On the stabilising component of the pen, a window was cut out to allow users to observe the amount of insulin left in the pen. This is useful for users to keep track and plan their routine accordingly.

The bottom of the penfill would align to the bottom of the window when at rest. An understanding of the use case guided me in the design of this element. Since the user would only care about the

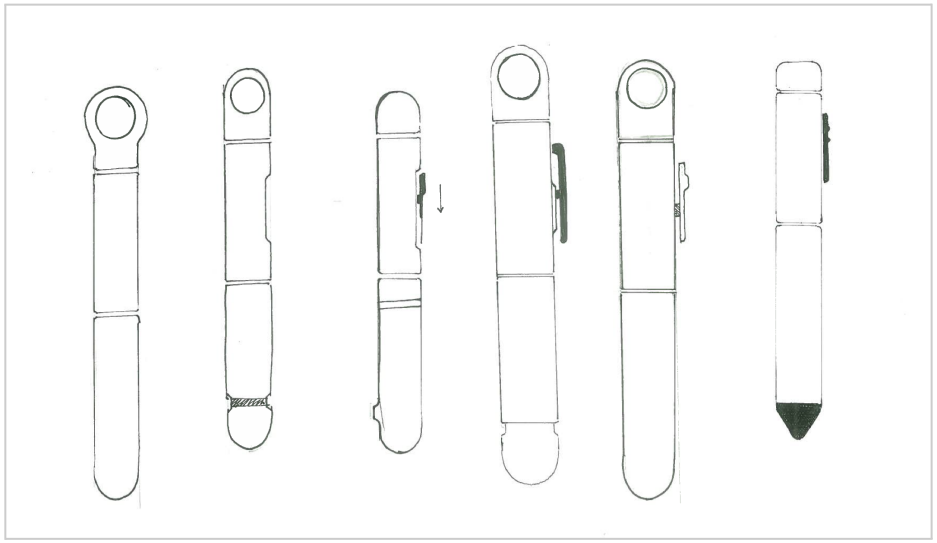
amount of insulin left when it is close to empty, I chose to allow for the top area of the penfill to be covered, but making sure the bottom part is completely visible.

An additional feature of replacing the stamp pattern was added on here to allow for personalisation by the user. The bottom part of the component can clip off and be replaced by a new pattern, giving users a feeling of freedom and control while managing their blood glucose.

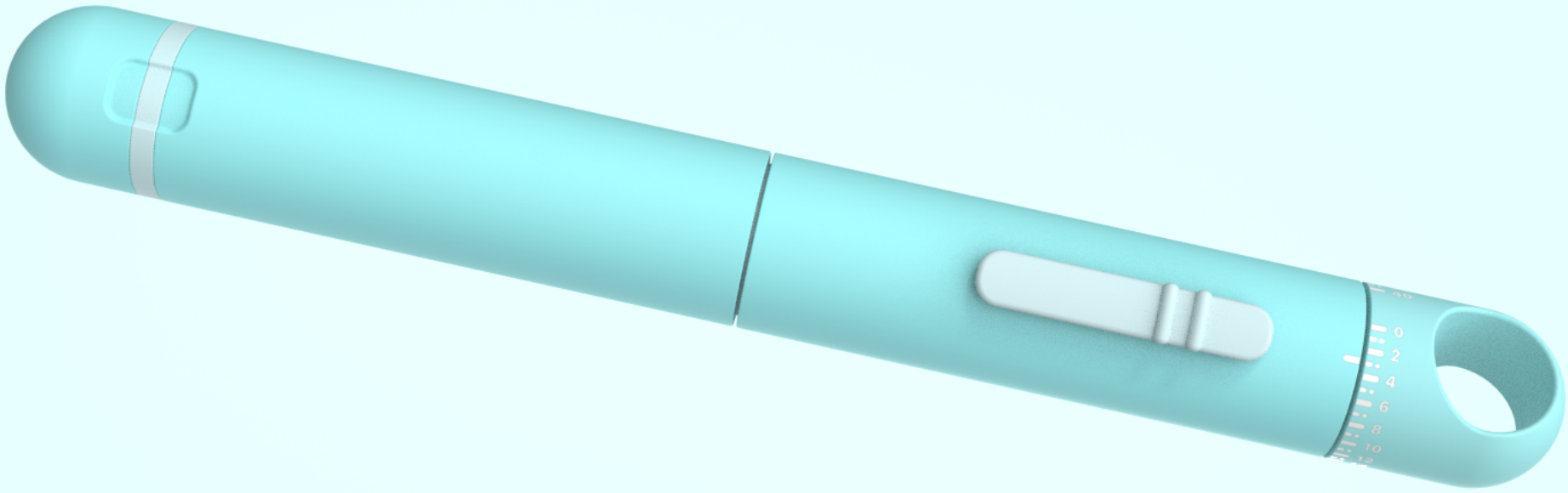


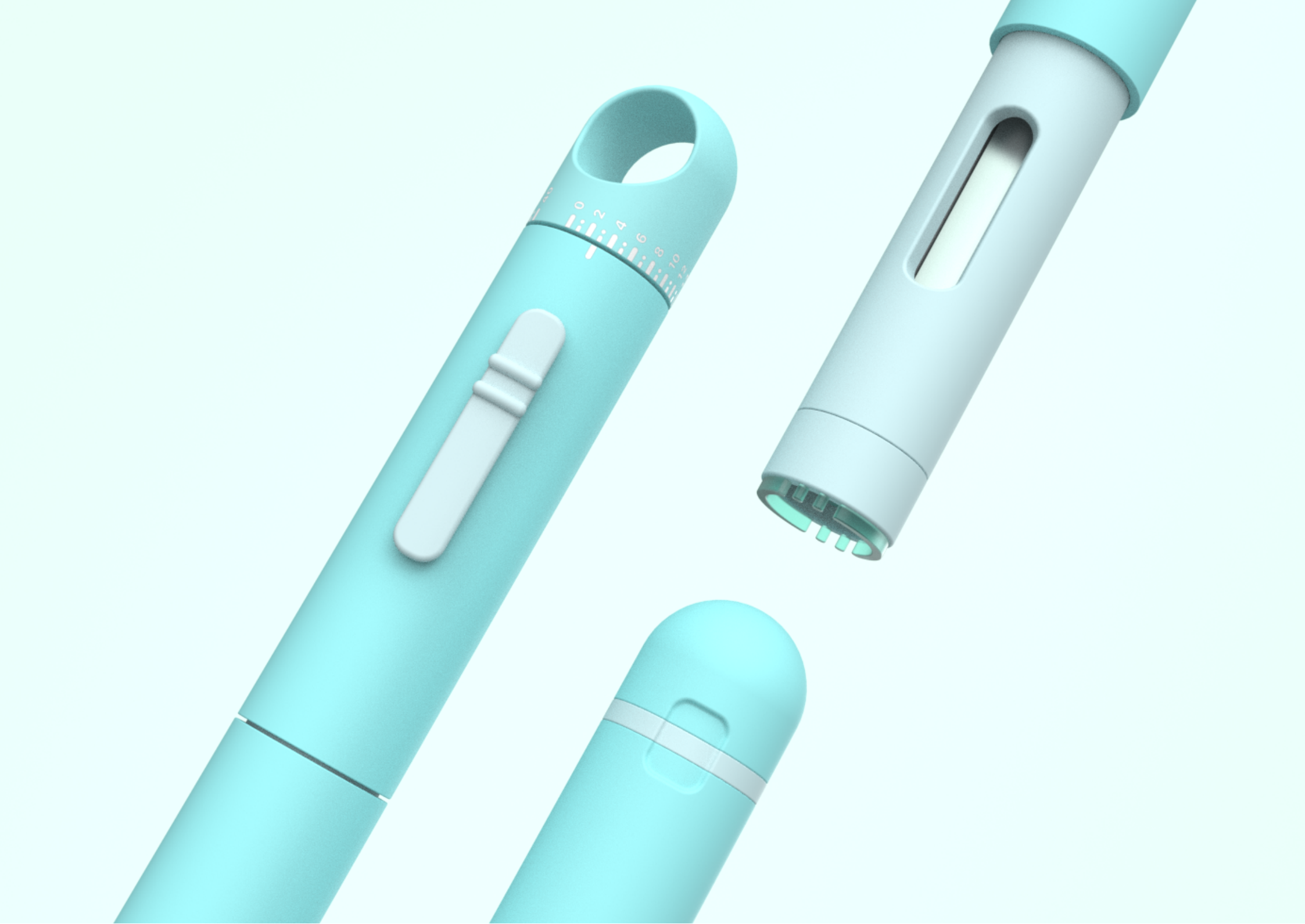
PRODUCT AESTHETICS

As highlighted in the mood board above, the core emotions I wanted the product to project were safety and comfort. After multiple attempts at communicating these emotions, I narrowed it down to a few basic concepts.



The product needs to have a very simple skeletal geometry, and not be unnecessarily complex. Flat surfaces of plastic would only enhance the simplicity of the product rather than adding in complex details like grooves and labels. Points of interest must be placed across the product evenly to maintain a level of visual balance. Rounded corners dramatically help in communicating the emotion of *softness* and *comfort*.


0
2
4
6
8
10


0
2
4
6
8
10
12

Reflections

The 4 month long project felt like a rollercoaster on a personal level. I started by distancing my personal experiences from any choices I made, to make sure I remain objective. It has always been a desire of mine for my work to mean something to someone or help another person. Due to the nature of the topic of diabetes however, getting people to open up was not easy.

As a diabetic patient for over 10 years, you start to accept the problems you face as the status quo and work around them. None of us (diabetics) chose to get diagnosed and we had to learn a completely new way of living. It is my opinion that we continue to adjust to the cards we're dealt, seldom asking ourselves the question if everything needs to be this hard.

Working on a project directed towards adolescent users reminded me of my years in school using the insulin pen. Looking back, I realised how uncomfortable I was using the insulin pen in public. I can recall so many instances of where I chose to fit in and comply with social norms of what 'normal' feels like over managing my condition.

This truly made me realise the significance of design in our lives and how it can heavily influence the way we choose to use products. I still ponder over the choices I would have made if the insulin pen I used back then was designed less intimidating and eye-catching and more stylish and comfortable.

I would also like to point out that while I tried to remain objective and validate my design choices, the project is undoubtedly biased because of my personal experiences. However, I strongly feel that because of the context and use case of an insulin pen, my personal experience guided me to make more informed choices for a user group I can very strongly empathise with.

In the research phase, I realised the complexity of the project I had set out on. There were areas like the injecting mechanism and the design of industry standard parts that I had no control over. While I did consider ignoring such limitations, it would have resulted in an overly optimistic and unrealistic solution.

Working around such limitations allowed me to study and focus more on the usability of the product. It also made the final design feel more realistic and one that could be implemented rather than remain an exploration in my portfolio.

I was not able to evaluate my final design with real users at the time of writing this report, but do hope to complete that step to understand the limitations of my design.

In the end, I am very pleased with what I was able to achieve in the course of this project. I am glad that I was able to work on a topic so close to me and not only learn new skills as a designer but grow in terms of understanding myself and my diabetes better.

References

1. https://www.idf.org/aboutdiabetes/what-is-diabetes.html - IDF
2. Shah, R. B., Patel, M., Maahs, D. M., & Shah, V. N. (2016). Insulin delivery methods: Past, present and future. International journal of pharmaceutical investigation, 6(1), 1–9. https://doi.org/10.4103/2230-973X.176456
3. Kumar K. M. (2015). Incidence trends for childhood type 1 diabetes in India. Indian journal of endocrinology and metabolism, 19(Suppl 1), S34–S35. https://doi.org/10.4103/2230-8210.155378
4. Hirsch I. B. (2012). Does size matter? Thoughts about insulin pen needles. Diabetes technology & therapeutics, 14(12), 1081. https://doi.org/10.1089/dia.2012.0274
5. Retnakaran, R., Hochman, J., DeVries, J. H., Hanaire-Broutin, H., Heine, R. J., Melki, V., & Zinman, B. (2004). Continuous subcutaneous insulin infusion versus multiple daily injections: the impact of baseline A1c. Diabetes care, 27(11), 2590–2596. https://doi.org/10.2337/diacare.27.11.2590
6. https://www.healthlinkbc.ca/health-topics/abk6153 - Healthwise
7. https://www.diabetes.org/healthy-living/medication-treatments/insulin-other-injectables/insulin-storage-and-syringe-safety - American Diabetes Association
8. https://uxstudioteam.com/ux-blog/design-for-kids/ - Molnar 2018
9. Bode A. (2009). Development of the SoloSTAR insulin pen device: design verification and validation. Expert opinion on drug delivery, 6(1), 103–112. https://doi.org/10.1517/17425240802636187
10. Hanas, R., de Beaufort, C., Hoey, H., & Anderson, B. (2011). Insulin delivery by injection in children and adolescents with diabetes. Pediatric diabetes, 12(5), 518–526. https://doi.org/10.1111/j.1399-5448.2010.00731.x
11. Heron, L., Reaney, M., Hermans, N., Abetz, L., Gregg, L. (2013). Perceptions of Usability and Design for Prefilled Insulin Delivery Devices for Patients With Type 2 Diabetes. Diabetes Spectrum 2013 Feb; 26(1): 16-28. https://doi.org/10.2337/diaspect.26.1.16