PullIt

no strain no pain

Product Report

ma4-id1 June 2024

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Title Page

Aalborg University // Industrial Design
Department of Architecture, Design and Media Technology

Project title	Pulllt
Project Theme	Work environment tool for the health care sector
Report Type	Product
Project group	ma4-id1
Supervisor	Christian Tollestrup
Technical supervisor	Matin Afshar
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Abstract

The following product report present Pulllt: a manual handheld work environment tool designed to aid nurses in the extraction and injection of 50 mL syringes. This task contributes to the Danish Health Care Sectors self-amplifying problems due to understaffing resulting in consequences for the individual nurse as well as financial consequences for the society. Nurses often experience severe finger pain, take sick leave, require surgery or retire early, leading to annual costs of at least 2.46 billion DKK. The report explains how adopting Pulllt aligns with the triple bottom line of sustainability, with a particular emphasis on societal benefits, including improved comfort and time-efficiency of nurses as well as patient safety. The tool has been developed by three Industrial Design Engineering students from Aalborg University, in collaboration with a variety of health care professionals and experts, alongside the partnership company byLink, for whom Pulllt is targeted.

Several hospital departments have already shown great interest in acquiring Pulllt with a requested purchase of 20 units from a department manager. A series-0 for maturation is forthcoming, following the outlined implementation plan.

Christoffer Agesen Valsted *Jens Øbro* *Sophia Rytter Møller*

Contents

Problem

Every year the Danish average life expectancy rises by around 2.5 months. Thus, enlarging the discrepancy between increase in patients and increase in Health Care Professionals. Consequently, leading to a highly overrun Health Care Sector, with nurses, amongst others, suffering mental and physical harm. In 2021 alone 18% of nurses changed job as a result, which in combination with 19 days of absence from work per nurse due to musculoskeletal disorders costs the Danish Health Care Sector 2.46 billion DKK annually.

Many nurses suffer from osteoarthritis, tendonitis inflammation or carpal tunnel syndrome on account of repeated motion of the wrist and fingers. For certain nurses such as those in the Intensive Care, Anaesthesiology or Neurology departments these musculoskeletal disorders can be largely attributed to the task of extracting and injecting 50 mL medical syringes. A task done upwards of 50 times a day reaching a force of 73 N equivalent to 7 kg on the area of a few fingertips. Pain, numbness, and weakness in the fingers, particularly the thumb, reduce the wellbeing of nurses, often forcing them to get surgery, change jobs, retire early or resort to inadvisable workarounds. Workarounds such as unnecessarily using 20 mL syringes and not using appropriate filter needles, which not only decrease patient safety and time-efficiency but also increase expenses and emissions.

95%

of nurses experience that understaffing and busyness leads to decreased quality in basic care

9%

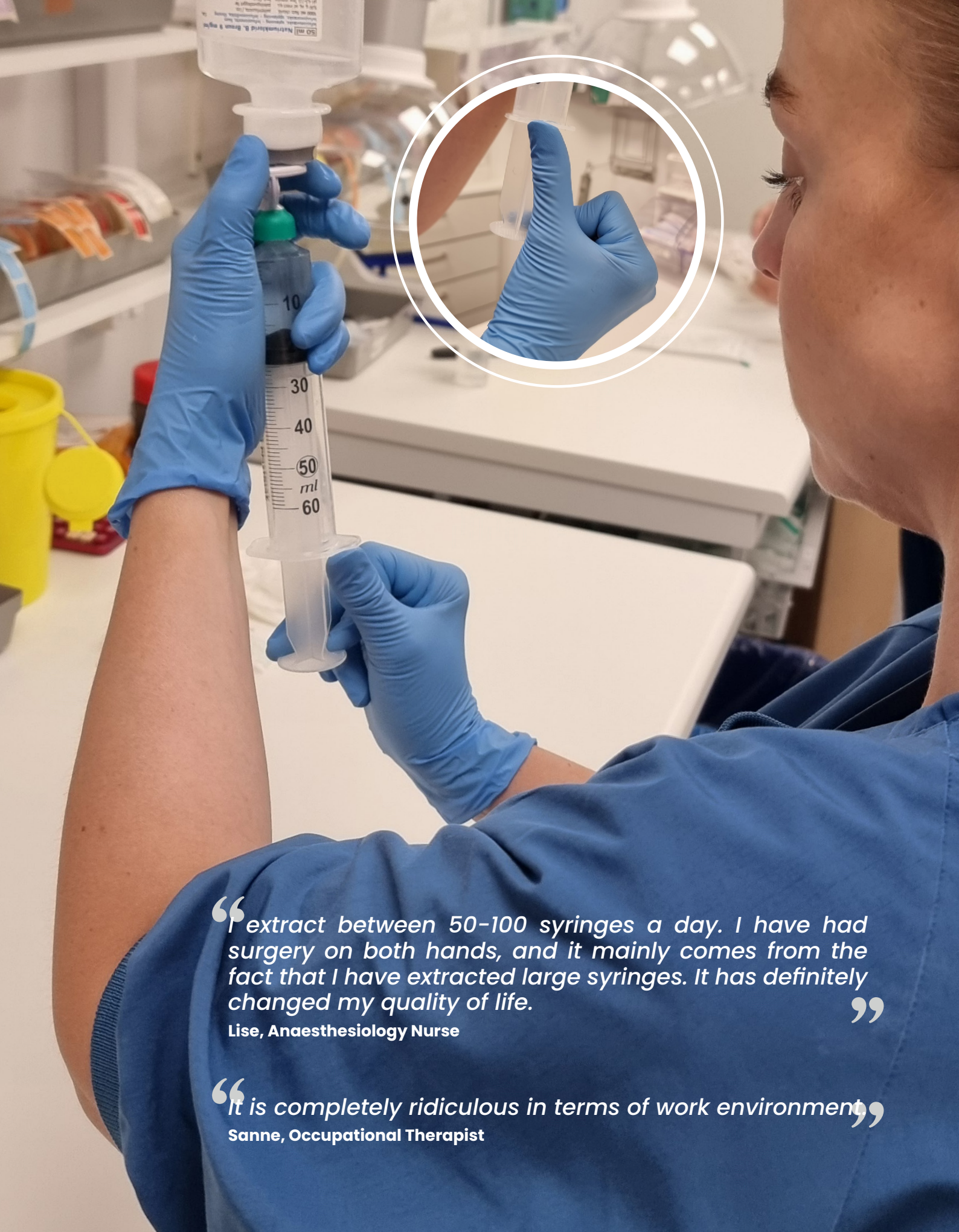
of nurses experience that understaffing and busyness are contributing causes to patient deaths

61%

of nurses experience musculoskeletal disorder symptoms in their wrist or hands

10%

of nurses have work absence due to musculoskeletal disorder symptoms in their wrist or hands



I extract between 50-100 syringes a day. I have had surgery on both hands, and it mainly comes from the fact that I have extracted large syringes. It has definitely changed my quality of life.

Lise, Anaesthesiology Nurse

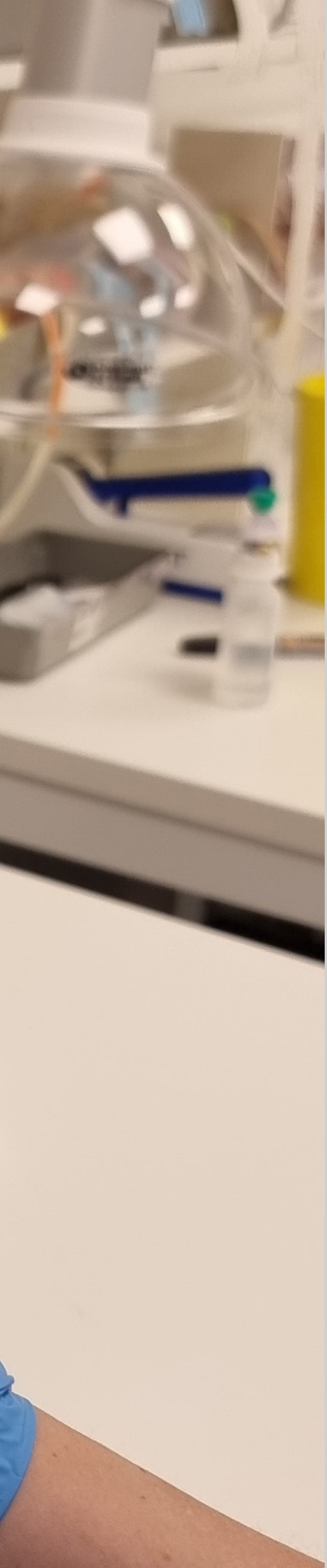
It is completely ridiculous in terms of work environment

Sanne, Occupational Therapist

Strain Points

Syringe

Pullt + Syringe

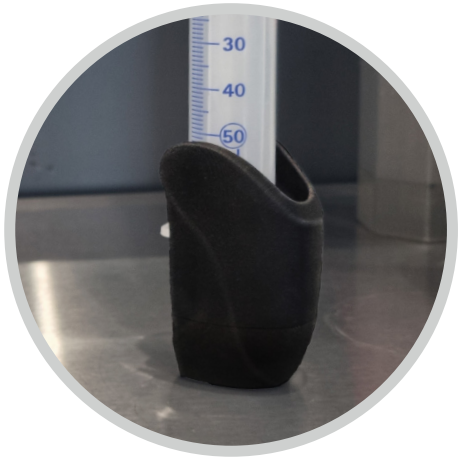


Presenting

PullIt

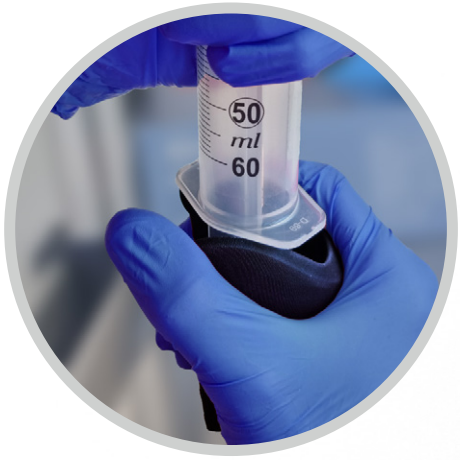
A simple manual, handy and mobile work tool designed to assist hospital nurses in the demanding task of extracting and injecting 50 mL syringes during medicine mixing or gastric suctioning. PullIt shifts the strain from a few fingers to both hands and larger muscle groups, providing relief from and prevention of musculoskeletal disorders in the fingers and wrist. Remedying the tendency of unhealthy work environment for the nurses, PullIt enhances their professional appearance and comfort, while elevating patient safety and time-efficiency, allocating more time to tending to the patient. The tool seamlessly integrates into their current workflow by blending in with the 50 mL syringe, offering free movement and no distractions with minimal interactions, thus ensuring a quick adoption. PullIt represent a timely and important step in the paradigm shift toward recognising nurses and their colleagues as the most valuable resource in the health care sector by contributing to a healthier work environment.

> *"Everyone was positively surprised of how much it relieves one's fingers and makes extracting so much easier. Younger and older nurses alike. There is no doubt that we need some! We will not buy just 5, but rather 20 units."*
>
> **Bente, Intensive Care Unit Nurse**



Hight

Ensures a visible mL scale throughout to assure correct dosage.



Funnel-shaped top

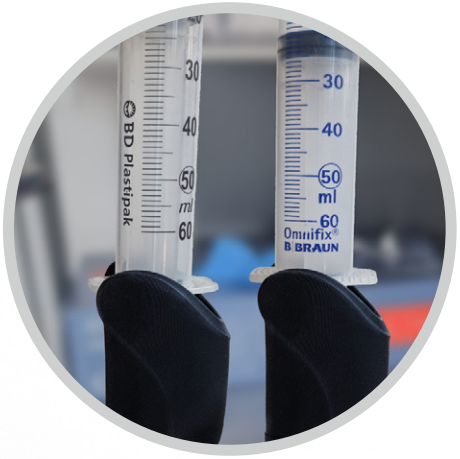
Guides the syringe barrel's flanges into the handle during injection for at seamless interaction.

Key Features

As a reusable manual tool, PullIt provides nurses with a tactile feeling during use. It features an ergonomic grip designed specifically to accommodate the nurse's hand.

Resistant to

- 100-180°C
- Water & Soap
- Grease & Oil
- Alchohol & Chlorine

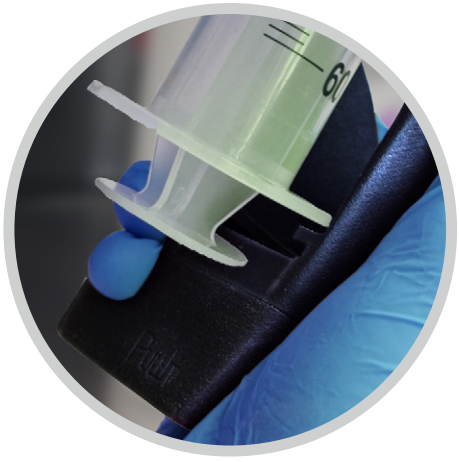


Interface

Is carefully designed and provides easy attachment and detachment of B. Braun and BD 50 mL Luer Lock syringes to accommodate 100% of the current Nordic Market.

Logo

Provides a readable feedforward of the function, while showing continuity with byLink's other handheld products.

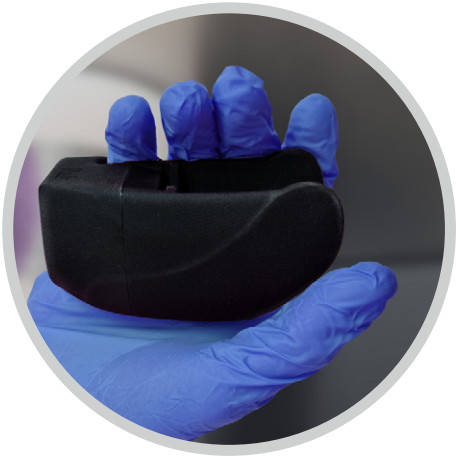


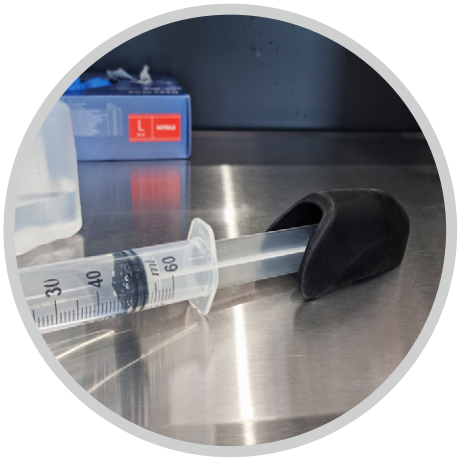
Guide Chute

Acts as feedforward on where to direct the plunger's thumb rest for a fast and sightless interaction.

Flow lines

Creates a visual affordance of hand's placement for the professional while offering comfortable angled surfaces to rest the fingers on.



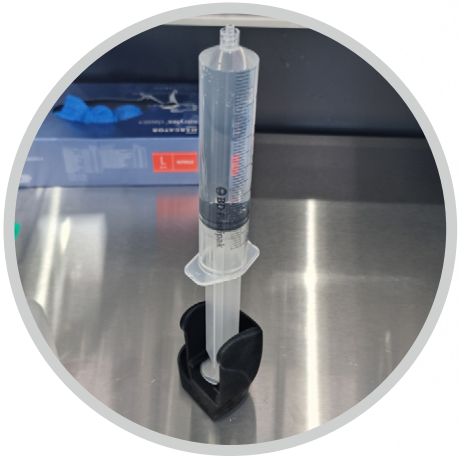


Depth & Weight

A protruding flange and the centre of gravity ensures a stable horizontal position to prevent contamination of the syringe tip.

Wing

Shifts strain from the fingers to the entire hand as well as biceps, triceps and deltoids to prevent and get relief from musculoskeletal disorders.



Flat bottom

Ensures a stable upright position to prevent contamination of the syringe tip while offering easy access to change attachments.

no strain
no pain

Storage

PullIt will be allocated to a specific medicine table whether that be in the medicine room or the patient's room. It can easily be transported to the department's sterilisation room or to the patient to perform gastric suctioning. PullIt fits nicely in the nurse's hand or pocket during transit and only occupies a negli-gible amount of space on the medicine table.

Grip

PullIt accommodates various grips depending on the nurse's current injuries, hand size and shape. Transitioning from gripping around PullIt's body with the distal, middle and proximal phalanges gradually render any involvement of the thumb redundant. For nurses with larger hands or pain in their little finger it can be positioned under the wing. In each grip a straight line from hand to the elbow during use is ensured as recommended by occupational therapists and physiotherapists. The operation of PullIt may be unclear to non-professionals, but the flow lines, guide chute and interface of the tool enable nurses to use it after a brief introduction. In addition, it gives nurses control over the assignment, which further highlights their professionalism towards patients and their relatives. PullIt weighs 94 grams, ensuring it is light yet provides a feeling of quality and stability, with the centre of gravity resting in the palm.

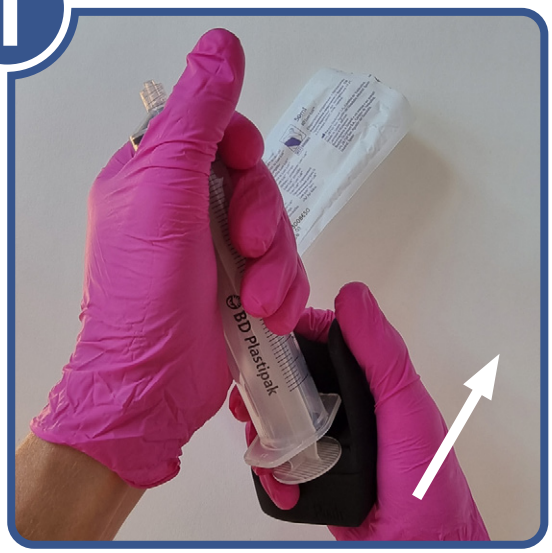
> *"I think it fits my hand nicely, I like the material and it also looks good. It is much better than using the thumb. I can feel that I pull more with my arm and shoulder which is nice. You can easily operate it."*
>
> **Tracey, Intensive Care Unit Nurse**

Recommended Usage

Full Ampoule Extraction

Partial Ampoule Extraction

1

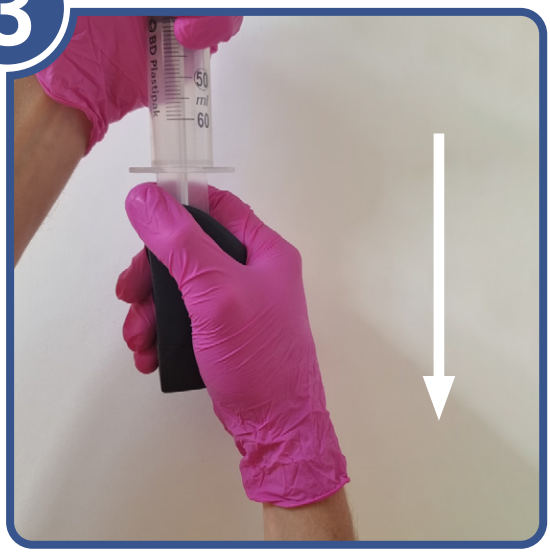


Attach the 50 mL syringe to PullIt after unwrapping to prevent contamination and use the grip that suits you.

2

Screw the mini-spike with saltwater onto the 50 mL syringe by rotating PullIt and container simultaneously.

3



Use a grip on PullIt that suits you, place your elbow close to your body and extract with an aligned wrist.

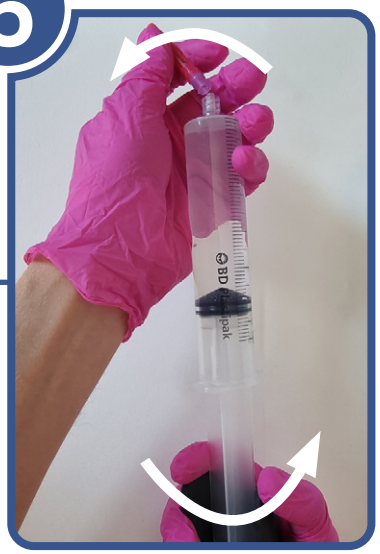
4

To remove bubbles, release PullIt and tap on the barrel. PullIt will remain fixed to the syringe.

5

Inject to remove air and get a correct dosage. Assume a grip that suits you, keep your elbow close to your body and keep an aligned wrist.

6



Unscrew the mini-spike and attach a needle with filter to the 50 mL syringe by rotating Pulllt and needle simultaneously.

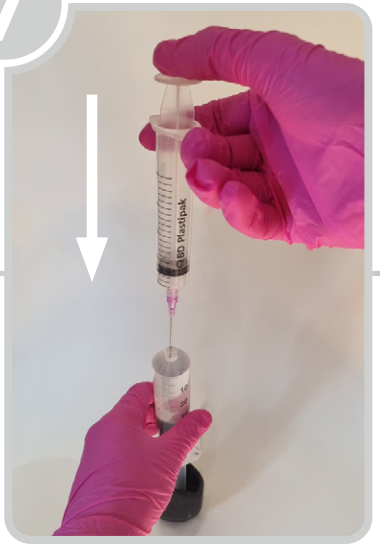
7

Extract with Pulllt while adjusting placement and angle of ampoule with your index finger and thumb. Remaining fingers grips the syringe.

6

Pulllt with the 50 mL syringe attached is placed upright on the table while medicine is extracted from an ampoule using a smaller syringe.

7



The glass shard contaminated needle with filter is changed and the contents of the 20 mL syringe are injected into the upright 50 mL syringe.

8

Unscrew needle and detach Pulllt from the 50 mL syringe. Add a seal to the syringe. Place Pulllt at medicine table or bring to sterilisation room.

Creating Value

The Patients
will experience an improvement in both perceived an actual safety with the introduction of PullIt. Nurses will feel more confident in their work, reassuring patients, while contamination risks are minimised by preventing syringe tip contact with objects and nurses touching the plunger's flanges. It also allows the use of filtered needles preventing micro glass shards from entering the patient's bloodstream. Filtered needles are normally avoided by most nurses because of the significant strain they create.

The Nurses
will encounter a significant upgrade in immediate workplace comfort and long-term quality of life, both on and off duty. This will extend their career longevity. Additionally, PullIt reduces medication mixing time by 4-17%, equivalent to 1-5 fewer interactions. Developed in close collaboration with 23 various nurses, PullIt is tailored to meet their specific preferences and needs. Regardless of whether they are already injured and recognise the problem, straight from school or more experienced and set in their ways with the problem being latent.

The Department Managers
will have the opportunity to foster a more positive work environment for their employees, resulting in fewer sick days, reduced stress, and cost savings on equipment. This would address challenges such as the need to limit patient capacity, faced by 36% of managers in 2023, and avoid assigning tasks to unqualified personnel, experienced by 66% in 2023. Additionally, eliminating current workarounds using medical equipment would allow for reallocating funds towards acquiring tools to enhance the work environment.

The Danish Health Care Sector
are facing a prospect of addressing the green transition in an area with options currently limited to transport and packaging. By eliminating workarounds, they could potentially save 373,215 20 mL syringes and needles each year. This is equivalent to annually saving 5 1/4 tonnes plastic, ¾ tonnes stainless steel and 18.6 kg CO_2 per PullIt. The tool also addresses the problem and expenses associated with nurses' musculoskeletal disorders, aiming to resolve an issue that costs the Danish Healthcare Sector at least 2.46 billion DKK annually.

Manufacturing

SLS 3D-printing

the body and wing to minimise start-up costs while allowing for design adjustments and refinement between production runs for an easier adoptable design. SLS provides great structural integrity, precision and minimal layer lines, enhancing cleanability. The division into components ensures optimised packing density, consequently reducing manufacturing costs and ultimately lowering the wholesale price.

Vapour Smoothing

melts the surface of the 3D-printed parts, transforming them into sealed, smooth, and shiny surfaces, that is easily cleaned. This post-processing enhances mechanical properties and moisture resistance as well as a reduction of 81% in roughness and 60% in bacteria growth.

Threaded Inserts fitting

is done post vapour smoothing using a soldering iron which heats the insert itself allowing it to be pushed into the plastic. The plastic then melts around the external knurled surface, thus ensuring a robust fixation of 2700 N of pulling force and 10 Nm of torque before failure.

Modular Design
accommodates repairs and potential future upgrades, with a symmetrical body that allows for wing attachment on either side, making PullIt suitable for both left- and right-handed nurses.

Body
Nylon 12

'Non-medical Equipment'
is the classification PullIt would receive according to the Medical Device Regulation, thereby avoiding multiple certifications and economic expenditures. In terms of cleaning PullIt is defined as 'Non-critical Equipment' meaning it must withstand chemical (detergents; soap, alcohol and chlorine) and a heat disinfection (1 minute at 80°C) which all the materials can handle. Additionally, the bolts are countersunk matching the bottoms plane with tight tolerances to accommodate a swift cleaning.

Threaded Inserts
Brass

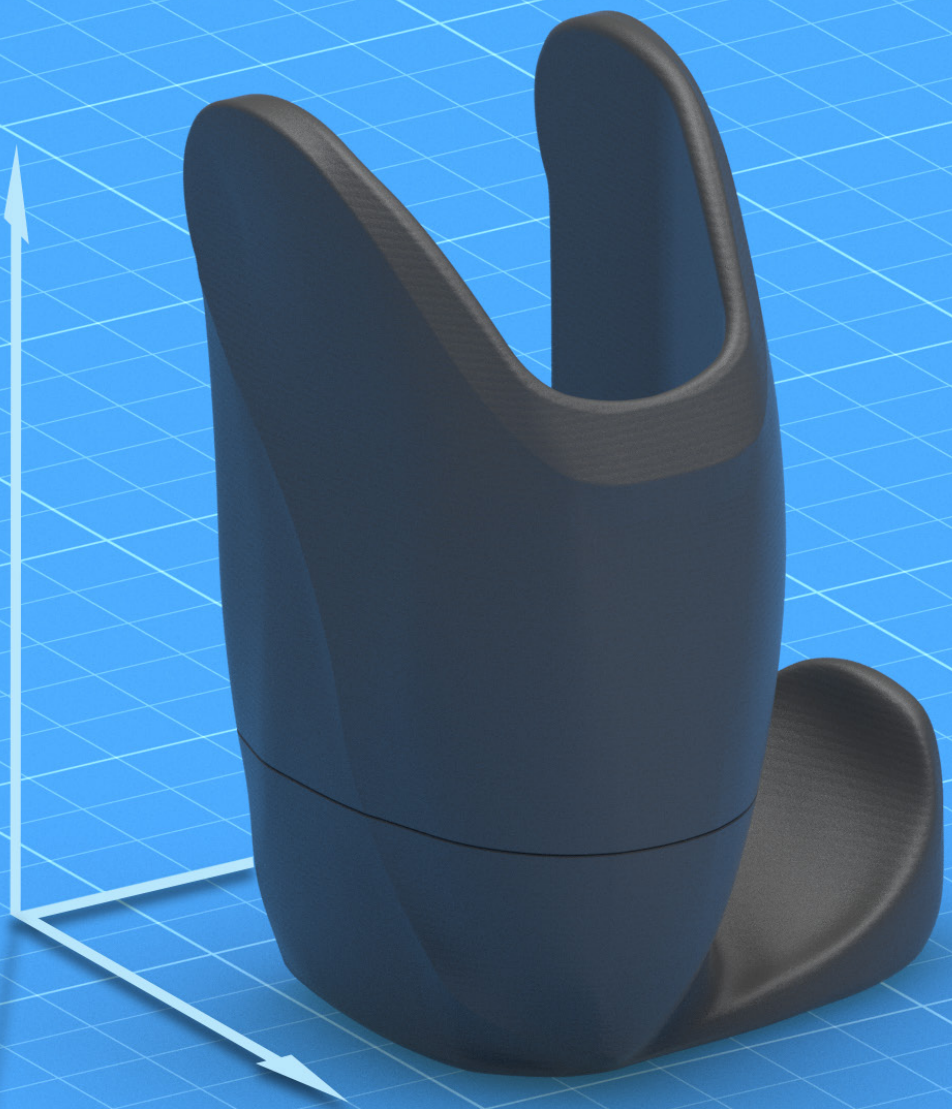
Wing
Nylon 12

Bolts
Stainless Steel

Stress	Displacement	Fatigue
11% of yield	0.02 mm	Inexhaustible use

Durability Analysis

The most critical point in PullIt in terms of wear and tear is the syringe interface. At the worst-case scenario of 73 N simulations show no problems of structural integrity.



Measurements

Width	Depth	Height	Weight
68 mm	52 mm	93 mm	94 g

Intructions

A concise pamphlet with a Quick Start Guide and other information will be included in every box.

599 DKK

exclusive VAT

Implementation

Phase 1

1st year

Smaller series of 105 units each is iteratively developed and marketed based on nurse feedback to refine Pulllt. SLS printing minimises risks while capital is raised for a manufacturing shift. Targeting B2G, progress follows a bottom-up approach, spreading through word-of-mouth nurse ambassadors up to purchasing departments.

cost price	sales price	breakeven
236 DKK	599 DKK	68 units
sold	**affected**	**profit**
319 units	831 nurses	0.1M DKK

contribution margin

61%

Key Challenges

- If splitting Pulllt in two is not adopted, due to hygiene, the cost price would reach 500 DKK due to packing density.
- If the only segment present at a department is those set in their ways, no nurse ambassador will be there to market Pulllt to their colleagues.

Phase 2

1st – 3rd year

Reaching a market-approved and matured product and enough accumulated profit to shift to injection moulding, reducing the cost price and creating opportunities for a variety of colours. Following a bottom-up approach, purchasing managers will reach out to suppliers like Abena, requesting them to add Pulllt to the Region's catalogue. This marks a shift to a B2B strategy. Abena requires a 40% cut of the profit.

cost price	sales price	breakeven
33.2 DKK	599 DKK	293 units

contribution margin

57%

Key Challenges

- If shifting to injection moulding would result in decreased ergonomics due to a need for an ambidextrous design with two integrated wings, to include left-handed nurses.
- If sufficient managers will be aware of Pulllt's existence when entering the product catalogue via suppliers such as Abena.

Danish
Saturation

3rd year

By the third year, saturation of the Danish public hospital market will be reached with one PullIt per operating room or medicine table in the departments of Intensive Care, Anaesthesiology and Neurology as well as one per every 20th remaining nurse. With 40,000 nurses in the public health care sector the potential for more sales remains.

sold	affected	profit
3,125 units	8,135 nurses	0.9M DKK

Nordic
Expansion

>3rd year

As medicine mixing and gastric suctioning are done in most countries, PullIt's natural expansion is to Norway, Sweden and Finland through Abena. These countries value work environment and exclusively use 50 mL syringes, which PullIt is compatible with. Later, Germany, the Netherlands, Belgium, and France will be targeted.

sold	affected	profit
14,518 units	37,793 nurses	4,1M DKK

Key Challenge

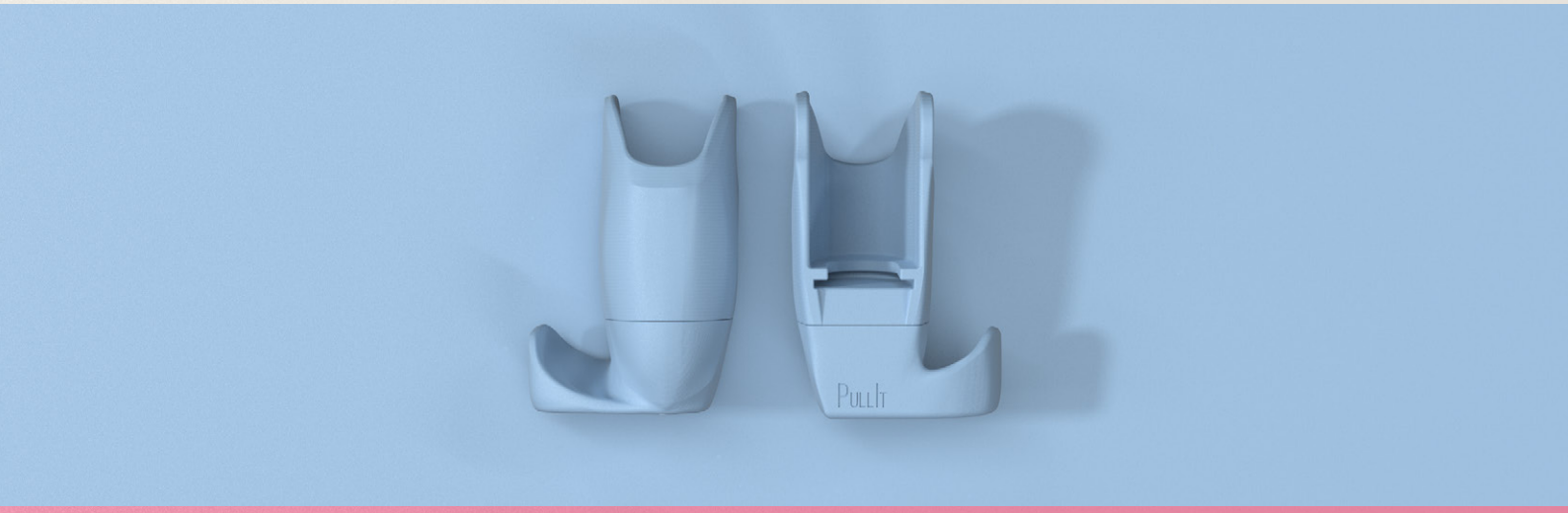
An expansion outside the Nordic countries is dependent on BD and B. Brauns market share of syringes within the targeted country.

Horizontal
Scaling

>1st year

As Phase 2 begins and responsibility of sales primarily shift to Abena, development on related products can begin, to create a family of work environment tools.

- **Compatibility** with different syringe brands and 20 mL syringes.
- **Assignments** such as tube food and cathether flushing.
- **Professions** like hospital pharmacists, laboratory workers and veterinarians.
- **Ambidextrous** design would be possible when injection moulding.



Colours

Injection moulding allows for new colour schemes. Distinct colours for left- and right-handed versions enhance visual affordance, speeding interaction. Pullit would become easily recognisable on any medicine table while addresses the lack of aesthetically pleasing products for the, primarily female, nurses.

Companion

In the near future, PullIt may welcome a new companion: an ampoule holder with dual functionality. The holder would assist in the safe extraction of ampoules using needles with filters by accommodating 5, 10 or 20 mL ampoules securely and enabling hands-free manual pivoting. This feature would allow nurses to maintain a firm grip on both the syringe and PullIt. The ampoule holder would serve as PullIt's home, providing a designated storage space and reducing the risk of misplacement.


10
20
30
40
50
ml
60
by Link

PullIt

no strain no pain

Process Report

ma4-id1 June 2024

Jens Øbro

Sophia Rytter Møller

Christoffer Agesen Valsted

Title Page

Aalborg University // Industrial Design
Create, Department of Architecture, Design and Media Technology

Project title
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Project Theme
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the health care sector

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Supervisor
Christian Tollestrup

Technical supervisor
Matin Afshar

Project period
February 1st 2024 -May 30th 2024

Number of pages
110

The design team

Christoffer Agesen Valsted

Sophia Rytter Møller

Jens Øbro

Pre-phase

This master thesis was developed by three Industrial Design Engineer students at Aalborg University. It is the culmination of five educational years, aiming at cultivating holistic abilities in an Industrial Design context where user-understanding, design, engineering, environmental considerations, and business converge in a harmonious union.

The thesis is developed in collaboration with a multitude of partners within the Danish Health Care sector alongside the company byLink. These partnerships were established to enhance the level of feasibility and possibility of realisation as well as means of smoothing the team members transition from students to work-ready alumni.

A resonating recognition is due to the supervisor Christian Tollestrup for his continuous wonder, acumen, and guidance throughout the project. Additional, acknowledgement is given to the technical supervisor Matin Afshar.

Abstract

The following process report is a part of a master's thesis developed by three students at Aalborg University majoring in Industrial Design Engineering. With input from the partnering company byLink and various stakeholders and experts, totalling at 34 participating individuals, the paper openly showcases the students' process of creating Pulllt, a professional and adoptable hand tool for hospital nurses in the Danish healthcare sector. The process follows a strategic oscillation between utilisation of entrepreneurial approach and Design Thinking, with a co-evolution of solution and problem space, to enhance process acceleration as well as refinement and appropriateness of the design. The report identifies, continuously verifies, frames and comprehends the problem of nurses injecting and extracting 50 mL syringes during medicine mixing within hospitals. The tough hard working conditions result in musculoskeletal disorders of nurses contributing to annual expenses of 2.46 billion DKK for the Danish health care sector. A design is subsequently conceptualised, detailed and matured for manufacturing with a feasible implementation plan catered specifically to byLink affecting an estimated 8,135 nurses within three years. The sustainable proposed solution relieves and prevents musculoskeletal disorders in nurses' fingers and hands by relocating strain during said task, to the entire hand and bigger muscle groups while maintaining mobility and promoting ergonomic use. Additionally, it optimises their time-efficiency upwards of 17% as well as patient safety.

With proven interest and presales, Pulllt represents a timely and realistic solution that improves nurses' quality of life, addresses healthcare expenditures, and sets a precedent for future work environment innovations.

Reading Guide

This master thesis consists of four induvial papers: product report, process report, technical drawings and appendix. It is recommended to read them in this order.

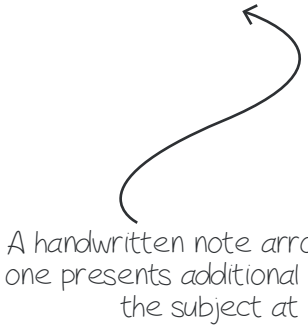
Harvard Referencing are used throughout, and a collected reference list can be found on page 101. A list of illustrations can be found on page 106.

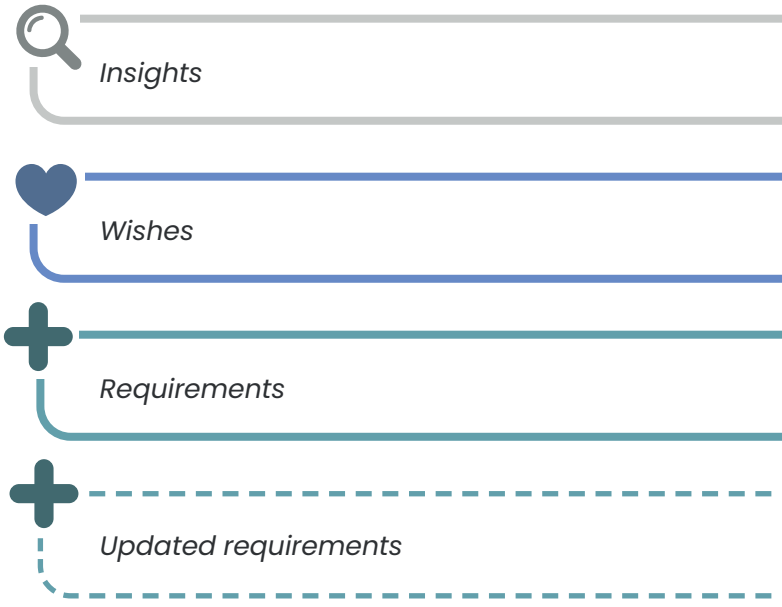
Quotes are presented with *cursive* with important notes highlighted in **bold**.

When a term occurs, its Danish translation is noted in parentheses for readability to Danish readers with a "DAN". When a Danish non-translatable proper noun occurs an English translation, is noted in parentheses with an "ENG". These translations are collected in Appendix 1, as they exclusively will be present when the word appears the first time.

Beware that the specific word "inject" does not, exclusively, refer to the act of injecting a liquid into patients, but rather as the opposite motion of extraction.

Seen below is an index of insights, wishes, new and updated requirements, as they are visually presented throughout in relation to their origin. Additionally, the use of informative arrows is used.





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6 Detailing

7 Business

8 Epilogue

1 Prologue

The prologue initiates the chapters by presenting the collaborative partners alongside the applied methodology. Moreover, a timeline summarises the project's entire iterative process.

Acknowledgements

Who helped the project along?

The project was highly dependent on the indispensable feedback, knowledge, and guidance provided by benevolent external partners. The collaborating stakeholders consist of the users (nurses), the buyers (department managers), the facilitators (byLink) along with a variety of experts on respectively ergonomics, work-related injuries, syringes, regulations, manufacturing & implementation. Without their contribution this project would not have been possible - a heartfelt 'thank you' to each participating individual.

illu. 1

Nurses

Tracey, Anja, Christina, Sanne, Larua, Linda, Lise, Bente, Vibeke, Lisbeth, Anne-Marie, Britta, Malene, Helle, Vibeke, Janni & Kirstine

illu. 2

Department Managers

Lone Grene
Lisbet A. Sigaard
Majbritt B. Riis
Sanne S. Knudsen
Merethe R. Møller
Lotte Knudsen
Heidi S. Hvistendahl

illu. 3

Hygiene Nurse

Irdi A. Dalsgaard

illu. 4

Experts in Ergonomics

Sanne H.-Lehmann
(Occupational therapist)
Fridel Laursen
(Physiotherapist)
Dr. Tine H. Malling
(Occupational and Environmental Medicine)

illu. 5

Expert in Syringe & MDR

Annette M. Nielsen
from BD Plastipak

Niels Peter Lindholt
from CE Toolbox

illu. 6

Expert in SLS

Nicklas Lassen
from Podovo

illu. 7

Expert in Implementation

Tue Lodahl
from Level Health

illu. 8

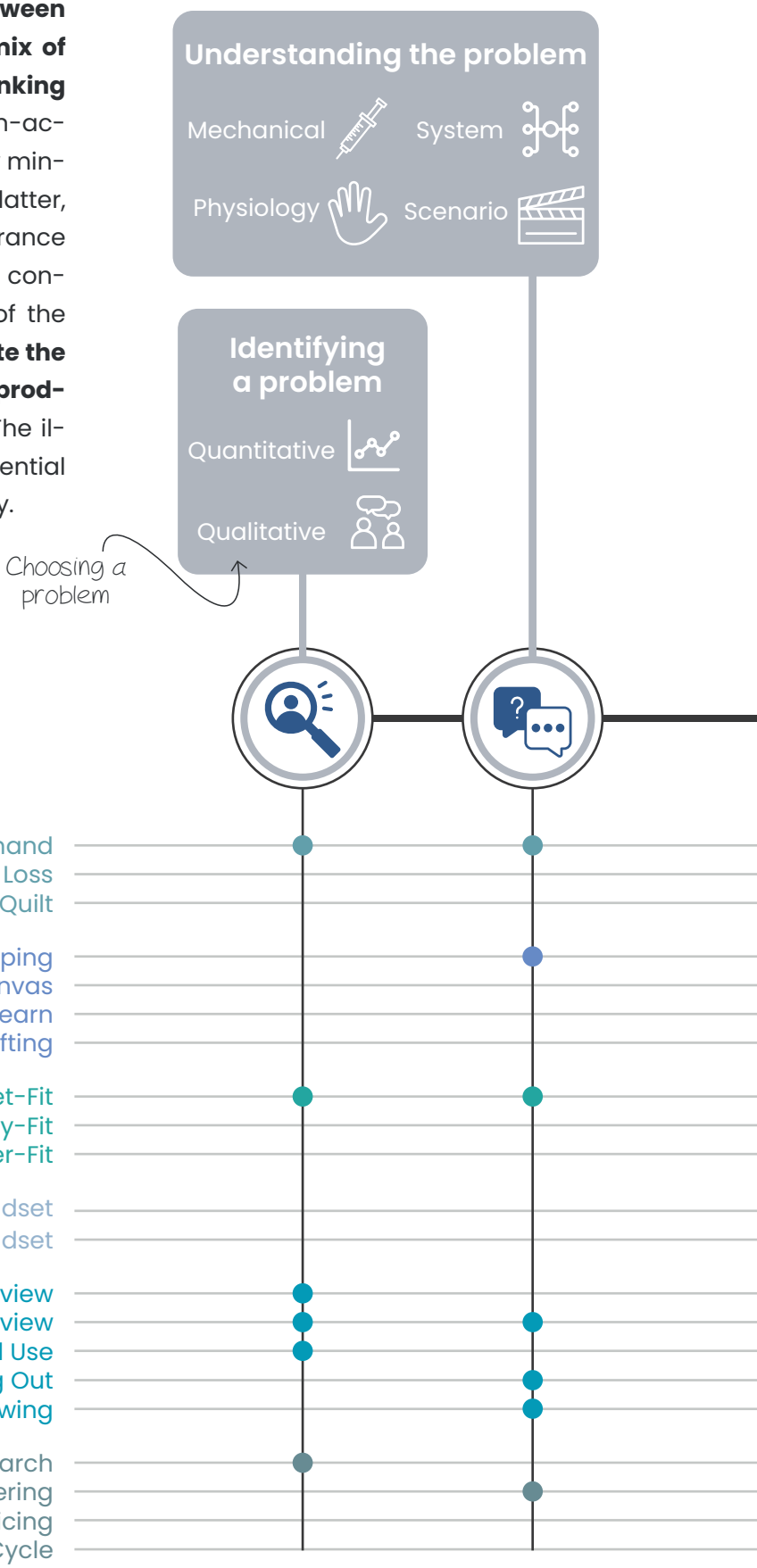
Business Partners

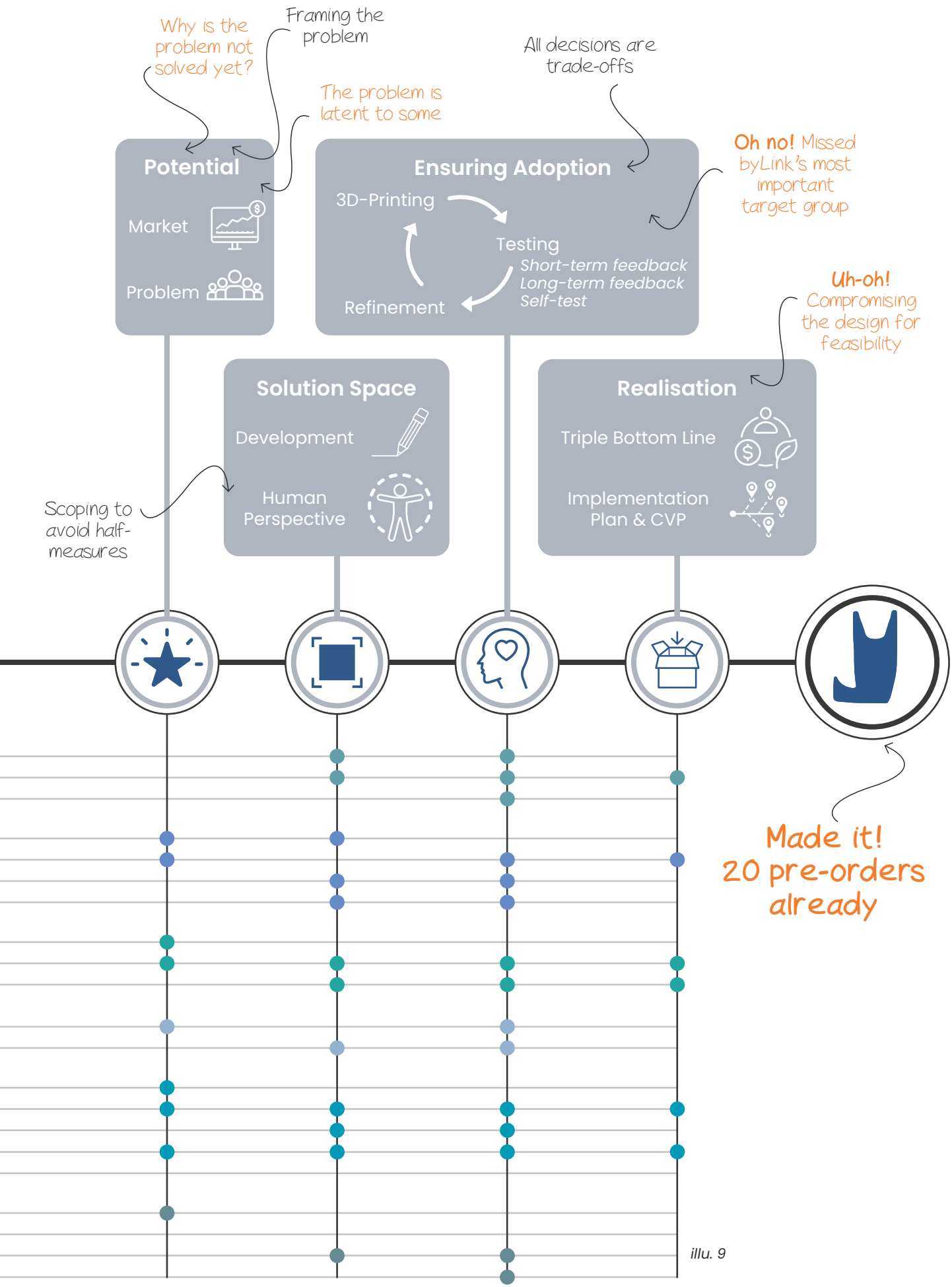
Liza H.-Larsen &
Line Bluhme
from byLink

Methods

How did the design process unfold?

The master thesis followed an **oscillation between problem and solution space applying a mix of entrepreneurial strategies and design thinking approaches**. The former with reflection-in-action to accelerate the process, subsequently minimising risks, while allocating time to the latter, which were utilised on exploration and assurance of quality, adoption and realisation through continuous reflection-on-action. A large part of the project was **modal shifting to accommodate the wickedness of ensuring a product user-fit, product market-fit and product company-fit**. The illustration depicts the development in essential steps with reference to applied methodology.




Why is the problem not solved yet?
Framing the problem
The problem is latent to some
All decisions are trade-offs
Oh no! Missed byLink's most important target group
Uh-oh! Compromising the design for feasibility
Potential
Market
Problem
Ensuring Adoption
3D-Printing
Testing
Short-term feedback
Long-term feedback
Self-test
Refinement
Solution Space
Development
Human Perspective
Realisation
Triple Bottom Line
Implementation Plan & CVP
Scoping to avoid half-measures
Made it! 20 pre-orders already

illu. 9

2 Identifying the Problem

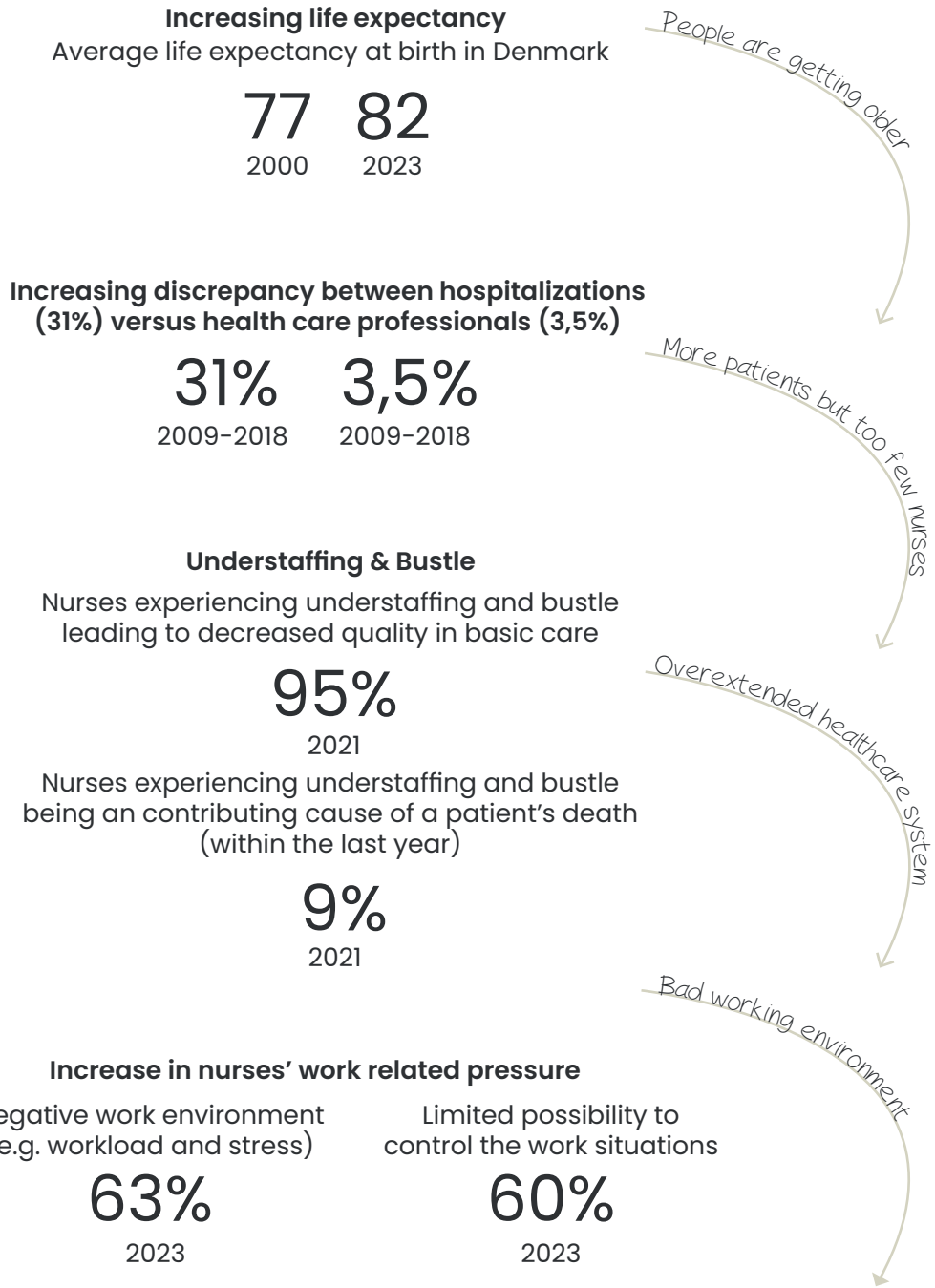
The following chapter covers the beginning of this master thesis. Elaborating on the scoping of who to aid, and what to address supported by objective and subjective findings. The chapter is concluded in an initial problem statement.

Motivation

Who should be helped?

This Master thesis originates in the commonality that the group's members all have **familial relations working within the health care sector**. A sector which carries an **ironic nature as these individuals who work hard caring for the public's health often are the ones who themselves work in an unhealthy environment.** An injustice which deserves to be enlighten and addressed.

This misdeed is excessively prominent in statistics (Appendix 2). **A snowball effect** initiating in increased life expectancy, leads to mutually self-amplifying consequences for both the health care professionals and the public:



illu. 10

The decision to do a project **aiding the health care professionals was strategic in terms of learning objectives.** Due to the sector being known for a myriad of problems in a **complex environment concerning regulations, adoptability and pricing**. This results in a multitude of requirements, some contradictory, making the task of creating a context-based design wicked.

Partial conclusion

Choosing the health care sector as the master thesis' focal point was supported by both personal interest and statistical motivations based on a stressed and overrun sector with highly damaging consequences, where creating a solution requires a high degree of complexity.

Pinpointing the Problem

Which problem should be addressed?

The health care sector faces numerous challenges. Early conversations with nurses revealed a **common issue: excessive use of their fingers and hands leading to musculoskeletal pains.**

This notion is supported by ample data (Appendix 3). Within the health care sector **nurses are those who experience the highest prevalence of musculoskeletal disorders**, ranging from 33% to 88% depending on the country. Studies have shown that '**cumulative and repetitive manual activities' contribute significantly to these symptoms**, with the repeated motion of the wrist and fingers being the second most common activity among nurses, affecting 68% of them (Soylar, 2018). This correlates with **61% of nurses having musculoskeletal disorder symptoms in their wrist or hands each year with 10% compelled to take absence from work** (Sheikhzadeh, 2009). Contributing to the nurses' yearly cumulative work absence related to musculoskeletal disorders, being the overall biggest cause of absenteeism, reaching 19.2 days on average in 2016 (Soylar, 2018; Pain-Related Work Interference). This is equivalent to a **yearly expense of 1.26 billion DKK for the Danish Health Care sector.** In severe cases musculoskeletal disorders may result in early retirement as was the case for 11% of Danish nurses in 2005 (Friis, 2005).

Musculoskeletal health refers to the performance of the locomotor system, comprising intact muscles, bones, joints and adjacent connective tissues" (WHO, 2022)

illu. 11

Problem space

As 'cumulative and repetitive manual activities' are physical, a possible solution seemed tangible and plausible to solve within the field of Industrial Design Engineering. Addressing the problem altogether with a single product is too far-fetched due to very different context requirements. It is more appropriate to solve the problem ideally in one context than partly solving the problem in several contexts. Therefore, a **specific assignment needed to be identifie**d. Based on interviews with nurses the more prominent assignments **where they use their hands and fingers repeatedly** were determined as:

De-blistering pills from blister packs

Redesign problem

Positioning and lifting of patients

Sourcing problem

Putting on compression stockings

Marketing problem

illu. 12

No solusions for exstration and injection of larger syringes

The strain on hands and fingers in the **three former assignments has already been addressed** by a whole range of products. Subsequently suggesting the products absence in the nurses' current workflow is a matter of sourcing or marketing problems, with the assignment itself possibly in need of a redesigned system. However, **the issue of extraction and injection of larger syringes has only seen peripheral solutions**. This observation is **supported by the company byLink,** which develop work environment related tools for the health care sector. They have **received numerous inquiries from individual nurses desperately seeking a product that aids them in this specific task**, due to injuries or increased discomfort.

Partial conclusion

The scale of the problem with extraction and injection of larger syringes is statistically significant, resulting in substantial expenses which further burdens the health care sector. As all nurses encounter the assignment at some point in their career the need for a solution aiding in this task is highly sought after. Highlighting, that the current peripheral solutions are inadequate. This is further elaborated on in a Market Analysis on page 32. But for which nurses are the challenges of this specific assignment most prevalent and to what extent?

Personal Experiences

Is the problem recognisable?

Through interviews with 17 nurses and 7 department managers (Appendix 4-12) the **identified problem was thoroughly verified**, with both numerical data and tangible consequences evident throughout the investigation process. Numerous nurses of varying ages substantiated the transcendence of the problem to different departments and assignments. **The daily frequency of injection and extraction of 50 mL syringes varied significantly,** ranging from 27 to 35 times in Home Health Care (Appendix 4 & 7), 4 to 48 times for nurses in the Neurology Department (Appendix 5), 10 to 40 times for nurses in the Intensive Care Department (not to be confused with Emergency nurses) (Appendix 10 & 11) and even 8 to 50 times for nurses in the Anaesthesiology Department (not to be confused with Surgical nurses)(Appendix 8 & 12). The nurses elaborated on their current interaction with larger syringes:

50 times a day

illu. 13

Lise

Nurse, Anaesthesiology at Hvidovre Hospital

*"I know that we [Anaesthesiology nurses] are **all talking about this [injection and extraction of 20 & 50 mL syringes].** I know that we all figure out some way to do it, to protect ourselves as soon as we start to feel pain. **I tell recent graduates to do such and such and be careful. But you only think about it when you actually got the problem.**"*

Must fit all possible size variants of 20 mL and 50 mL syringes from different brands

27 times a day

illu. 14

Christina

Nurse, Home Health Care Nurse at Distrikt Vesterparken

*"**I think you can feel that when you get to the fourth [50 mL] syringe, when you are out administering tube food, your fingers get tired.** The same applies when **flushing the catheter**. [...] i**f you do not have long fingers, then it can be hard to reach all the way.**"*

4 times a day

illu. 15

Helle

Nurse, Neurology at Regionshopitalet Viborg

*"At times it [administering tube food] **can be tough**. It is **very noticeable, especially because we use our hands for many other activities**."*

8 times a day

illu. 16

Vibeke

Nurse, Anaesthesiology at Regionshopitalet Viborg

*"**I use a lot of effort** [to extract & inject syringes] even though I have relatively strong fingers."*

10 times a day

illu. 17

Bente

Nurse, Intensive Care at Aalborg Universitetshospital

*"For those who **administer tube food several times a day** using 50 mL syringes, it is **extremely challenging**. **Aspirate is also really really hard for the fingers**"*

20 times a day

illu. 18

Anna-Marie

Nurse, Intensive Care at Regionshopitalet Viborg

*"I am **glad that some people are working on solutions** for this problem because **I often wonder if I will develop osteoarthritis.**"*

In more serious, but not uncommon, cases the **strain can lead to injuries.** This was true for Lise, Vibeke and Lisbet (Appendix 6, 8 & 12), who all were operated after working just 5 years as nurses at Anaesthesiology Departments. Before surgery Vibeke was not able to either bicycle or sleep properly, while Lisbet still has pain and difficulty doing various tasks such as wringing up dish cloths, lifting weights and twisting lids of jars. She elaborates on sleeping:

13 times a day

illu. 19

Lisbet

Department Manager and nurse, Anaesthesiology at Esbjerg Hospital

*"If you are able to **sleep at night, you should be happy.** And if you can not, you **have to consider surgery, even if it comes at a price.**"*

Lise has it even worse:

> *I have* ***had surgery on both hands because I had worn them down. The bones were completely destroyed, so it is osteoarthritis*** *[...] I have had one and a half bone removed in one [thumb], and one bone in the other [...] I think it* ***mainly comes from the fact that I have extracted large syringes.*** *[...] I do not have a lot of strength and it can easily hurt if I do something where I use my hands. [...]* ***It has definitely changed my quality of life. There are many things that I cannot do. For example, I cannot open a soda bottle.*** *[...] Therefore, I have auxiliary tools both at work and at home.*
> *So because of this,* ***im very careful with how I extract and what syringes I use****. It is only in very urgent situation, that I skip.*

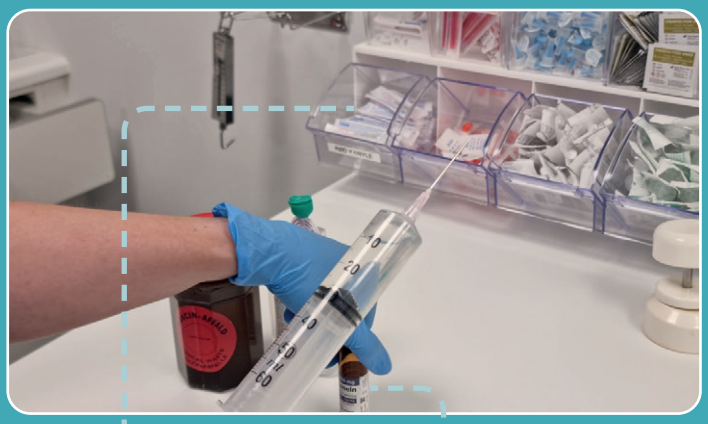
Must be able to aid in extraction and injection

Various preliminary **shadowing showed that nurses rarely have an identical approach to injection and extraction of syringes** in addition to a variety of workarounds which is not appropriate, efficient, or still putting strain on the fine motor skills (DAN: Finmotorik).

Nurses primarily has varying workflows

Three pictures of workarounds

Some nurses does not use needles with filter as they are too strenuous.

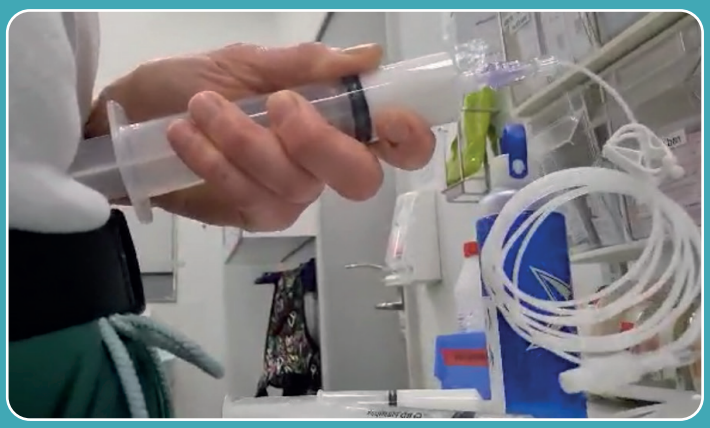


illu. 20

> *If we* ***extract from ampoules, then we are supposed to use needled with a filter.*** *But this is too challenging. Therefore,* ***many resort to just using regular needles****.*
>
> Tracey, Nurse, Intensive Care at Regionshopitalet Viborg

When cracking an ampoule there is a risk of glass shards contaminating the medicine, hence the nurses require a needle with a 5-micron filter for extraction

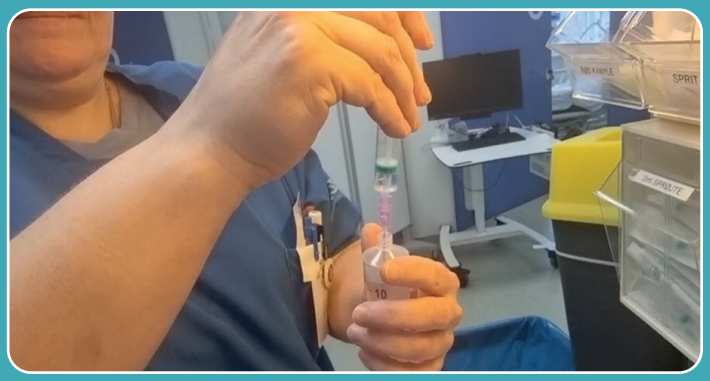
Some nurses use other body parts to inject.



illu. 21

> *I **make every effort to care for my hands** and avoid applying excessive force. I have **invented another technique to inject with**. Frankly, I stand and **use my stomach to inject it**. So, it gives stability and everything. It is definitely messier […] **My method takes more time.** But sometimes, unfortunately, I must do it quickly. Changing habits can be challenging.*
>
> Lise, Nurse, Anaesthesiology at Hvidovre Hospital

Some nurses use smaller syringes to put into the bigger one, which takes longer time and makes the use of needles with filter indifferent



illu. 22

> *It is much less strenuous to extract from small syringes and inject into the bigger ones, than it is to use the big ones to start with.*
>
> Lisbeth, Nurse, Intensive Care at Regionshopitalet Viborg

Workarounds puts the patents' health at risks and is an unnecessary expense both environmentally and financially

Partial conclusion

The experience of the interviewed nurses was consistent with the statistical data. When performing repeated extraction and injection using larger syringes, the strain and subsequent pain are immense, regularly leading to a decreased quality of life. The numerical worst case is the extraction and injection of approximately 50 daily 50 mL syringes. However, on a typical day it would be around 10-20 syringes. Yet, the nurses still resort to various workarounds which either compromise patient safety or increase time, expenses and waste. Consequently, it was deemed necessary to investigate why the injection and extraction of syringes are strenuous and what anatomical consequences they may entail.

Initial Problem Statement

Who should we help?

Through quantitative data about nurses' working environment and qualitative data of different nurses' personal experience regarding larger syringes, the framing of the project had become more defined. As a result, the following problem statement was formulated, but will be subject to ongoing refinement as new information emerges throughout the project.

How to create a solution which diminishes or prevents attrition and aids the Danish health care sector in the extraction and injection of various liquids using 20 mL and 50 mL syringes?

3 Framing the Problem

Through a multitude of interviews and tests this chapter sees to frame the problem. By covering the physical influential factors and its consequences to mapping out the current range of the problem and workflows of nurses it is sought to establish the legitimacy of the problem. The findings are ultimately collected in the first Design Brief.

The Mechanical Problem

Why is it a problem?

On the surface it might **not seem too difficult to extract and inject a syringe, but the reality is, that a lot of nurses feel pain in their fingers when working with syringe**s. This begs the question: What kind of forces comes into play when extracting and injecting a syringe and what different factors impacts these forces?

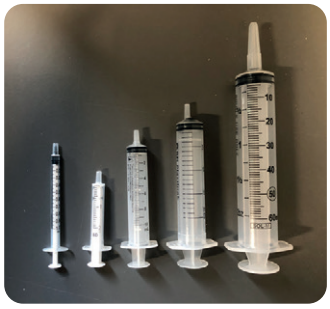
To gain insight into the problem, a basic **understanding of the syringe and the syringe's physics must be comprehended.** This was obtained by desktop research, situated interviews, shadowing the nurse's workflow, and acting out extraction and injection tests. The tests were conducted such that only one variable was changed each test, and was then repeated five times each, to obtain an average force (Appendix 13 & 14). The tests were based on real syringe scenarios observed in different contexts (Appendix 5, 7, 9, 10 & 15).

illu. 23 Extraction

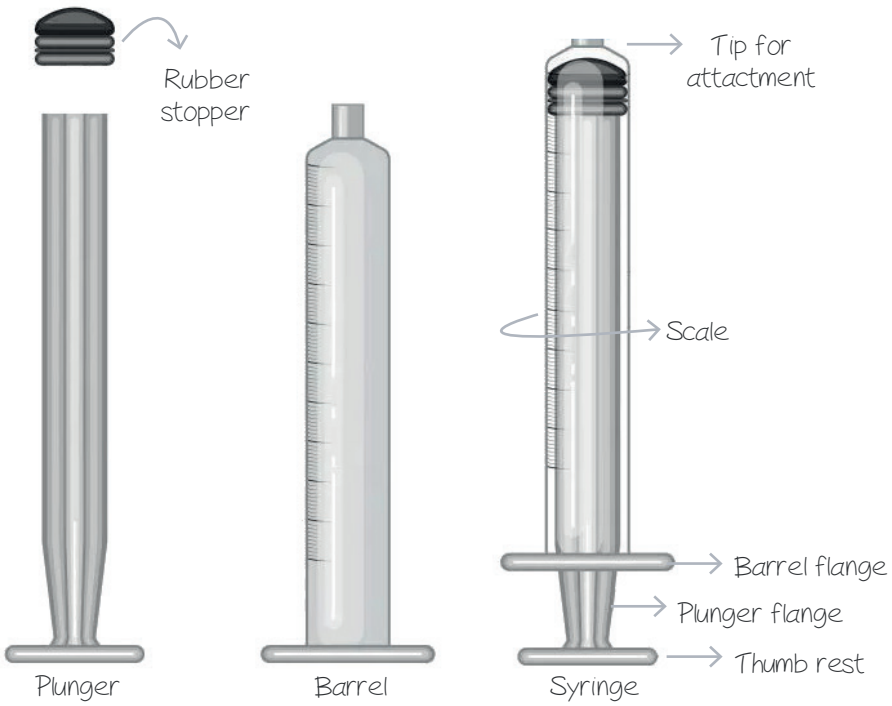
illu. 24 Injection

There are **two kinds of syringes:** A **2-component syringe** that consist of an injected moulded barrel and a plunger, and the more common **3 component syringe** which also includes a rubber stopper.(Appendix 16). On both kits, there is a scale on the other side of the barrel where the nurses can see the volume.

illu. 25: 2- & 3-component



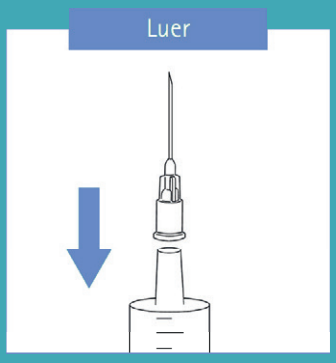
illu. 26: 1, 2, 10, 20 & 50 mL



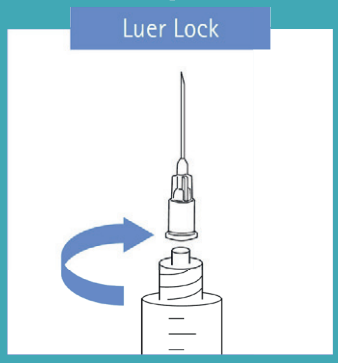
illu. 27 Anatomy of a syringe

Syringes can vary in proportion between manufacturers (Appendix 16). Especially the flanges and thumb rest, where some have a larger surface area for the force to be distributed.

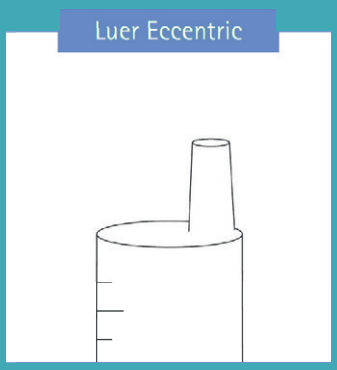
Furthermore, **the tip of the barrel can have different interfaces for a variety of attachments depending on the nurse's assignment.** One of the most common interfaces, observed in the Danish health care system (Appendix 5, 7, 9 & 10), is the Luer Lock where the nurses screw the attachments into the syringe to secure it. Other interfaces include, Luer slip tip, eccentric tip, catheter tip, NRFIT and ENfit. (B. Braun, 2022).



Friction fit connection

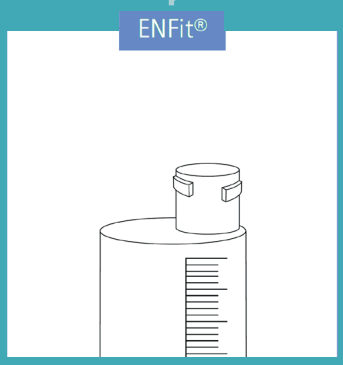


Locking fit secured by screw type connection for strong needle connection.

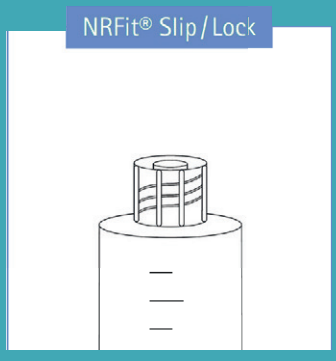


Off center Luer tip for injection into a vein.

Longer sliptip used for irrigation of a catheter or with medical tubing



Locking fit secured by screw type connection specifically designed for tube food to prevent unintentional connections between enteral and intravenous systems.



Locking fit secured by screw type connection specifically designed for neuraxial and regional anesthesia applications to reduce the risk of wrong route medication errors.

illu. 28

illu. 29

Luer Lock attachments

There is a large variety of attachments to the Luer Lock system though some of the most common, are: **needles, mini-spikes, and venflon.**

illu. 30

The **mini spikes** are made to **help the extraction of medicine** by creating airflow into the medicine container to combat the under pressure created though it can still be hard to extract the syringe with a mini spike.

The **needles** can be **used for injection into patients**, but they are also commonly used to **extract medicine out of ampoules**. **Ampoules** are **small medicine canisters that needs to be cracked** open thus the mini spikes cannot be attached is type of medicine. When cracking an ampoule there is a **risk of glass shards contaminating the medicine,** hence the nurses **require a needle with a 5-micron filter** for extraction (B. Braun, n.d.a).

illu. 31

The **venflon** is a peripheral venous catheter and **gives access directly into the veins of a patient**. Venflon often come with a Luer Lock and are intended to generate intravascular access to sample blood, administer medication, fluids, and blood intravenously (B. Braun, n.d.b).

illu. 32

ENfit attachments

The **ENfit syringe is specifically designed for tube feeding** and has a unique interface that ensures that these cannot be used for any other application. They are typically used with an **NG tube** inserted into the nose, (nasogastric tube) or a **PEG tube** (Percutaneous Endoscopic Gastrostomy) inserted through a cut hole in the abdomen.

illu. 33

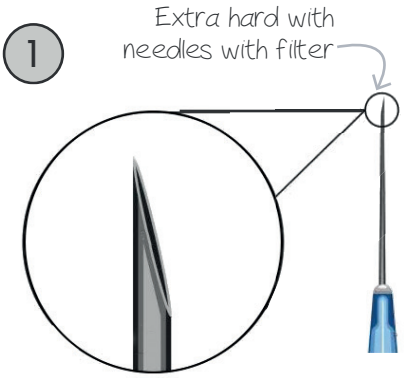
Cathether tip attachments

As the name suggests these syringes are **mostly used to flush out clogged catheters or for expanding the ballon** when placing the catheter. The syringe tip is press fitted into the tube which has a conical shape that creates a friction lock.

All these **different attachments change the force required to extract and inject a syringe**, but there are **further factors that come into play** as well.

When testing the different extraction and injection scenarios (Appendix 13 & 14) it was found that there are **7 main factors that influence the force required to actuate the syringe**:

1



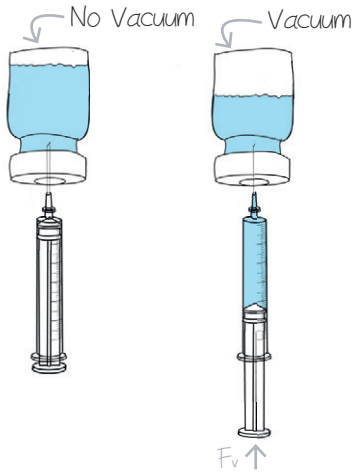
illu. 34

The cross-sectional area of the tip

When the syringe is pulled, a big volume of liquid is forced through a small hole. Liquid is extracted, and **the smaller the cross-sectional area of the needle or the tip of the syringe is, the harder it is to extract and inject due to fluid dynamics**. This toughness is further amplified in 50 mL syringes because of the larger volume that needs to be extracted or injected. The cross section of the tip is **the primary factor that influences the force**, and this is clearly seen in the results when comparing extracting with a catheter syringe (17 N) and through a filter needle (73 N).

Must be able to overcome forces of 17-73 N during extraction and injection

2

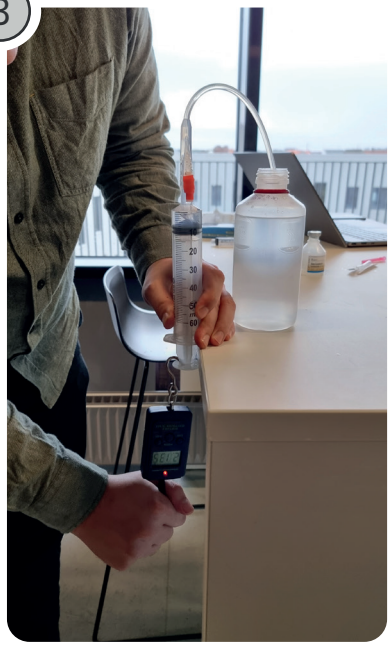


illu. 35

Vacuum in the medicine container

When the syringe is pulled, and the medicine is extracted, **negative pressure is created in the medicine container which generates a pushing force** on the plunger that counter acts the pulling force. This force gets larger the more volume that is extracted so a common workaround is to either pump air into the container with the syringe before starting the extraction or using a minispike. This is especially **present in hardshell medicine containers** that cannot deform to accommodate the negative pressure.

3



illu. 36

Speed

The speed at which the plunger is extracted and injected significantly impacts the force. **The faster extraction/injection the harder it is**, though it is observed that if extracted too quickly the medicine is more prone to create air bubbles which can be a potential patient hazard, hence the pace for filling a 50 mL syringe is approximately 30 seconds (Appendix 5 & 9).

illu. 37

illu. 38

4

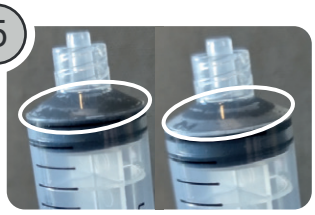
Thick and hard to extract

illu. 39

Viscosity of the liquid

The viscosity of the liquid can vary depending on the type of medicine or food, and the temperature of the liquid. **Thicker liquids** like tube food and some anesthesia medicines like propofol **are harder to extract** (Appendix 5 & 9).

5

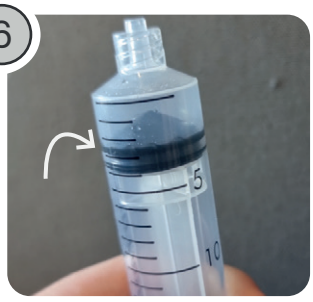


illu. 40

Initial vacuum

The initial vacuum created **between the rubber stopper and the barrel needs to be overcome** before it gets easier to extract the plunger.

6



illu. 41

The friction of the rubber stopper

The **rubber stopper creates friction when sliding on the inside of the barrel** (Appendix 14). **To combat the friction**, syringe manufacturers coat the inside of the barrel with **a thin layer of silicone base oil** (Appendix 16). This friction is especially present when using the same syringe multiple times, because the silicone layer will wear off.

7

illu. 42

What medium the medicine is injected into

The place the liquid is injected into and **the amount of space for the liquid** inside the patient's body is going have a **big impact on the forces required to inject the plunger**. Sometimes liquid needs to be injected directly into tissue, which is hard, where conversely in the tube food scenario directly into the stomach, which is easier. (Appendix 5, 6, 8, 9 & 10)

Partial conclusion

Through extensive testing, based on real situations (Appendix 13 & 14), it was found that worst-case scenario for extraction with a syringe was 73 N where a typical scenario was 47 N. If injection directly into tissue is excluded, the injection force is approximately the same as the extraction. These forces are spread over the middle finger, the index finger, and the thumb, which creates a lot of strain. How this strain affects the nurses over time and the consequences of this will be covered in the next section.

The Problem's Physiology

How is the body impacted?

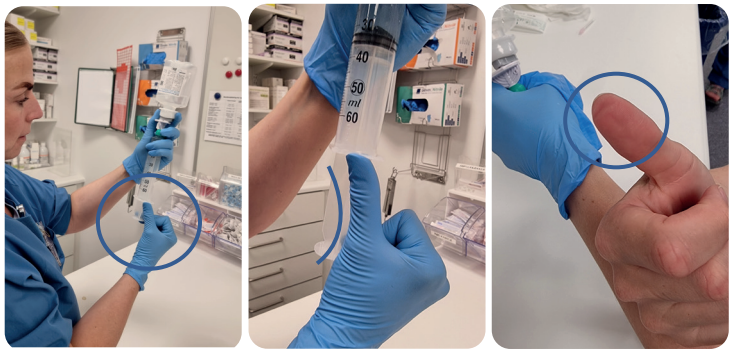
When a nurse extracts 100 different syringes of various sizes each day for years (Appendix 6), with the forces spread over a small area of the thumb, middle and index finger, it creates a lot of physical strain. Combined with numerous additional manual labour tasks where the nurses use their hands, they will often feel great pain when using a syringe. **To understand the impact of syringe extraction and injection on nurses' hands and fingers** and what could be done to help, desktop research aided by **interviews with two experts were conducted**.

Interview with an Occupational Therapist

Master in rehabilitation, occupational therapist (DAN: Ergoterapeut) and current lecturer of tomorrows physiotherapists at UCN in Aalborg, Sanne Heidemann-Lehmann were contacted **to evaluate the validity of the problem at hand and exactly where the strain is on the body as well as the consequences** of this. Additionally, to guide the design of the solution in a more ergonomic appropriate direction. (Appendix 17)

Sanne explained that the fingers **do not have any cartilage (DAN: Brusk) between the joints hence why it can be easy to develop injuries such as osteoarthritis (DAN: Slidgigt) in the fingers** (illu. 47). This tendency is especially concerning amongst nurses as **studies points to the fact that women are much more likely to get musculoskeletal diseases in their hands and fingers than men** (Gigtforeningen, n.d.). On the task of extraction and injection she noted:

In 2022 men only made up 4.2 % of the entire population of nurses in Denmark (Danmarks Statistik, 2023)



illu. 43

illu. 44

Sanne Heidemann-Lehmann

Occupational therapist at UCN in Aalborg

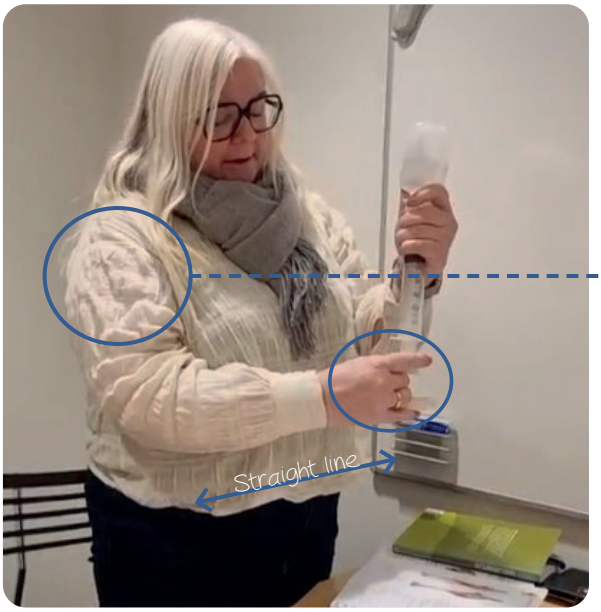
*"If you must do that [syringe extraction and injection] a lot, it is **completely ridiculous.** In terms of work environment, this [thumb] is where you [nurse] are challenged. **There are a lot of people who suffer because of their thumbs**."*

Furthermore, she suggested, that if it is not possible to redesign the syringe, then the solution should **move the strain away from the tendons (DAN: Sener) in the fingers and into the hands and larger muscle groups** that are superior at handling this type of strain. These **include the biceps, triceps and deltoid** (illu. 146). Additionally, she advised to **ensure that the wrist was not at an angle** during usage as well as incorporating **both hands to divide the strain** further.

> *It is crucial to **avoid the fine motor skills in the finger**s and divide the forces to the bigger muscles and the whole hand. […] It is also **important to have a straight pull from the hand to the elbow** […] I think when you develop the solution, it is important that you nudge to usage of the other hand as well.*

Must decrease fine motor skills usage

Should allow only two-handed use



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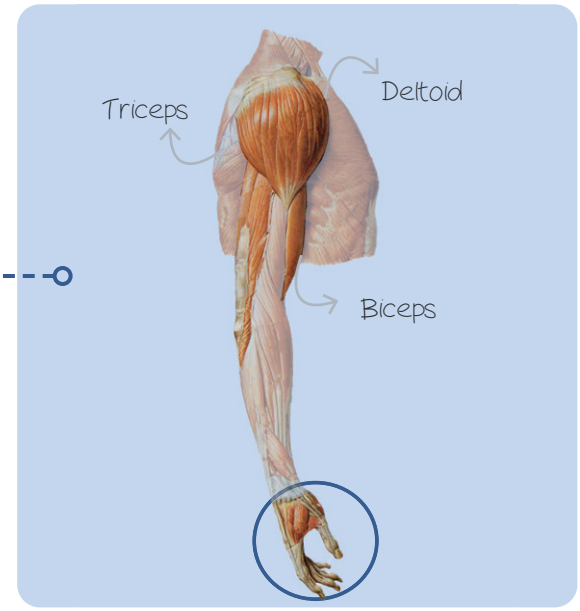
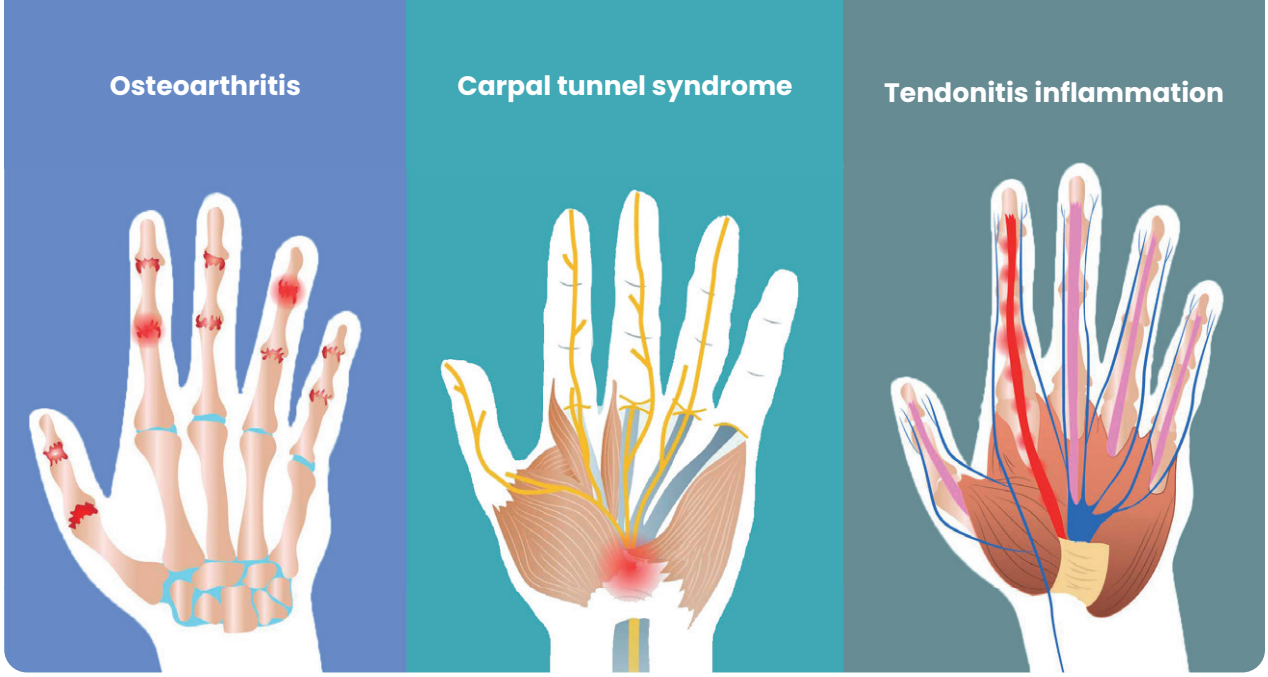


illu. 46

Interview with an injury and sickness evaluator

Dr. Tine Halsen Malling who works as a head physician the Department of Occupational and Environmental Medicine at Aalborg University Hospital where **she evaluates work related injuries and sickness** were approached to understand if the finger strain of nurses is recognised as an occupational injury. (Appendix 3 & 18)

Tine explained that **she would not be able to recognise syringe extraction and injection as a direct catalyst to an occupational injury** due to this task not exceeding the majority of a nurse's workday alongside **the fact that they us their hands for a variety of other tasks**. Despite a lot of **nurses suffering from hand and finger pain, often caused by osteoarthritis, tendonitis inflammation (DAN: Seneskedehindebetændelse) or carpal tunnel syndrome**, as verified by Tine (Illu. 147). In other word, the task of extracting and injecting syringes is a contributing factor to hand or finger pain, which has multiple contributors making the pains' origin point fuzzy, unrecognisable and legally invalid.



illu. 47

She further elaborated that for the most part work-related injuries must be really severe and are often seen in craftsman trades. **Work environment is in general getting more and more attention, but the law is still very flexible and accommodating of many unreasonable assignments.** However, she concluded that even though this task might not cause occupational injuries on paper it can definitely trigger painful symptoms in the nurses' fingers that she does not seek to undermine the significance of despite her judicial position:

illu. 48

Dr. Tine Halsen Malling

Occupational and Environmental Medicine at Aalborg University Hospital

*"No matter how the defect originated; osteoarthritis, tendonitis inflammation or carpal tunnel syndrome, finger strain will hurt, and **anything that can be done to remedy it is just damn good.**"*

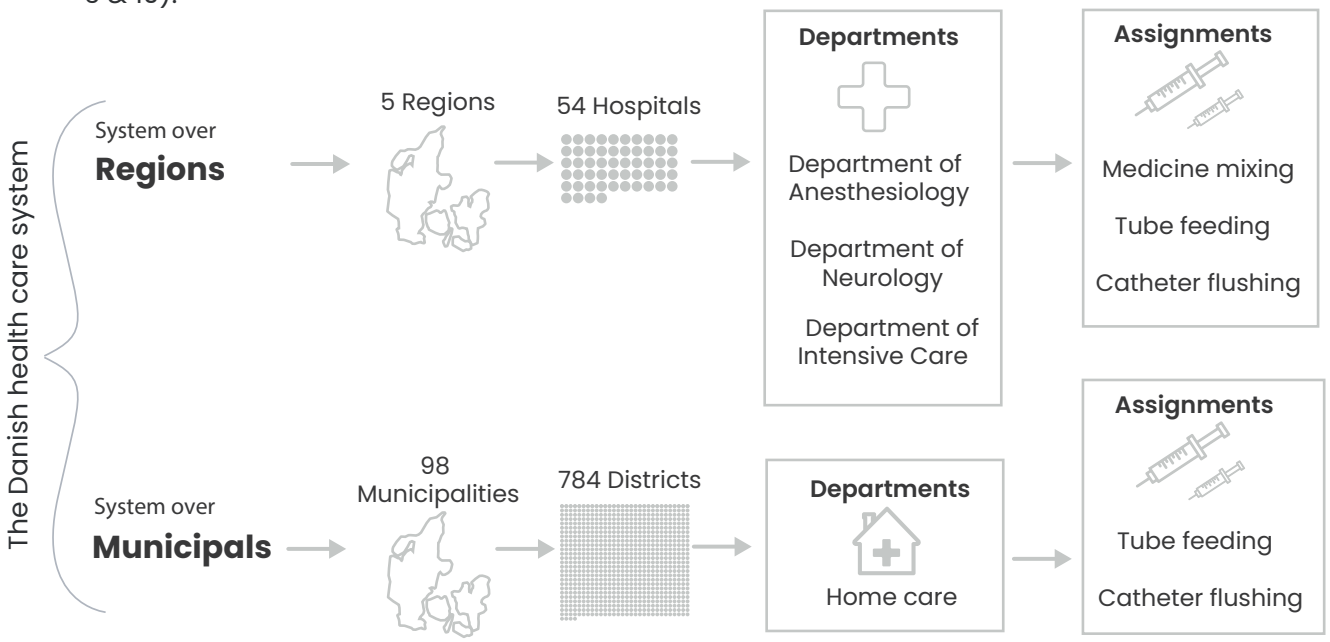
Partial conclusion

Based on interview with an occupational therapist and a head physician from a Department of Occupational and Environmental Medicine it became evident that the pain in the thumb, middle and index finger during extraction and injection is due to the development of osteoarthritis, tendonitis inflammation or carpal tunnel syndrome. Despite the pain being a physiological understandable consequence of the applied strain during this task, the task itself cannot be defined as the sole contributor, as nurses carry out many different tasks, rendering a legal connection invalid. However, a remedy was still relevant and needed. According to the occupational therapist the solution should shift the strain to the entire hand and bigger muscle groups while possibly even afford a two-handed use to split the strain.

Extend & Context

Who face the problem and when?

To identify who mainly faces the problem of extracting and injecting larger syringes, a mapping of the Danish healthcare system was developed based on a lot of field research (Appendix 4, 5, 6 & 10).



illu. 49

The illustration shows that the **Danish health care system** consists of **five regions with 54 hospitals and 98 municipalities with around 784 home care districts**. The hospitals have different departments with **Intensive Care Unit, Anaesthesia, and Neurology** supposedly being among those who use the most syringe, due to assignments like **medicine mixing and administering, tube feeding and catheter flushing**. In the hospital it is solely nurses, who perform these assignments, whereas in the home care it is both home care nurses and social health care assistants (DAN: Social- og sundhedsassistent). In the latter context they mainly use larger syringes for tube food and catheter flushing.

illu. 50: District Vesterparken

illu. 51: Viborg Hospital

The problem itself is more tied to the specific assignment rather than the specific system or department.

To get a better understanding of the different assignments carried out in various contexts **Viborg Home Care District Vesterparken and Viborg Hospital were contacted and several of their nurses were shadowed during medicine mixing and administering as well as tube feeding** (Appendix 7, 10 & 19). It was not possible to shadow catheter flush due to the patient's dignity why the workflow of this scenario relied on oral explanations mixed with online resources.

Assignment 1: Medicine mixing & Administering

Across different departments nurses always extract from the confines of the medicine table, which is placed in the hallway or in the patient's room. The medicine table stores all medical equipment like syringes, different add-ons, saltwater containers, alcohol wipes, etc. The only thing the nurses need to bring to the table is the medicine, which is stored in a medicine room located in the centre of the department.

illu. 52

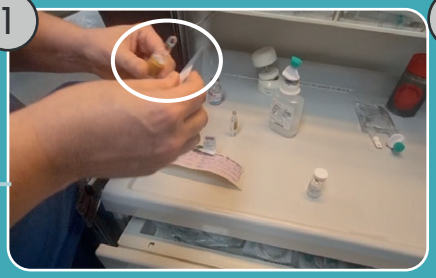
illu. 53

Must not exceed 5% of the available table area of 0.2 m2, equivalent to 100 cm2

Must have a usage which combined timespan of retrieving, attaching, injecting, extracting and replacing that is competitive with the current of extraction and injection

The following depicted scenario of medicine mixing & administering is carried out by Libeth working in the Intensive Care Unit as Viborg Hospital, where time-efficiency is alfaomega. Lisbeth starts by picking up the medicine containers in the medicine room:

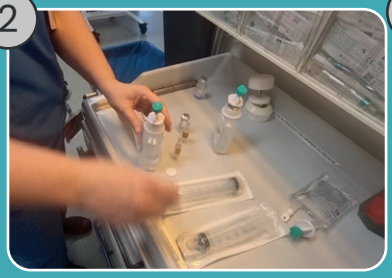
1



Disinfection of the medicine containers using wipes.

Must be resistant to alcohol, water and soap

2



Retrieving 50 mL syringe, 100 mL saltwater and mini-spike in drawer. Unpacking mini-spike and attaching it to saltwater.

3

Unpacking 50 mL syringe and activate the medical silicone oil to smooth the movement of the plunger by pushing it to the bottom of the barrel.

4

Attaching 50 mL syringe to mini-spike by rotation 180 degress.

- Must allow various needles and mini-spikes to be attached to the tip
- Must allow syringe to be rotated 180 degress during Luer Lock attachment and last medicine drop extraction with needle

5

Extracting saltwater, a couple of millilitres more than needed.

- Must be able to let the syringe be extracted and injected within 360 degrees free movement

To gain control over the syringe and relieve the fingers of a great workload the nurse grabs around the internal sides of the plunger with the entire hand and uses the thumb to push against the barrels flanges to extract the plunger. This workaround can be a challenge when wearing plastic gloves due to friction. If it should be done by the (unwritten) book the **nurses should not touch the internal sides of the plunger due to risk of contamination and need to use gloves**.

- Must be operational whilst wearing plastic gloves

6

Tapping the 50 mL syringe to remove hazardous air bubbles.

- Must be fixated to syringe during rotation and air bubble-tapping

7

Injecting saltwater a couple of millilitres to match need.

8

Detaching 50 mL syringe from mini-spike.

9

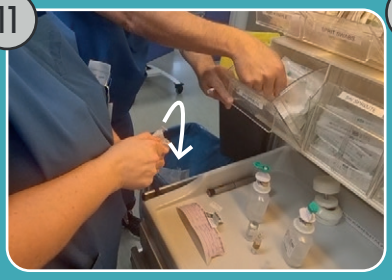
Placing and balancing the syringe atop another syringe to ensure the tip stays sterile.

- Must be able to see mL scale during extraction and injection

10

Retrieving 20 mL syringe & ampoule-cracker.

11



Open ampoule using ampoule-cracker.

12

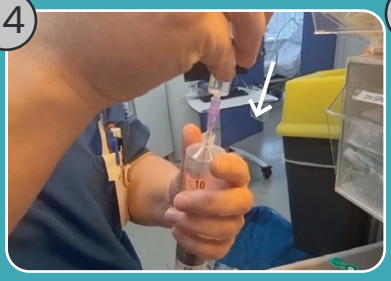
Retrieving and unpacking a needle with filter and attaching it to the 20 mL syringe.

Must accommodate current one-handed use ampoule scenarios

13

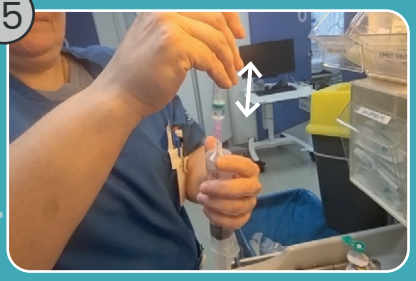
Extracting medicine from the ampoule using the 20 mL syringe.

14



Inject medicine from the 20 mL to 50 mL syringe.

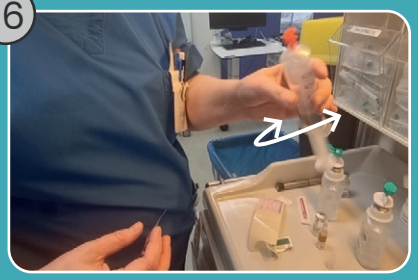
15



Extract and inject again using the 20 mL to get all medicine from the 20 mL syringes' internal walls.

As a **workaround, the nurses use a smaller syringe to extract from ampoules** because it is too strenuous to extract directly with the 50 mL syringe when using the required needle with a filter. It is both time-consuming as well as financially and environmentally heavy for the hospital.

16



Attaching a seal. Flipping the 50 mL syringe around ten times to mix the medicine with the saltwater.

illu. 54

Must be moveable by hand, in pants and on table

After preparing the syringe **the nurse places it in a syringe pump** standing beside the patient's bed, removes the seal and attaches the tip of the syringe to the extender. The syringe pump is programmed to automatically inject the medicine into the patient with a specific flow rate. Thus, making the **administering part of the task automated** and therefore, in comparison to medicine mixing and other tasks, not strenuous, **disregarding this part of the task**. **One patient can receive up to sixteen 50 mL syringes in one day** depending on the patient's circumstances.

illu. 55

Assignment 2: Tube feeding in District Vesterparken

The tube food procedure is more or less the same in the hospital as in the home care. The biggest difference is that the **hospital patients often have an NG tube** (Nasogastric tube) whereas **the citizens in the home care mainly have a PEG tube** (Percutaneous Endoscopic Gastrostomy).

With a NG tube it is important that **tube food does not enter the lungs** hence **why the nurse needs to see, listen and have a tactile feeling during injection.**

The following depicted scenario of tube feeding with a PEG tube is carried out by Anja working in District Vesterparken. Anja starts by driving out to the citizen, where all the equipment is stored:

- Must be relatively silent
- Must be able to have a tactile feeling with resistance during injection

1

Putting on plastic gloves and pouring the fridge-stored tube food and tap water into glasses.

2

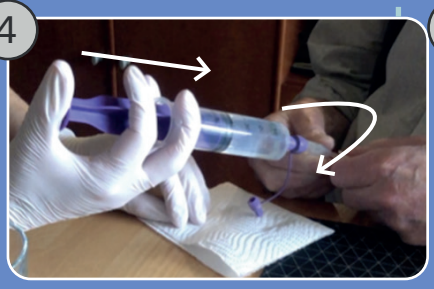
Transporting the glasses and a 50 mL syringe to the dining table, where the patient has prepared himself by finding his PEG tube under his shirt.

3

Starts by extraction 50 mL of water.

- Must be operational whilst wearing plastic gloves
- Must be moveable by hand, in plastic bag and backpack
- Must be able to see mL scale during extraction and injection.
- Must allow extenders to be attached to the tip.

4



Attaching the syringe to the PEG tube and injecting water using one hand to hydrate the citizen.

5

Detaching the syringe from the PEG tube and extracting 50 mL of tube food.

6

Attaching the syringe to the PEG tube and injecting tube food using one hand.

Must be able to let the syringe be extracted and injected within 90-180 degrees

If the **injection is too fast the citizen can feel nauseous** or experience acid reflux. It should align with a normal meal, but is **typically twice as fast.**

Must have a usage which combined timespan of retrieving, attaching, extraction, and replacing that is competitive with the current of extraction while injection, 16 minuts, in isolation, must be slower than the current timespan

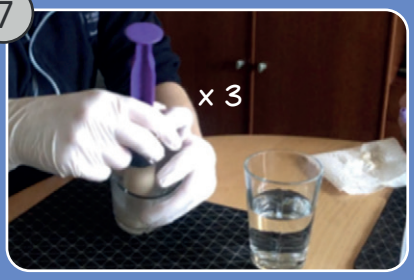
Must be resistant to alcohol as well as water and soap solution.

In the home care one syringe can be used for 24 hours whereas hospitals need to discard it after each tube feeding. With extended usage the syringe gets more difficult to extract and inject due to increased friction caused by the degradation of the silicone oil coating.

The citizens covers the equipment used for tube food, as to **not be reminded of their illness**

Must look harmless and non-institutional

7



The same procedure was repeated for three more 50 mL of tube food and one more water

8

Lastly, cleaning of the 50 mL syringe using tap water and placing it in the basket with a towel over.

illu. 56

The amount of **tube feeding per patient per day can vary a lot from 3-5 depending on the citizen's condition.**

Partial conclusion

The problem is specific to the assignment rather than the system or department. Key assignments using 50 mL syringes include medicine mixing, tube feeding and catheter flushing. Core requirements emerged, including mobility around the syringe, visible mL scale, moveable by hand, attaching add-ons and extracting/injecting with 360-degree free movement. Hygiene standards differ between hospital medicine mixing and home tube feeding, but both need resistance to alcohol, soap and water, and must be operable with plastic gloves. Core requirements are divided into identical and varying values. Context-specific requirements also emerged, but product development will initially focus solely on the core requirements (Appendix 35).

Design Brief 1

Problem Statement

How to create a solution which diminishes or prevents attrition and aids the Danish health care sector in the extraction and injection of various liquids using 20 mL and 50 mL syringes?

Target group

The Danish health care sector, including nurses and social and health case assistant, both regionally (hospitals) and municipally (home care).

Assignment

Medicine Mixing, tube food and catheter flush.

Requirements & Wishes

No.	Core Requirements – Common Values	Source
1	Must be able to aid in extraction and injection	Personal Experiences
2	Must decrease fine motor skills usage	Problem's physiology
3	Must be resistant to alcohol as well as water and soap solution	Extend & Context
4	Must be operational whilst wearing plastic gloves	Extend & Context
5	Must be able to see mL scale during extraction and injection	Extend & Context

No.	Core Requirements - Varying Values	Source
1	Must fit all possible size variants of 20 mL and 50 mL syringes from different brands	Personal experience
2	Must be able to overcome forces of 17-73 N during extraction and injection	Mechanical problem
3	Must allow various needles, mini-spikes, catheters and extenders to be attached to the tip	Extend & Context
4	Must be able to let the syringe be extracted and injected within 360 degrees free movement	Extend & Context
5	Must be moveable by hand, in pants, plastic bag, backpack and table	Extend & Context

No.	Context-specific Requirements	Source
1	Must not exceed 5% of the available table area of 0.2 m2, equivalent to 100 cm2	Extend & Context
2	Must allow syringe to be rotated 180 degress during Luer Lock attachment and last medicine drop extraction with needle	Extend & Context
3	Must be fixated to syringe during rotation and air bubble-tapping	Extend & Context
4	Must accommodate current one-handed use ampoule scenarios	Extend & Context
5	Must be relatively silent	Extend & Context
6	Must be able to have a tactile feeling with resistance during injection	Extend & Context
7	Must have a usage which combined timespan of retrieving, attaching, extraction, and replacing that is competitive with the current of extraction while injection, 16 minuts, in isolation, must be slower than the current timespan	Extend & Context
8	Must have a usage which combined timespan of retrieving, attaching, injecting, extracting and replacing that is competitive with the current of extraction and injection	Extend & Context
9	Must look harmless and non-institutional	Extend & Context

No.	Wish	Source
1	Should allow only two-handed use	Problem's physiology

4 Understanding the Industry

This chapter investigates current market solution, whether they solve the problem, why they do not and why it is an opportune and feasible moment to do so, referencing legislation, interviews, market information and societal tendencies throughout. Additionally, an entry point to the market is established through a partnership with the company byLink. Finally, a second Design Brief creates an outline of the project's settings.

Market Analysis

Is the problem already solved?

Parallel to elaborating the breadth and depth of the problem from a humanitarian perspective by conversing with nurses, the current market was meticulously searched for solutions (Appendix 20), supported by said conversations. It became apparent that the present contenders for solutions could be **divided into syringe redesigns and additive products**, respectively.

Syringe Redesigns

illu. 57

Auto-injectors facilitate the injection of small doses of medicine. They can be manually loaded with a medicine cartridge or pre-armed, and are available in spring-loaded, electrical, single-use, or reusable designs.

Price: 200-4,000 DKK, Capacity: 1-5 mL, Injection only

illu. 58

High Pressure Injectors enable needleless injection of tiny doses of medicine, around 0.1-0.25 mL, by using pressure to jet-stream the medicine under the skin. They come in single-use or reusable varieties with one or up till 40 doses.

Price: 7-4,200 DKK, Capacity: 0.25-20 mL, Injection only

illu. 59

Spring Controlled Syringes are used by veterinarians for vaccinating animals. They are reusable and require one or multiple squeezes to move the plunger forward depending on size and capacity.

Price: 120-700 DKK, Capacity: 1-50 mL, Extraction & Injection

illu. 60

Control Syringes are designed with holes for the thumb and possible the index and middle finger rather than barrel flanges and a plunger thumb rest. Comes in both single-use and reusable varieties.

Price: 8-1,050 DKK, Capacity: 12-100 mL, Extraction & Injection

illu. 61

VacLok sustains a vacuum using an integrated locking mechanism, giving the user a 'break' during the extraction process, thereby relieving hand fatigue temporarily.

Price: 50-80 DKK, Capacity: 10-50 mL, Extraction & Injection

illu. 62

Mini-Spikes (also called Air Vents) equalizes the negative pressure created in the medicine container through filtered venting, thereby reducing the necessary exerted forces. Comes in great variety of shapes and sizes and are exclusively single-use.

Price: 10-20 DKK, Capacity: 1-50 mL, Extraction & Injection

illu. 63

Hand Filler by B. Braun uses manual leverage to extract syringes. It is only compatible with their own 50 mL syringes.

Price: 5,000-6,5000 DKK, Capacity: 50 mL, Extraction only

illu. 64

Syringe Pumps precisely controls the flow rate of injection electrically.

Price: 1,5000-6,800 DKK, Capacity: 20-50 mL, Injection only

illu. 65

Manual Syringe Dispensers works by a locking pinion system where multiple squeezes injects the plunger. Used for precise applications of e.g. adhesive or solder mask.

Price: 14-680 DKK, Capacity: 10-50 mL, Injection only

illu. 66

Injector Handles increases surface area thereby divides the strain. Compatible with various syringe sizes and brands which is achieved by a multitude of varying products.

Price: 27-138 DKK, Capacity: 1-100 mL, Injection only

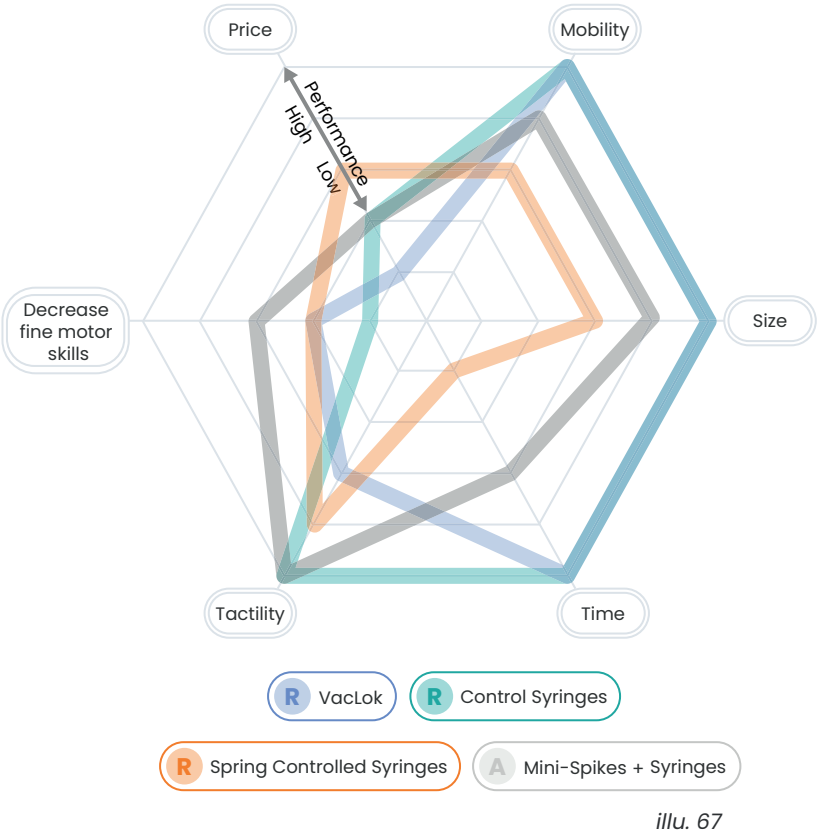
Requirement-fulfilling contenders

The market contenders for a solution were initially **evaluated based on two binary requirements** from Design Brief 1:

- Must be able to aid in extraction and injection
- Must fit all possible size variants of 20 mL and 50 mL syringes from different brands

These are the preeminent requirements in terms of accommodating the entirety of the problem's context. In this evaluation, six fell short, while **only three syringe redesigns remained alongside the Mini-spikes as the only additive product** (Appendix 20)**.** These were subsequently mapped against each other on selected non-binary parameters based on relevant requirements in **a spider web diagram, where the values range from one to five in ascending performance.**

Upon examination of the spider web diagram, it is apparent that the syringe **redesign generally decreased use of fine motor skills, albeit to a modest degree as the fingers**, and hand for the spring controlled syringes, are still used.



illu. 67

Their sizes and mobility are comparable with the regular syringe, with the 90-degree handle of spring controlled syringe being the outlier. They perform well on tactility with the exception of VacLok, that offer extraction without feeling, due to its locking mechanism. VacLok and control syringes has the same time-efficiency as regular syringes while the spring controlled syringes, which are reusable, need cleaning between each use, which is unfitting for a sterile, short-staffed and fast-paced workplace such as hospitals. **The syringe redesigns minimum prices range from 8-120 DKK, with only the Spring Controlled Syringes justified by reusability, all three syringe redesigns fall short economically**. Especially when compared to a regular 50 mL ENFit syringe costing mere 3 DKK on tender (Appendix 21). As one nurse explained:

illu. 68

Tracey Christensen

Nurse, Intensive Care Unit at Viborg Regionshospital

*"The **price is crucial**. If you can save 0.5 DKK, then that is what determines your choice of solution."*

The real contender for an existing solution is the Mini-spikes, which is well integrated in some nurses' workflow today, despite a price with an order of magnitude larger than regular needles. **Pointing to the fact that aiding in the decrease of fine motor skills, as exhibited in the diagram, alongside additional benefits ensure an adoption in spite of a relatively high price point.** This presents a **blue ocean opportunity, in an additive product where a parallel compliance with the two binary requirements, and a fulfilment of decreasing the use of fine motor skills significantly, while not exacerbating the price, mobility, size, time, and tactility of the present syringe alongside adding beneficial features to the workflow.** Designing with this objective in mind would confer a competitive advantage and ensure a strong product-market fit (Haase, 2022). However, accomplishing these goals appears complex, requiring comprehensive reasoning and careful argumentation of eventual trade-offs to ensure strategic market durability.

Partial conclusion

A comprehensive market analysis was conducted to determine if an adequate solution already existed. Ultimately, all potential candidates were deemed peripheral. The Syringe Redesigns deficient on price or time caused by necessary cleaning due to reusability. Similarly, the Additive Products falls short in meeting crucial binary requirements or lack compatibility with certain interactions or assignments. Nonetheless, the discovery of a blue ocean within the highly optimized health care sector was remarkable. The cause of this being a seemingly unresolved problem needed uncovering and enlightenment, to ensure no stone was left unturned, which could disprove the feasibility of the project.

An Unresolved Problem

Why is the problem not solved already?

The reality that the problem exist with no relevant contenders for feasible solution was remarkable and needed elaboration to verify that no facts of great importance had gone unnoticed. Through internship experience, interviews, and desktop research the explanation was **found to be threefold:**

illu. 69

1 Syringe manufacturers' Perspective

An obvious candidate to tackle the problem would be syringe manufacturers. However, admitting that their products is not optimal in terms of the personnels' usage could backfire. **Addressing the problem with a workflow additive product would be an undermining of the validity and quality of the syringe manufacturers' own products**. Yet, they are aware of the problem as they address it with an alternative to needles, the vacuum diminishing mini-spikes, and by applying lubrication to the syringes' rubber stoppers to reduce friction. The former is only applicable in certain scenarios and the strain, as shown in tests, remains significant (Appendix 13 & 14).

The single example of an additive workflow product by a syringe manufacturer is B. Brauns 'Hand Filler', which in addition, has very limited commercial availability. This is exclusively compatible with their own syringes deeming it non-adoptable by the Danish health care system which has a call for tender (DAN: Udbud) for syringes every fourth year (Appendix 22). However, it is an understandable design choice as **a universal solution could potentially allow sales of syringes from other manufactures subsequently cannibalizing on their own.** Additionally, Annette Mølby Nielsen, the Danish Key Account Manager at the syringe manufacturer Becton Dickinson (BD) and a nurse for 13 years, explains that they are often told their syringes are strenuous to use. Customers request needles with a greater flow rate, as this is the only solution they are familiar with. Historically, BD's focus has not been on the work environment but rather on patient safety and hygiene (Appendix 16).

2 Nurses' Perspective

With the habit of prioritising the needs of patients over their own, nurses do not actively seek a solution, but instead simply accept their situation. Furthermore, the problem is based on dark

numbers as syringes are used in various scenarios, with typical research being based on specific contexts and not transcending work tools. **The problem remains largely unnoticed by both healthcare professionals and the Danish system, leading to a lack of awareness within the market.** As one Intensive Care nurse elaborated on her colleagues:

illu. 70

Bente

Nurse, Intensive Care at Aalborg Universitetshospital

*"**When they do not have a problem, they do not do anything about it.** It is* **only the day that they have a problem, that they think about protecting themselves**."

The proposed solution would serve as an awakening, prompting nurses and the system to recognise the problem through a bottom-up propagation of the solution, and subsequently create its own need, similar to the adoption of byLinks' multitool OpenIt. Meaning, with no current feasible solution the problem remains largely latent.

3 The problem's Perspective

As previously established, a solution would need to accommodate a variety of economic and physical contexts, assignments, and scenarios besides personal workflows. It must also be compatible with a range of brands and syringe sizes, as well as compliant with a habituated and conservative target group, not all of whom recognize the extracting and injection of syringes as a problem before it is too late. Designing a holistic solution that meets the necessary requirements for adoptation is a complex task and especially when the solution is for a target group, who don't need a solution. **Simply put, it is difficult to solve.**

Partial conclusion

The problem remains unsolved because implementing a universal solution would undermine the manufacturers' own products and open the market to competitors. Additionally, the general lack of focus on the work environment of nurses, including the problem of extraction and injections of syringes, means the demand for additive products would first shift from latent to evident with an introduction of such products, thereby creating their own demand through existing. Lastly, due to the creation of said universal products being fairly complex in terms of context requirements and adoptability. Merging these reasons, it became evident that the problem indeed presents a blue ocean. The next logical step was to cynically assess whether creating a solution to the problem would be opportune and worthwhile, not only from a humanitarian perspective but also from a societal as well as a necessary economic standpoint.

Potential

Is it an opportune and feasible time to solve the problem?

An evaluation of the project's potential was conducted by unfolding the present societal tendencies, the target group's size and placement in the Danish health care system as well as economic aspects.

Societal Tendencies

Despite the current latency of the problem from a societal, and from conservative nurses, standpoint, the tendencies in the Danish system points to the fact that focus on the work environment of health care professionals are on the rise.

> *I know that t**he Danish Health Act is putting more and more focus on the prevention of occupational injuries**. It is going to be more prominent. Because we simply cannot afford for people [health care personnel] to get sick. It is too financially heavy.*
>
> Sanne Heidemann-Lehmann, Occupational therapist at UCN in Aalborg

A solution will become increasingly relevant.

CEO and partner of **byLink Line Bluhme affirm this tendency** pinpointing its noticeable beginning back to 2015 with the implementation of regulations and guidelines on patient positioning and lifting (DAN: Forflytningsguide). **The progression is also visible in general law and regulations** (Appendix 23) initiating with the '**Sundhedsreform**' (ENG: Danish Health Reform) of 20th May 2022 directly stating:

> *"The parties involved in the treaty agree that the health care professionals are the health care service's most important resourse."*
> (Indenrigs- og sundhedsministeriet, 2022)

The 'Sundhedsreform' also led to the establishment of the '**Robusthedskommission**' (ENG: Resilience Commission) who was tasked to determining, amongst other things, **ways of improving work environment, to retain personnel**. Their recommendation number 7, is particular interesting in context of the project:

> *"A better framework must be ensured for the rapid deployment of proven labour-saving technology"*
> (Robusthedskommissionen, 2023)

This is reflected in the **Danish Working Environment Authority**'s (DAN: Arbejdstilsynet) current applicable law:

> Chapter 2, Section 3, Subsection 2
> *"Manual handling which may present a risk to safety or health must be*

avoided by appropriate work organisation, including the use of technical aiding devices."
(Arbejdstilsynet, 1992)

Chapter 2, Section 6
"Appropriate technical aiding devices must be used whenever possible […]."
(Arbejdstilsynet, 1992)

Occasionally the application of this law leads to **immediate or time-limited injunctions, as was the case for laboratory technicians at Novo Nordisk doing repetitive motions using pipettes** (Appendix 17). It happened in the wake of COWI's report on unilateral strenuous work in laboratories in 2010, reviewed and approved by the Danish Working Environment Authority, which additionally acknowledged the strain of working with syringes:

"Microfiltration using a syringe is used by many different analytical methods in the laboratory. This method is very stressful for the shoulders, wrists and especially the thumb, since it is necessary to press relatively hard with the thumb on the plunger. Repetitive hard pressure is stressful, and the more pressure per minute, the greater the risk of physical strain on the fingers, hand and arm."
(Industriens Branchearbejdsmiljøråd, 2010)

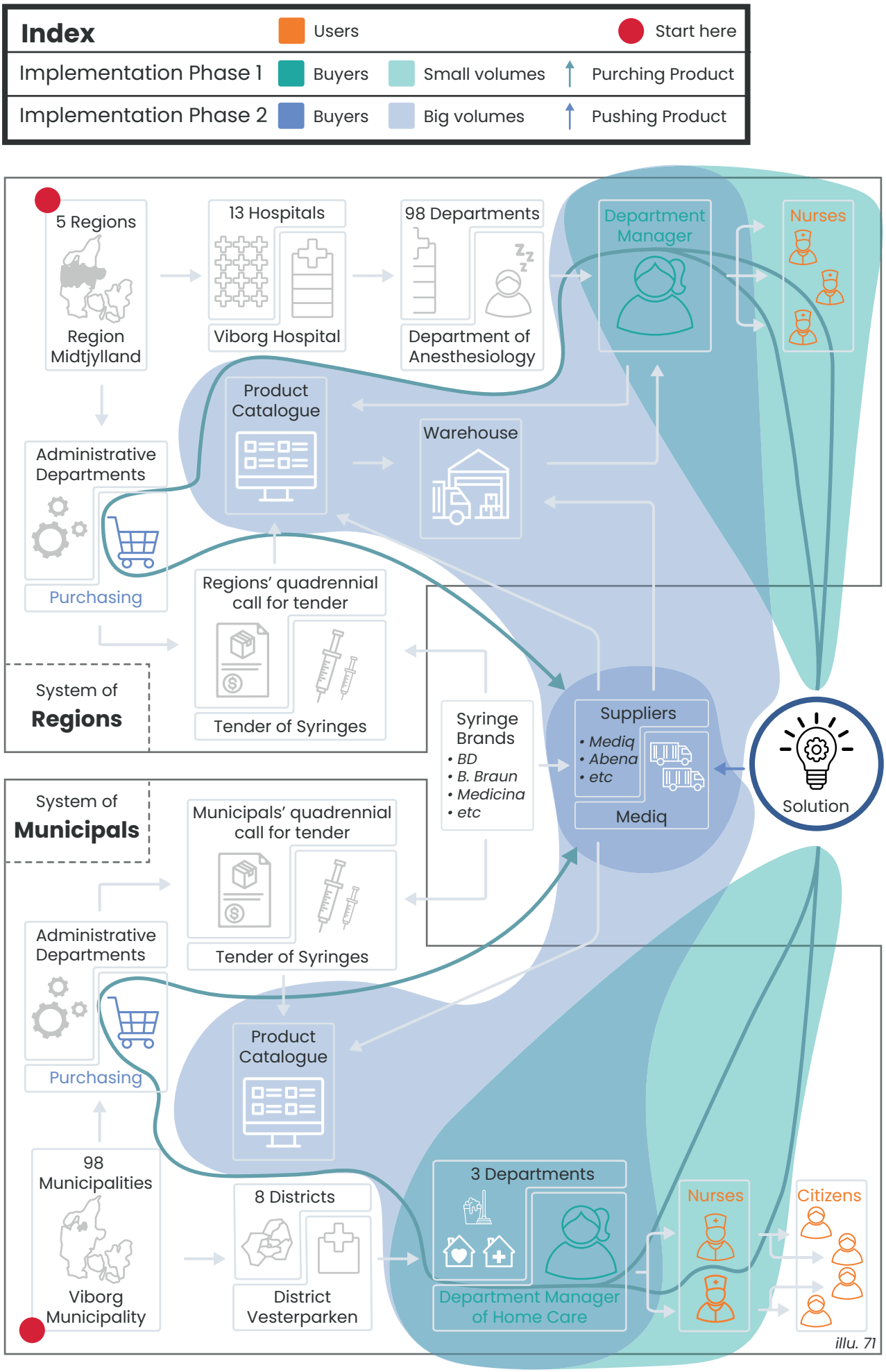
However, an injunction (DAN: Påbud) on addressing **this project's problem does not seem realistic according to earlier acquainted Dr. Tine Halsen Malling**. As elaborated on page 22-23, it cannot be definitively claimed that an injury is solely caused by performing this particular task, given that nurses utilise their hands for a wide range of activities. Nevertheless, she did acknowledge the potential significance of the issue on an individual basis:

> *kudos for taking care of the problem. Whether you get sick from it or not, it is a problem for some, and a solution would be great.*

Collectively, **societal tendencies across various professions indicate that the present moment marks a pivotal shift in the perception of nurses' health. This renders the issue of extracting and injecting syringes relevant to solve at present. But whether there is a market for such a solution remains to be determined.**

The Target Group

To determine **the potential size of the target group as well as the system in which the nurses operate in, a data-driven and visual breakdown was conducted**. The Danish health care system can be divided into two. Firstly, the smaller private sector, consisting of a myriad of home care companies in addition to 20 private hospitals. Secondly, the public sector consisting of a multitude of home care services divided between 98 Municipalities and 58 hospitals which are spread across five Regions. **Illustration 71 provides an example of the system of Municipalities using Viborg Municipality as well as the system of Regions using Region Midtjylland**. Both include how and how often the syringes arrive in the health care system as well as an entity representing whoever is pushing and selling the solution. (Appendix 22)


Index
Users
Start here
Implementation Phase 1
Buyers
Small volumes
Purching Product
Implementation Phase 2
Buyers
Big volumes
Pushing Product
5 Regions
Region Midtjylland
13 Hospitals
Viborg Hospital
98 Departments
Department of Anesthesiology
Department Manager
Nurses
Product Catalogue
Warehouse
Administrative Departments
Purchasing
Regions' quadrennial call for tender
Tender of Syringes
System of Regions
Syringe Brands
• BD
• B. Braun
• Medicina
• etc
Suppliers
• Mediq
• Abena
• etc
Mediq
Solution
System of Municipals
Municipals' quadrennial call for tender
Tender of Syringes
Administrative Departments
Purchasing
Product Catalogue
98 Municipalities
Viborg Municipality
8 Districts
District Vesterparken
3 Departments
Department Manager of Home Care
Nurses
Citizens
illu. 71

Despite **the systems on illustration 71 slightly differ, the main takeaways are the same**. A call for **tender every fourth year potentially changing the supplier of syringes**, and subsequently the syringes themselves, **the customers being departments leaders**, the **users being the nurses** and a bottom-up approach to infiltrate the system with a solution. A very conservative estimate on **numbers of 20 mL and 50 mL syringes in Denmark was calculated**. It was based on insight of purchases of Viborg Municipality and 'Hospitalsenhed Midt' as well as the Region's syringes call for tender for 2025. (Appendix 21)

The calculation is exclusive

Private Sector
Syringes in kits
2-component syringes
Eccentric syringes
Centric syringes
Municipally: ENfit syringes
Municipally: Luer syringes
Syringe pump non-compatible Luer Lock — Regionally

20 mL syringes = 2,600,555 per year
50 mL syringes = 6,502,707 per year

The international syringe market reached 124.6 billion DKK in 2024 and is expected to reach 195 billion DKK in 2029. (Appendix 21)

When you compare the number of syringes in Denmark with the regional public nurses, totalling 39,616 individuals, **they will on average use less than one 20 mL and 50 mL syringe per day**. Which through their career is equivalent to 1,575, 20 mL and 3,939, 50 mL syringes. This seems **relatively insignificant.** However, through various interviews (Appendix 4-12) it became evident **the exact number various a lot from department to department**. The **worst case**, based on personal account, was an anaesthesiologist extracting up towards 50, **50 mL syringes per day, which potentially means 438,000 times in her career** (Appendix 6). Based on purchases from Hospitalsenhed Midt the hospital departments which use larger syringes the most was identified. With the assumption that every 20th remaining regional nurse would use the solution and added to the home care nurses working in municipalities, doing tube food and catheter flushing, **the total number of potential nurses affected by a solution was found**. (Appendix 21)

Departments using the most 20 & 50 mL syringes

Regionally	Neurology	1,755
Regionally	Anaesthesiology	2,340
Regionally	Intensive Care	2,383
Regionally	Every 20th remaining regional nurse	1,657
Municipality	Home Care Nurses	2,219

In total there is 10,354 nurses, who are affected by 20 & 50mL syringes

The three main syringe-using hospital departments nicely aligned with those in which the interviews were conducted. The problem was verified at these encounters, supported by research indicating that nurses working in Intensive Care Units had the highest prevalence of musculoskeletal disorders. (Soylar, 2018). Additionally, **98% of nurses in the Intensive Care Units and the Anaesthesiology departments as well as 95% of home care nurses experience the necessity to work fast, highlighting the need to address the problem at hand** (Dansk Sygeplejeråd, 2021)

However, despite possibly **affecting 10,354 individual nurses**, it was still to be determined whether **they were receptive of solving the problem with a product, was tested by bringing three quick and dirty prototypes the initial interviews** (Appendix 4-6 & 8). It was done to spark a conversation on the solution space with the minimal effort and development time (Ries, 2011). The nurses were **exclusively positive towards the idea of a work environment tool** which could diminish or prevent attrition, when extracting or injecting syringes. They had additional comments on the direction of each prototype (Appendix 24).

The standing concept was swiftly discarded as it, even with severe changes, would have difficulty abiding several requirements such as free movement, rotation and size.

Furthermore, the **nurses and department managers** provided **estimates of the wholesale price for a solution**, which varied dependent on the number of units required per department (Appendix 4-6 & 8):

- The maximum wholesale price must be around **200-300 DKK if the solution is for all nurses.**
- The maximum wholesale price must be around **500-1,000 DKK if the solution is for around three nurses per department**, equivalent to one per patients room.
- The maximum wholesale price must be around **1,500-5,000 DKK if the solution is for an entire department**

However, throughout the various interviews, it was, independent of assignment, **evident that one solution was needed per patients room, operating room or home health care nurse**, making the targeted sales price 500-1,000 DKK (Appendix 4-6 & 8-11).

Must not exceed a wholesale price of 1,000 DKK

Economic Feasibility

A reasonable **estimate of potential solutions sold was calculated** based on the aforementioned target group.

	Expected amount of solusions	
Municipality	1 for Tube Food per district 1 for catheter flushing per district	2,219 units
Regionally	1 per medicine table within the Neurology, Anaesthesiology and Intensive Care 1 per every 20th remaining nurse	3,125 units

In total there could potentially be sold 5,344 units in the Danish health care sector.

Additionally, there is a **great potential scalability of a solution to particularly the Nordic countries but the rest of the world as well**, the **private sector** and even **other professions** and sectors such as dentist, chemist, laboratory workers and veterinarians. Furthermore, the solution would address a problem which presents **the Danish Health Care Sector with a yearly financial burden of 2.46 billion DKK** when looking at statistics on nurses changing jobs and absence from work due to musculoskeletal disorders alone. A guesstimate on the economic consequences of a solution, based on these two statistics alongside four others, did present **economic incentive to pursue a solution**. (Appendix 21).

0.5 million DKK / year
If nurses using 20 mL syringes with needle with a filter as a workaround, now does not

1.3 million DKK / year
If 1/250 nurse who goes on early retirement due to musculoskeletal disorders, now does not

0.5 million DKK / year
If 1/250 nurse have two less absence days due to musculoskeletal disorders.

Total potential savings:
32 million
DKK / year

2.4 million DKK / year
If 1/500 nurses who change job, now does not

1.3 million DKK / year
If the estimated 15 yearly operations on nurses due to syringe extraction and injection are made unnecessary

26 million DKK / year
If half of tube food receivers on PEG who gets visited by Home Health Care Nurses exclusively for tube feeding are made autonomous

Partial conclusion

The evolution of the project's potential made it apparent that it would be a strategic point in time to design a solution, as the Danish society is beginning to acknowledge and invest in solutions for issues similar to the project's problem. With the potential of affecting 10,354 individual nurses, who, based on interviews and quick and dirty prototypes are receptive to an aiding product and in addition a very conservative approximation of 5,433 units sold, the project was deemed economically feasible and worthwhile to pursue. Especially considering the guesstimated yearly savings of 32 million DKK, and the effect it could have on the wholesale price. However, to make sure the project reached its potential it was vital to establish a collaborative partnership in terms of implementation.

Collaboration with byLink

What is a realistic entry point?

One of the **project's goals was to surpass the common hypothetical-project-barrier** encountered by most university projects and realise the proposed solution as a market contender. Therefore, it was **strategically decided to partner with a company.** One team member completed an internship at, **byLink,** who seemed like the appropriate associates who **could offer relevant insights, due to the coherence between the projects' direction and their competencies developing work environment related tools for the health care sector**. Additionally, as mentioned earlier during the identification of a problem, page 9, byLink have had inquiries regarding the exact problem of extraction and injection of syringes. Meaning they would be the perfect acquirer for a developed solution to the problem, again enhancing the realisation of the product. A contract was written up, ensuring the project's integrity towards the most appropriate solution remained intact (Appendix 25), However, for the sake of realisation the most direct approach would be to make a strategic company fit with byLink which was considered whenever appropriate and applicable. In accordance with Haase & Laursen's (Haase, 2022) trifecta for **ensuring a strong company-fit;** 'Strengths', 'Credibility' as well as 'Values and Purpose', **byLink's design DNA and purpose was deciphered and boiled down to six core principles** with an accompanying board of their current portfolio.

Should fit into byLink's product portfolio

1 **Legitimate problems**

byLink addresses genuine issues with its products, always situated in inquiries from the users' themselves. They do not develop or push irrelevant consumer products.

2 **True to the user**

The Health Care Personnels' well-being is always the uncompromised top priority, materialised through innovation bettering their work environment and elevating their quality of life.

3 **User-driven Development**

byLinks' products are thought of, developed with and tested by Health Care Professionals resulting in an increased adoptability of and adaptability towards their products with a huge network at the ready for future creations.

4 **Environmental Considerations**

byLink exclusively develops reusable products in quality materials addressing and justifying the environmental impact through longevity, repairability, recyclability, and transport.

illu. 73

5 Competitive Pricing

Considering longevity, byLinks' products all share a focal point of competitive pricing as this is a keystone within the Health Care Sector.

6 Simplicity & Legibility

By making straightforward and comprehensible products which are not defined as medical equipment byLink ensures increased implementation with possibility of continuous refinement.

- Should be reuseable
- Should be ambidextrous
- Should not be certified as medical equipment

illu. 74

byLinks first major **advice was to avoid creating a solution which would be classified as medical equipment** and thus require a CE marking. This would complicate the project, make it more **time consuming, expensive, and difficult to implement**. It was deduced (see Appendix 23) that European law defines medical equipment based on three criteria, each of which must be answered with a resounding "No" (European Union, 2017):

1) Can the equipment cure the patient?
2) Is the equipment in direct contact with the patient?
3) Is the patient or health care professional dependent on the equipment?

To prevent the proposal from being classified as medical equipment, three criteria must be followed.

Partial conclusion

The established collaboration with byLink served as an entry point to the industry, increasing the likelihood of realising the project. As would the compliance with the seven traits of byLink thereby reaching a strategic company-fit by advantageously building on their strength, credibility and values. Keeping these considerations, along with the three criteria for non-medical equipment, in mind, the next step was to develop the actual product.

Design Brief 2

Problem Statement

How to create a solution which diminishes or prevents injuries while aiding the Danish health care sector in the extraction and injection of 20 mL and 50 mL syringes?

Target group

The Danish health care sector, including nurses and social and health case assistant, both regionally (hospitals) and municipally (home care).

Assignment

Medicine Mixing, tube food & catheter flush..

Mission

To develop a working environment related tool for the health care sector for byLink.

Vision

To aid in the paradigm shift of the health care sector's work environment shifting from unhealthy to healthy conditions by a movement of work-related assistive technologies.

Requirements & Wishes

No.	Core Requirements – Common Values	Source
1	Must be able to aid in extraction and injection	Personal Experiences
2	Must decrease fine motor skills usage	Problem's physiology
3	Must be resistant to alcohol as well as water and soap solution	Extend & Context
4	Must be operational whilst wearing plastic gloves	Extend & Context
5	Must be able to see mL scale during extraction and injection	Extend & Context
6	Must not exceed a wholesale price of 1,000 DKK	Potential

No.	Core Requirements - Varying Values	Source
1	Must fit all possible size variants of 20 mL and 50 mL syringes from different brands	Personal experience
2	Must be able to overcome forces of 17-73 N during extraction and injection.	Mechanical problem
3	Must allow various needles, mini-spikes, catheters and extenders to be attached to the tip.	Extend & Context
4	Must be able to let the syringe be extracted and injected within 360 degrees free movement.	Extend & Context
5	Must be moveable by hand, in pants, plastic bag, backpack and table.	Extend & Context

No.	Context-specific Requirements	Source
1	Must not exceed 5% of the available table area of 0.2 m2, equivalent to 100 cm2	Extend & Context
2	Must allow syringe to be rotated 180 degress during Luer Lock attachment and last medicine drop extraction with needle	Extend & Context
3	Must be fixated to syringe during rotation and air bubble-tapping	Extend & Context
4	Must accommodate current one-handed use ampoule scenarios	Extend & Context
5	Must be relatively silent	Extend & Context
6	Must be able to have a tactile feeling with resistance during injection	Extend & Context
7	Must have a usage which combined timespan of retrieving, attaching, injecting, extracting and replacing that is competitive with the current of extraction and injection	Extend & Context
9	Must have a usage which combined timespan of retrieving, attaching, extraction, and replacing that is competitive with the current of extraction while injection, 16 minuts, in isolation, must be slower than the current timespan	Extend & Contect
10	Must look harmless and non-institutional	Extend & Context

In Worksheet 35 it is possible to see where the specific context requirement originates from

No.	Context-specific Requirements	Source
1	Should allow only two-handed use	Problem's physiology
2	Should fit into byLink's product portfolio	Collab with byLink
3	Should be reuseable	Collab with byLink
4	Should be ambidextrous	Collab with byLink
5	Should not be certified as medical equipment	Collab with byLink

5 Concept Development

Supported by the problem's validity and insights from workflows, the conditions and boundaries were set, and the concept development began. Looking at a variety of solution spaces the working principles was explored and prototyped. Feedback was given throughout leading to further scoping of both system, assignment, problem and solution. Eventually, recapitulated in the third Design Brief.

Alternative Solution Space

Why not redesign the syringe?

Before delving into innovative concept development one conspicuous **solution space were investigated** to assess its potential in terms of meeting the learning objectives and realisation: a redesign of the syringe.

As elaborated in the Market Analysis, page 32-34, **an approach could be to redesign the syringe itself, and tackling the issue at its core.** However, this approach faces several challenges. A new syringe would be **defined as medical equipment class IIA** (Appendix 23). This **conflicts with byLink's strategy** of non-medical equipment and on-the-go refinement of early designs while imposing a significant **economic and time burdens on the project's realisation**. This would be **reflected in the price**, which is the **parameter where all current syringe redesign falls short** (see illu. 67), evidently never winning the call for tenders. Additionally, it is likely that a redesign would face resistance from the conservative target group, as confirmed by the Danish Key Account Manager at BD, Annette Mølby Nielsen:

> *It [reconfiguration of syringes] will be **difficult to change**. Because it is **common knowledge and agreed upon what a syringe looks like**.*

Changing the use of a syringe all together and how its substitute would **interact with other equipment**, the patient and the Health Care Professionals **would constitute system redesign rather than industrial design**. Thereby rendering the project unable to showcase the needed skills to fulfil the learning objectives. Also, this would **require for the hospital significant time and economic recourse** as changing just one minor detail on **already existing syringes results in incompatibility with existing equipment such as syringe pumps**. Even changing the supplier of a, supposed, identical material in manufacturing of syringes has shown to create critical patient-safety issues (Appendix 16).

illu. 75: Syringe pumps

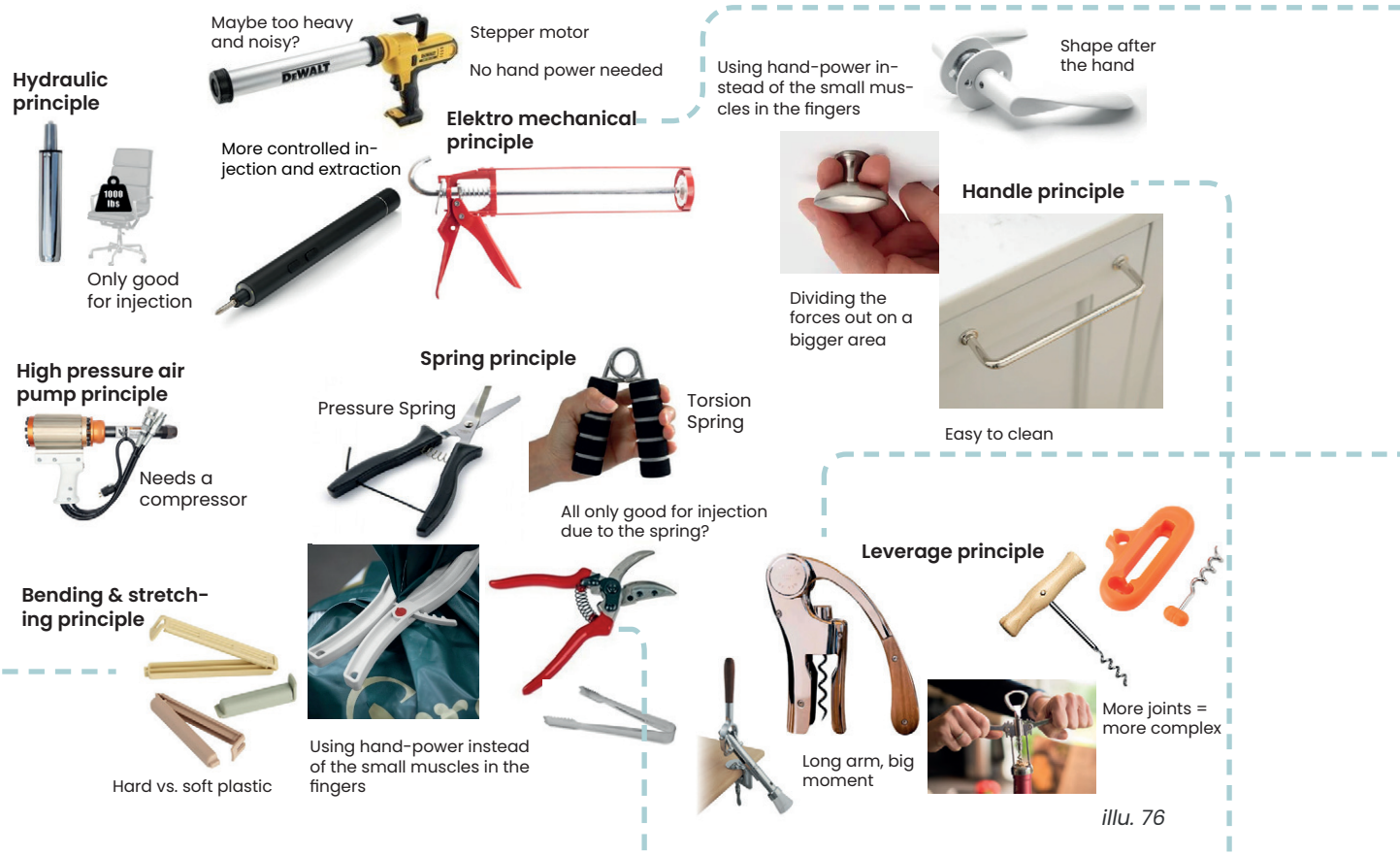
Partial conclusion

Neither redesigning the syringe nor rethinking its contextual place and use would be a strategic approach for solving the problem. Both in terms of adhering to the learning objectives as well as maintaining a realistic impact factor of the project, despite the initial appeal this apparent reframing approach would seem to offer.

Initiating Ideation

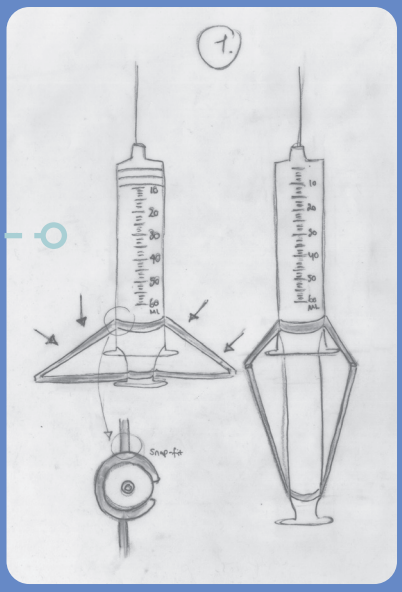
Which working principles can be applied?

To **diverge the solution space inspiration from different contexts was found** through desktop research and reviewed to identify appropriate existing working principles to ground the initial development process. These **principles were collected and clustered** in illustration 76 (Appendix 26). Based on this board, some basic ideas were sketched, to prompt a discussion on which working principles should be pursued.



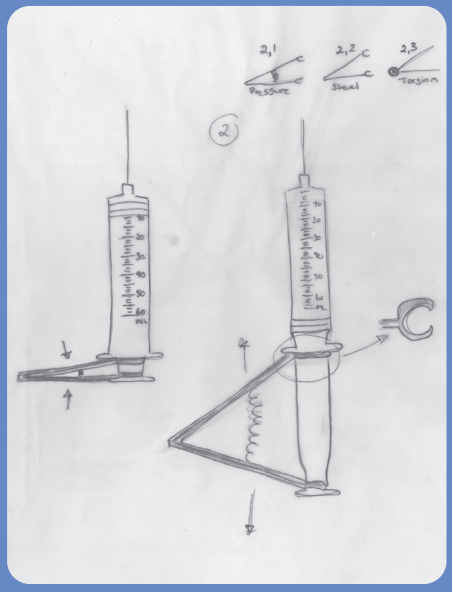
illu. 76

Bending & Stretching



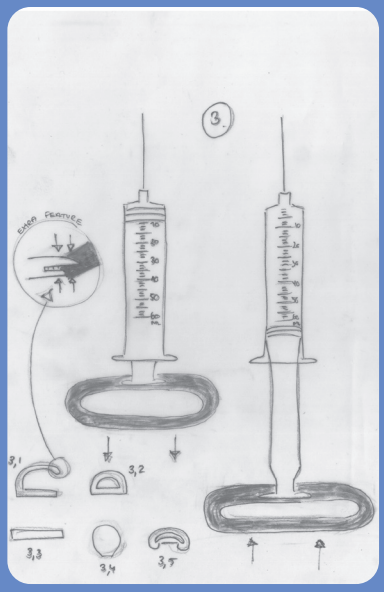
illu. 77

Spring



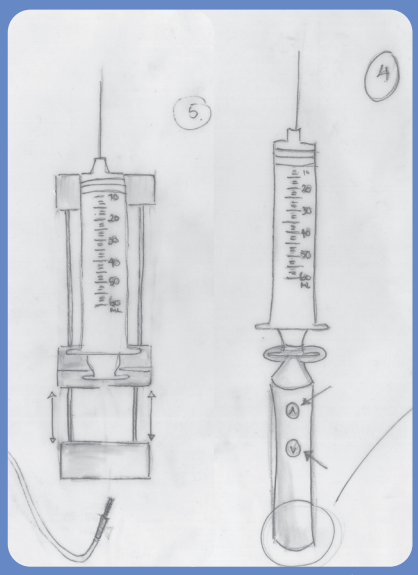
illu. 78

Handle



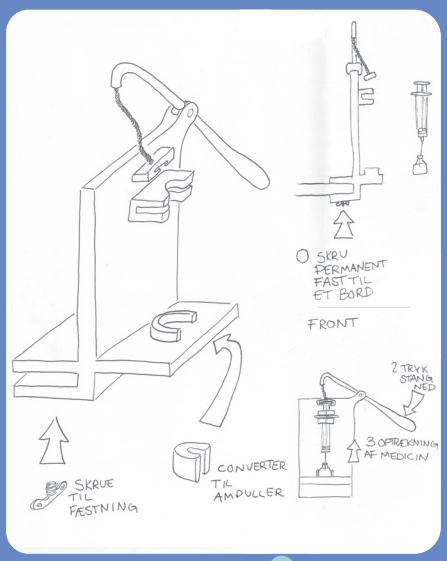
illu. 79

Electrical



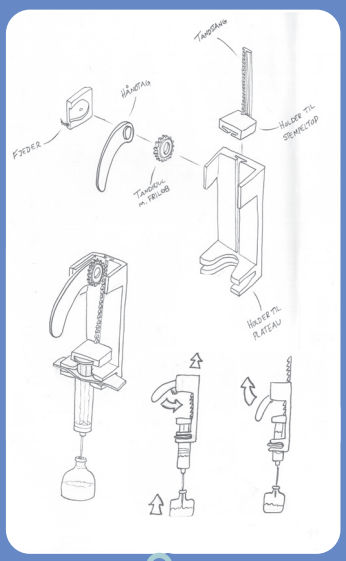
illu. 80

Leverage



illu. 81

Mechanical Locking



illu. 82

Evaluating the principles on illustration 77-82 against the second Design Brief on page 45-46, and glancing at the Market Analysis on page 32-34, the **'Bending & Stretching', 'Leverage' and 'Mechanical Locking' principles were terminated**. **The former due to serious doubt about overcoming forces of 73 N and decreasing usage of fine motor skills, the latter two due to seemingly unnecessary complexity, subsequent price point implications and hygiene**. All three were found to be concerning in relation to aiding in injection. The remaining three principles progressed with an overview of their initial benefits and concerns to be mindful of during further exploration.

	Spring	**Electrical**	**Handle**
Benefits	Extraction is semi-automatic	Full-automatic both in injection and extraction	Simplicity and legibility Cheap
Concerns	Hard to load as you work against the spring Spring size?	Price Point Weight Preventing free mobility?	Aiding enough Too simple for master thesis?

Partial conclusion

The working principles of 'Spring', 'Electrical' and 'Handle' were determined to have the most potential when cross-referencing with the requirements. The next step was to discover which of the three was the most feasible through research, prototyping and testing involving both users and various experts.

Three Concepts

What are some suitable solution directions?

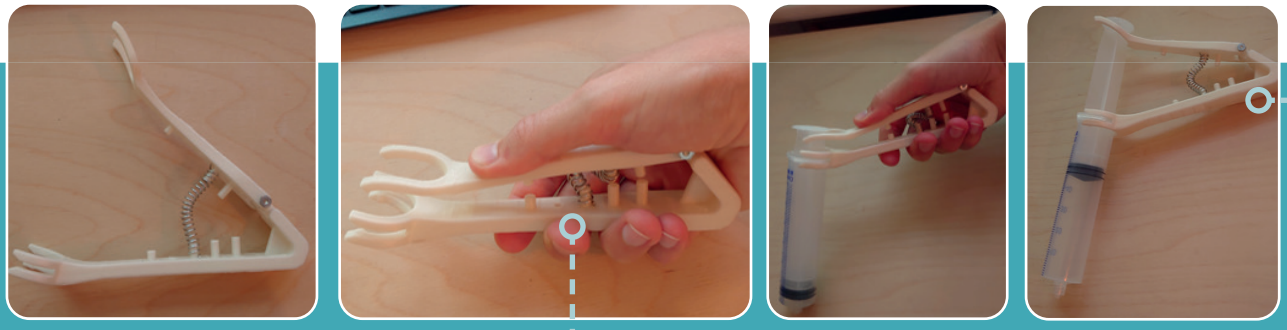
The **three working principles, all handheld, were explored** independently but in parallel as they were intended to be sequentially presented at **various user-visits** (Appendix 4, 8, 9 & 10). The following sections elaborate on their development, key features, challenges and user-feedback (Appendix 27).

Spring

The first concept **builds on the idea that a spring is loaded by squeezing a handle with hooks which is inserted between the plunger's thumb rest and the barrel's flange**. Releasing the grip causes the hooks to extract the syringe as they reform, rendering the solution semi-automatic. This energy storage mechanism is **comparable to the Spring Controlled Syringes**, on page 32, but **differ as it is an additive product** and more time efficient as sterilisation from extraction to extraction is unnecessary. **Three types of spring** were initially deemed suitable: compression and torsion springs alongside spring steel. However independent of type, there would be a trade-off between dimensions and ergonomics, offering two scenarios presented bellow.

illu. 83

A partly **functional prototype** (illu. 84) was devised to assess the feasibility of the spring direction. A compression spring were utilized as torsion springs are less available and spring steel too cumbersome to process. During **testing in context** (illu. 85-86) **three main concerns** arose:



illu. 84

1. **Buckling of the Spring**
   Could be fixed with a guiding rod, as seen in a stapler. Although, this rod would poke out through the handle.

2. **Force of spring**
   The small compression springs used in test were far from capable of extracting 73 N.

3 Inability to control the decelerating pace

> *I think it is **smart that it pushes itself up**. But I do **not like that I cannot control the pace. Especially with the medicine that foams** a lot, which must be pulled up slowly.*

Tracey, nurse at the Intensive Care at Viborg Regionshospital

illu. 85 *illu. 86*

To identify springs capable of exerting a force of 73 N, Technical Engineer Rene Hegelund from Hagens Fjedre A/S, a spring manufacturing company, was visited and consulted (illu. 87). A worst-case and typical scenario were discussed. In both cases he deemed spring steel inadequate, while the **compression spring were deemed too large** (Ø13-55 mm and length of 140-420 mm) and **torsion springs too difficult to compress** (170-200 N if they were to exert forces of minimum 80 N for the entirety of the springs' deflection) in the worst-case scenario. One promising compression spring for the typical scenario were found exerting forces of 40-80 N. However, when combining said spring with the initial prototype (illu. 88), **making the dimensions compatible seems extremely challenging**. Additionally, the spring expert noted:

> *It is going to be some fierce spring for your little handle. We can fine-tune a little, but it is trifles. Possibly 10% on dimensions.*

illu. 87

illu. 88

Hookes Law states a linear relationship between the forces required and the distance of compression or stretch of springs. Meaning the forces needed to compress the spring would surpass the current forces needed to extract a syringe

The Key Features and Challenges were compared to make a finite decision on whether the solution should use springs. Evidently, **this direction was dismissed**.

Benefits
- Decrease use of fine motor skills
- Semi-automatic, with resting time

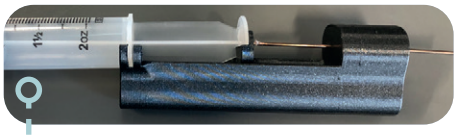
Too many concers

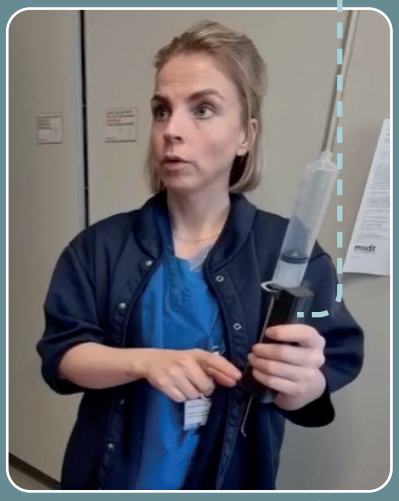
Concerns
- Dimensions, difficult to carry, hygiene, no injection due to the spring
- Difficult to control decelerating pace
- Need to exert more force than without a spring due to Hookes Law
- Multicomponent risking wear problems

Electrical

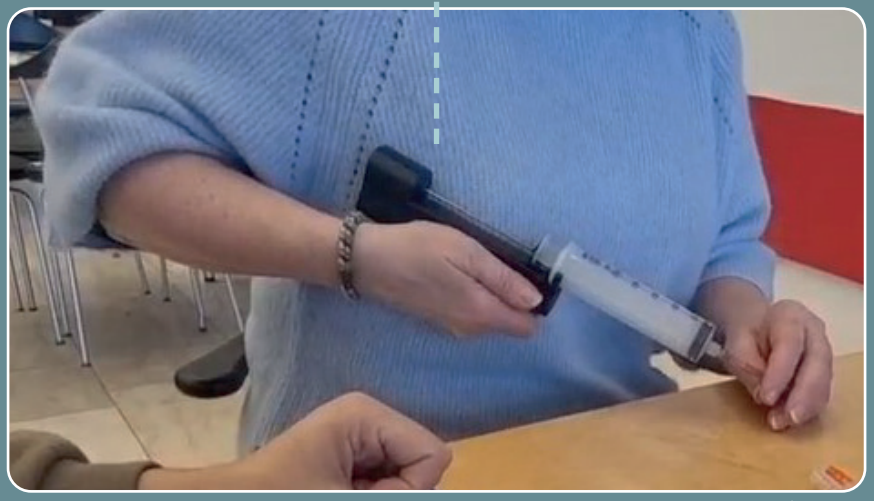
This concept is centred around the notion that **both extraction and injection can be achieved by fixating the barrel and enabling linear movement of the plunger's thumb rest, using an 'actuator' - a device the converts energy into motion or force**. This linear movement was presumed to be created by electricity making the concept **comparable to a syringe pump, but as a handy and mobile version.** However, by broadening the solution space additional principles of creating this linear movement were investigated: pneumatic, hydraulic and mechanical (Appendix 27). These were deemed either too unprecise, big, expensive or cumbersome in labour. This left the option of an **electrical actuator as it is moderate in size, fairly cheap, controlled and precise, making it the most suitable option for the project's objective.**

A **low-fidelity model** able to fixate the barrel and extract the plunger using a metal rod was fashioned, to **simulate the intendent purpose with an estimated correct volume** based on the size of supposed components. The nurses' feedback on this concept showed promise, yet also highlighted concerns.





illu. 89



illu. 90

> *You relieve your finger the most here. It **is not stupid** – **I do not have to do anything**. Only make sure that I hit the ampoule […] **I am unsure whether it will be too complicated**. It is probably because I **really want a small and handy tool like im use too**. […] But it is a bit like a syringe pump, which we are familiar with. […] Are we **able to afford such a solution**? We are very economically challenged.*
>
> Bente, nurse at the Intensive Care at Aalborg Universitetshospital

> *This solution will be **good for my colleagues who have arthritis in their finger**. […] There is always **a challenge with electric products as they rely on power**. Because you depend on someone to charge it and we know that **some people forget to do that.** […] I **need to try a working prototype** to know whether I like it.*
>
> Tracey, nurse at the Intensive Care at Viborg Regionshospital

Again, the Key Features and Challenged of this direction was put in comparison, to evaluate the potential. It was **decided to investigate an electrical design further**.

Benefits
- Almost remove use of fine motor skills
- Aids in both injection and extraction
- Making the elderly autonomous

Concerns
- Price Point
- Weight, Size and Control
- Adaptability in relation to complexity

Still have potential

Handle

The third working principle was revolved around the **simplicity of attaching the syringes' plunger to a handle via a slit to perform manual extraction and injection.** Various fixation methods (see Appendix 37) in combination with varying designs were CAD-modelled, 3D-printed (illu. 91-92) and tested by nurses (illu. 94-99). The Design they favoured the most included a possible fixation of 20 mL and 50 mL syringes in a singular line, one at a time, while keeping their fingers together on a thick and sturdy handle. The nurses primarily exhibited the **most excitement with the particular working principle but did also have adjacent worries.**

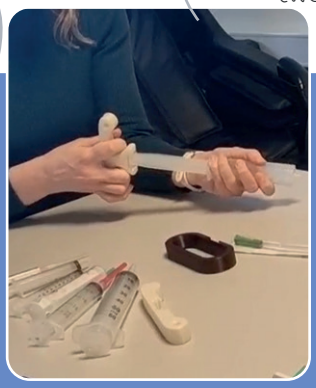
Everyone's favorite

Need to use two hands

Falls often off

illu. 91

illu. 92



illu. 93

illu. 94

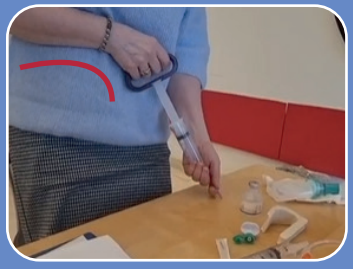
> *I think is **makes a big difference** – I am stealing it right this moment.*
>
> Merethe, Department Manager at District Vesterparken

> *It is **much easier to extract using this handle** […] It is a fairly **easy tool to use and comprehend**.*
>
> Vibeke, nurse at the Anaesthesiology Department at Viborg Regionshospital

> ***I can't use the solution with one hand**. […] It has to fit better in the hand. It **must be shaped according to the hand.**"*
>
> Bente, nurse at the Intensive Care Uni at Aalborg Universitetshospital

This is actually an improvement as you divide the strain

illu. 95: Normally Bente push the thumb against the barrel flange to extract with one hand

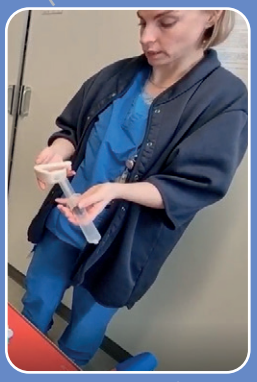


illu. 96: Needs to use two hands with the handle, but dont have a straight wrist

Super easy to take on and off the syringe

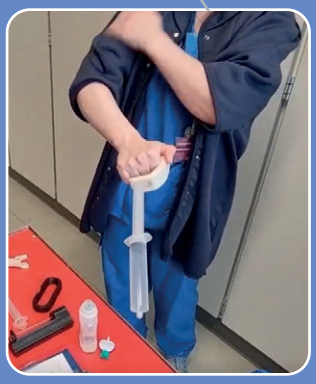
illu. 97

Really intuitive



illu. 98

Can feel it in the shoulder



illu. 99

> *This is **brilliant and very easy to use. It is fool proof.** […] I **can see myself using this solution because I can feel that I pull more with the big muscles**. However, **I can still feel the strain on my wrist** […] You must constantly think that you do not make the workflow additionally cumbersome , which is why, I like that the handle is **simple and not dependent on anything else** […] It would probably be easy to produce and **maybe cheap for us to buy** […] It is **important that I can let go of the solution without it falling off**.*
>
> Tracey, nurse at the Intensive Care Unit at Viborg Regionshospital

Key Features and challenges for the handle direction were identified. It was determined to explore and **further develop a manual handle solution.**

Benefits
- Decrease use of fine motor skills
- Simple and legible
- Hygiene and Universality
- Production and wholesale price

Concerns
- Awkward extension of syringe
- Not applicable for the elderly wanting autonomy

Partial conclusion

Feedback from the users and evaluation of Key Features and Challenges, led to the dismissal of the concept of using a spring as a working principle primarily due to form factor, inability to inject and requiring more exerted force than the existing syringe. However, an electric solution was to be explored through a high-fidelity working prototype in parallel with a further development of the manual handle. This approach aimed to address known issues while ensuring that existing Key Features were not compromised. But first, the average nurse needed to be deciphered and understood as it had become increasingly evident that an inclusion of the human perspective in the project was lacking. A comprehension made to ensure the most complex yet evidently essential part for realisation: adoption.

Comprehending the Nurse

What is required for product adoption?

The realisation of **the project depends on whether the users adopt the solution or no**t. Developing a product that resonates with the nurses and aligns with their habituation and world view is a conundrum and the most complex aspect of the project (Appendix 28). As emphasized by the Health & Safety Representative nurse at Esbjerg Hospital Maria, nurses tend to have **overambitious demands for new products**:

illu. 100

Maria

Health & Safety Representative nurse at Esbjerg Hospital

"It is about having this [the solution] ***available, right where and when you need it****, and being* ***able to get rid of it when you are done with it****. Then it should disappear and then magically reappear when you need it again. Because they [work tools]* ***get lost and occupies space****."*

To capture this human perspective and attain a deeper understanding of adoption and its necessities desktop research, interviews and shadowing were conducted (Sanders, 2006). The **end goal was converting new insights to operational parameters for adoption which would ensure a long-lasting strategic product-user-fit**. Meaning a solution which would be meaningful to the nurses and fulfil their explicit and latent needs (Haase, 2022).

Putting the patient first

The acceptance of extraction and injection procedures as-is stems partly from nurses' recurring prioritisation of patients' health over their own well-being. Approximately 90% of nurses cite meaningful work and interaction with people as crucial or significant factors in choosing their profession, illustrating their inherent dedication, consideration and **main focus on the patient and their relatives** (Danmarks Statistik, 2023).

> *Of course we need to follow the rules, but it also needs to* ***work in practice.*** *We cannot use 30 seconds to disinfect our hands, we need to do it on the go […]* ***Our time should be used on the patients*** *not on practical things.*
>
> Tracey, nurse at the Intensive Care Unit at Viborg Regionshospital

> *I* ***hate things that distract and take my time from the patient****. We have a machine inside the patient's room, where a light constantly flashes, and we are all going crazy. It is the only thing I can think about. We have been trying to put some tape on top of it, but it does not help.*
>
> Anne-Marie, nurse at the Intensive Care Unit at Viborg Regionshospital

The nurses want a simple solution which offers no distractions nor noticeable time-usage.

Recognition as professionals

A notable part of **patient care is that the patient feels safe**. This is partly achieved **by the nurses exhibiting complete calmness and control** throughout the patients' admission. These external signals are **dependent on the nurse looking proficient, effortless, and structured** when carrying out their assignments. As one nurse explained:

> *The **most important for me is that the patient knows and feels that I can take care of them** […] The patient must trust me and have faith in that I can help them in curing their disease.*
>
> Bente, nurse at the Intensive Care Unit at Aalborg Hospital

Must look professional and in control

Interaction Vision: To give hospital nurses a feeling of professionalism through power, control, and comfortability.

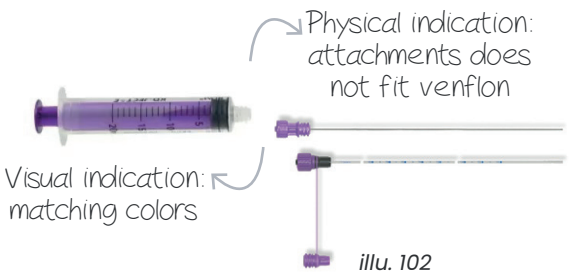
illu. 101

Justified conservatism

With the everyday reality of a misfortunate wrongdoing possibly resulting in an **untimely death of a patient**, highly contrasting their ideals, **the nurses' conservatism towards and sceptics of new and complicated products** is understandable. Multiple nurses highlight that the solution should **be fool proof**, not allowing wrong usage, thereby ensuring patient and user safety.

> ***We love colours**. For example, like here on the syringe pump. I do not need to think, **I just need to match the different colours with each other. No one can do it wrong** […] It is important not to accidentally use the equipment for anything other than what it is intended for. E.g. the syringes are in different colours. Thus, we know that the purple colour [ENFit syringe] must never be attached to venflon because it is a different colour. **We love equipment that is easy and intuitive to decode and, of course, to use**.4*
>
> Tracey, nurse at the Intensive Care Unit at Viborg Regionshospital

Must be easy to decode placement of hands and syringe as well as use of any other feature



illu. 102

illu. 103

illu. 104

Above all, equipment must be functional

The nurses have a clear hierarchy for prioritizing the various aspects of equipment. Tracey, a nurse at the Intensive Care Unit at Viborg Hospital, explains:

> *The most important thing for us when it comes to **equipment is that it is functional** and that it is intuitive and easy to use.*

Tracey further elaborates that the functionality is tied to the nurses **using their tactile, visual and possibly auditory senses** when handling preferable equipment:

illu. 105

illu. 106

illu. 107

> *All the time we are **using our ears at work**. We know exactly the different bip-sounds and what they mean. Besides that, we also **use our eyes**. We write things down on a paper, where we have **different colours which represent different things**. So, if I need to check something specific, I just need to look after a specific colour. **Super easy and fast**.*

> *We **love everything on wheels**, because then we can transport things wherever we want and it is **not physically hard to use**.*

> *We also **love everything with a clip system**. Like the one we have for our keys and our key card. It is so **fast to use, take on and off**.*

This means that equipment should be designed with careful considerations of nurses' workflow as it needs to be **well-fitted or directly increase the efficiency by reduction of either time or interactions.**

A glimpse of individuality

The nurses all **wear the same work clothes**, making their appearance uniform to the patient. However, **their individual personality comes to light in the details**. These can vary from hair accessories to pins on pockets, necklaces, or even their key cards portraying a nickname or showcasing a sticker. Bente, a nurse at the Intensive Care at Aalborg Universitetshospital explains:

> *"People usually wear accessories. Preferably in a **colour that stands out**. […] It is trendy to wear crocs with all kinds of pins on."*

This **tendency is transcending into work-related tools**, linking character to commercial success. Bente explains, which byLink confirms, that this happened with byLinks multi-tool OpenIt:

> *We got OpenIt in such a fancy pink colour. It definitely has an impact. Also, the fact that it **looks inviting,** because then it **becomes kind of smart and trendy**. […] If you can incorporate some fashion into it, that would be great.*

illu. 108

illu. 109

Shop our color

Operational Parameters for Adoption

Following the nurses and conversing with them painted a picture of a successful adoption being dependent on compliance with **three main operational parameters**.

Ensure safety

1. A clear feedforward offering unambiguous, automatic and safe interactions, for both patient and user.
2. Simple interactions, offering no inaccurate and misguided usage.
3. Allow only secure fixations and controllable interactions, highlighting professionalism aiding in the patient's peace of mind.
4. Accompanying visual quick guide to validate perceived use.

> *We would like to have a manual on how to use the tool. Ideally a **quick guide and preferably with pictures, so you are not in doubt about how to use it**. Because typically it is a 70-page manual, and no one reads it.*
>
> Tracey, nurse at the Intensive Care Unit at Viborg Regionshospital

Many departments have half an hour per nurse per week to learn the application of new technologies, following the current Danish Working Environment Act (DAN: Arbejdsmiljøloven) (Arbejdstilsynet, n.d.) (Appendix 12 & 29)

Preserve time-effciency

1. Eventual extra interactions and their time usage must be justified by an equal reduction of current interactions in both number and time.
2. Compliant with current individual workflows or streamline with an enhancing workflow.
3. Usability and legibility throughout workflow including placement, use and cleaning, offering no distractions and all within arm's reach.

> *It should almost **be as easy as not doing it.** It is centred around nudging.*
>
> Lisbet, department manager at Anaesthesiology at Esbjerg Hospital

Enhance comfort

1. Decrease strain and discomfort.
2. Maintain free mobility around the syringe.
3. Keep it lightweight.
4. Afford only appropriate ergonomic use.

> *The best way to make nurses adopt technologies is to make the technology inseparable from their workflow. It would need to somehow* ***make the nurses' workdays easier.***
>
> Tue Lodahl, nurse and health care sector implementation expert at Level Health

Feedback pointed to the fact that nurses above approximately 55 years of age, already injured nurses, as well as newly educated nurses would be prone to adopt a solution. The difficult part of the target group to persuade would be the confident, conform and not yet injured nurses. Meaning nurses of around 30-55 years of age, constituting the majority with around 60% in 2022 (Dansk Sygeplejeråd, 2022)

Partial conclusion

By designing strategically towards a good product-user-fit it was sought to enhance the most complex part of the project, yet most pivotal for success: adoption. To achieve this, it was established that the solution should be simple, offering no distractions. It should not increase, but possibly decrease, the time required or the number of interactions, allowing more time to be allocated to tending to the patient. Adding up to a fool proof and highly functional solution, which ensures patient safety while giving the nurse a professional appearance. Simply put, it should abide by a trifecta of adoption parameters: ensure safety, preserve time-efficiency and enhance comfort. Additionally, creating a characteristic and noticeable design would enhance commercial success.

With this in mind, attention returned to the design, focusing on both an electric solution and a manual handle, now incorporating the human perspective in their development. Furthermore, it became evident that a closer examination of both the product language and product identity of nurses' equipment was necessary to ensure appropriate aesthetics while enhancing the external signals of the user's professionalism.

Two Concepts & Scoping

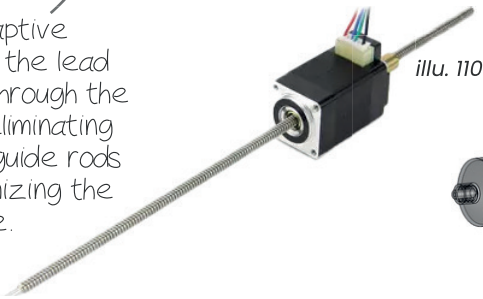
What is the most suitable solution direction?

The further development of both the electric solution and the manual handle was done in parallel. The **electrical solution applied the bird-in-hand principle of effectuation** by utilizing an acquaintance aiding in Arduino (Sarasvathy, 2005). Meanwhile, the **manual handle was problem-sliced into interface and ergonomics** (Dubberly, 2004). Working prototypes of both solutions underwent **user-testing** at Hospitals and a Municipal District, which, coupled with a **systematic evaluation against requirements**, informed the decision to **scope context, assignment, solution direction, assignment yet again as well as problem.**

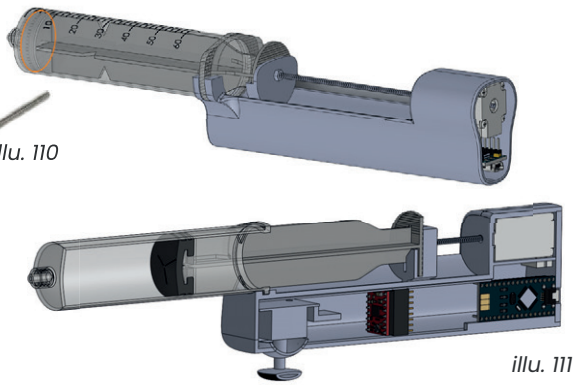
Electrical Solution

Nurses had a difficult time comprehending the **initial low-fidelity simulating prototype of the electrical solution and were in dire need a functioning one.** The first step in developing such was to find a feasible motor as this was the make-or-break component of this solution direction (Appendix 27 & 30). **A stepper motor** was appropriate as they can provide a more precise actuation than DC motors (Teknic, 2020). This stepper motor would be **paired with a lead screw,** with a preference for a non-captive version. **The Nanotec Nema 8 non-captive stepper motor emerged as the optimal choice for the projec**t. Its compact dimensions (20 x 33 mm), impressive power and speed capabilities (10 mm/s at 46 N), lightweight design (54 g), and affordability (max. 285 DKK) made it highly suitable. Moreover, its internal ball bearings eliminated the need for a complex swivel joint design (Nanotec, n.d.).

In a non-captive configuration, the lead screw passes through the motor itself, eliminating the need for guide rods and thus optimizing the volume.



illu. 110



illu. 111

A **working prototype was devised through 3D-printing** in partnership with outsourced acquisition, building, soldering and coding of an **Arduino-system to control the speed and direction** of the plunger through a joystick.

Not hard for the fingers but attention-demanding

illu. 112

Not hygienic with the screw

illu. 113

Too heavy and long

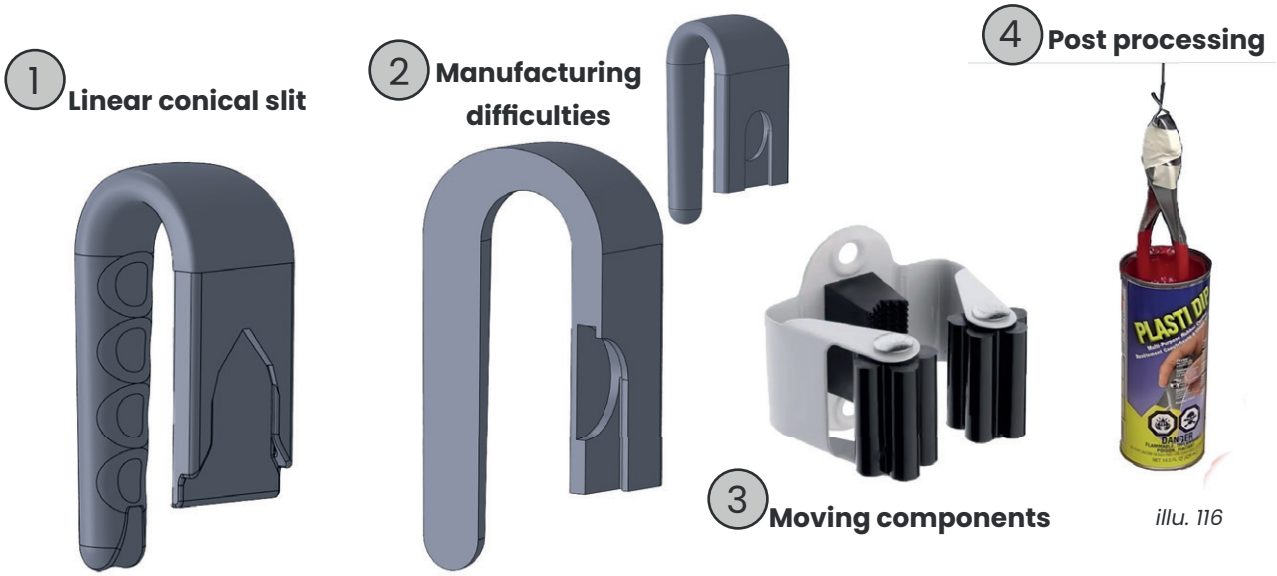
illu. 114

Weird hand position due to the moving screw

illu. 115

Manual Handle

To **ensure fixation of the handle** to the syringe during rotation and air bubble-tapping **the initial design was revisited**. However, this reaffirmed the principle of a **linear conical slit** capable of accommodating both 20 mL and 50 mL syringes, each at a time – given that it worked. **Alternative designs or principles introduced unnecessary complexity** through manufacturing difficulties, moving components or post-processing material application.

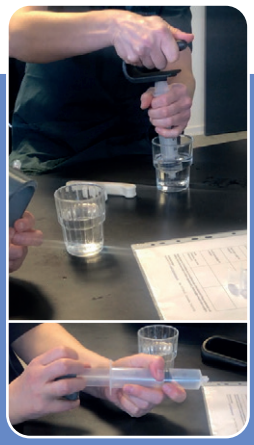


illu. 116

Using this principle of attachment the **ergonomics** and positioning of the handle relative to the syringe were explored **through sketches, low-fidelity mock-ups and two 3D-printed handles**. The latter was **tested** over a period of respectively **seven days at an anaesthesiology department and two days by a home care nurse** (Appendix 31). The weeklong test period was carried out to gain more in depth feedback on the design.

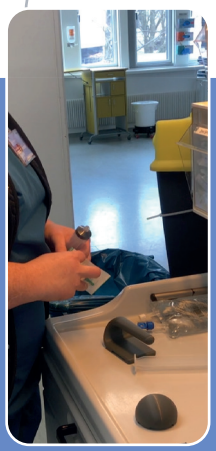
Simple, intuitive and foolproof

illu. 117: 'Ball' & 'Trowel'



illu. 118

Light & small in size, but what about cleaning?



illu. 119

Needs to be ergonomic to grip and close to the syringe

illu. 120

illu. 121

For both handles the **attachment was not secure enough, at times making the syringe slip out** accidentally, questioning the legitimacy of this principle. While previously mentioned **advantages such as size, weight, and simplicity were reaffirmed,** neither handle provided adequate relief from strain. Because at some point during their interactions if was **shifted to the wrist rather than the bigger muscle groups**. The handles had reverse attributes, with the **'ball shape' providing control, due to its proximity to the syringe,** whereas the **'trowel shape' offered greater strength and overall better ergonomics**. (Appendix 32).

Scoping of system and assignment

It had become **increasingly evident that despite effort to solve the problem of injecting and extracting syringes within the health care sector as a whole, there were too many contradictory micro-interactions,** such as an upright or seated work position. Each combination of tasks (tube feeding, catheter flushing as well as medicine mixing) and system (municipalities or regions) required a different design approach. Attempting to solve all of them simultaneously would **results in half-measures that addressed none of them effectively.** Thus, before deciding on a solution direction it was essential to **define which specific assignment and system a solution should address**. A rationale guided by impact factor, market competition and business case.

Impact fact

Assignments

	Force in Newton	Extract-inject motions per day per nurse	
Tube Feeding	19 N	27	21
Catheter Flushing	14 N	0.042	0.017
Medicine Mixing	**47-73 N**	Not applicable	**8-50 motions per day**
	Simulated, probably harder in real scenario	Municipalities	Regions

Market Competition

Assignments

	Competing Products		
Tube Feeding	 Tube Bottle		 Syringe pump, Fill reservoir
	illu. 122	illu. 123	illu. 124
Catheter Flushing	Not applicable	 Accordion Syringe	
		illu. 125	
Medicine Mixing	**Not applicable**	**Not available**	
	Municipalities	Regions	

Business Case

	Estimated available Market in Units
Municipalities	2,219
Regions	**3,125**

Evidently, **the greatest potential lies within the regional system and the assignment of Medicine Mixing which the project was scoped towards** (Appendix 33). Expectantly, with a return to see if a more or less finalized design could be slightly tweaked to accommodate the deselected assignments and system. This convergence also **aligned with user-feedback as the Anaesthesiology departments and Intensive Care Units** within the regional system exhibited **the most excitement amongst all participants.**

The new project scope would not impact the 2,219 home care nurses potentially using it, reducing the total number of possibly affected regional nurses to 8,135.

Must be able to overcome forces of up till 73 N during extraction and injection

Scoping of solution direction

With this scoping of assignment and system the electrical solution and the manual handle were subsequently **evaluated in a revised version of Ulrich and Eppinger**'s (2012) approach to product specifications using the established requirements (Appendix 33). Here the manual handle outscored the electrical solution with a ratio of 1.4. **They scores approximately equal when looking at functional requirment alltogehter, but the electrical solution did not perform on the more 'human' requirements.** Combined with the feedback from nurses on both directions and bearing in mind that they **requested a foolproof and simple solution it was decided to continue with the manual handle** rather than the electrical solution (Appendix 11 & 32-33). A concise overview of the decisive parameters guiding this decision can be found below.

This assertion needed verification from experts

Parameters approximated	Electrical Solution	Manual Handle
Weight	320 g	72-127 g
Wholesale Price	2.332 DKK	450 DKK
Medical Equipment	Yes	No
Implementation Timeframe	4 years	1 year
Economic Risks	High	Low
Complexity	High	Modest/Low
Adoptability	Uncertain	Verified

With the scoping to only aid in Medicine Mixing the found Nema 8 motor were not strong enough. As a result, a more powerful, and subsequently heavier, motor needed to be sourced, making the actual weight exceed the approximated 320 g.

Scoping of problem

Following the stepwise scoping just presented it became **relevant to understand their internal coherence in relation to the current workflow of nurses.** To do so, the assignment of medicine mixing was revisited, measuring the potential consequences of a solutions implementation against the **three Operational Parameters for Adoption,** presented on page 59-60. In other words, to assure that the design is context-fitted in 4D. This means an incorporation of the before, during and after use enhancing adoption and nurses' eventual adaptability towards slight workflow alterations.

The referred assignment exists in a multitude of slightly differing configurations with the one on page 25-27 depicting an archetypical workflow. **Overall taking 4 minutes and 20 seconds to complete, split between 80 seconds of preparation time and 180 seconds of carrying out the medicine mixing** (Appendix 34).

The illustrated workflow **includes the interactions of balancing the 50 mL syringe atop another object to avoid contaminating the tip**, which takes 10 seconds, as well as the **workaround of transferring medicine to the 50 mL syringe via a 20 mL syringe due to strain**, which takes 35 seconds. These interactions will be made **redundant with the implementation of a solution**, if done right. These are possible benefits amongst others which makes coherence between the scoped assignment scoped solution direction and Operational Parameters for Adoption evident, as highlighted below. The manual handle could potentially...

Ensure Safety by making it unnecessary to touch the plunger while encouraging to a sensical and proper use of needles with filter.

Enhance comfort by moving strain from the fingers to larger muscle groups.

Preserve time-efficiency by decreasing total interactions by five as well as time by 17%.

Must encourage to appropriate ergonomic use

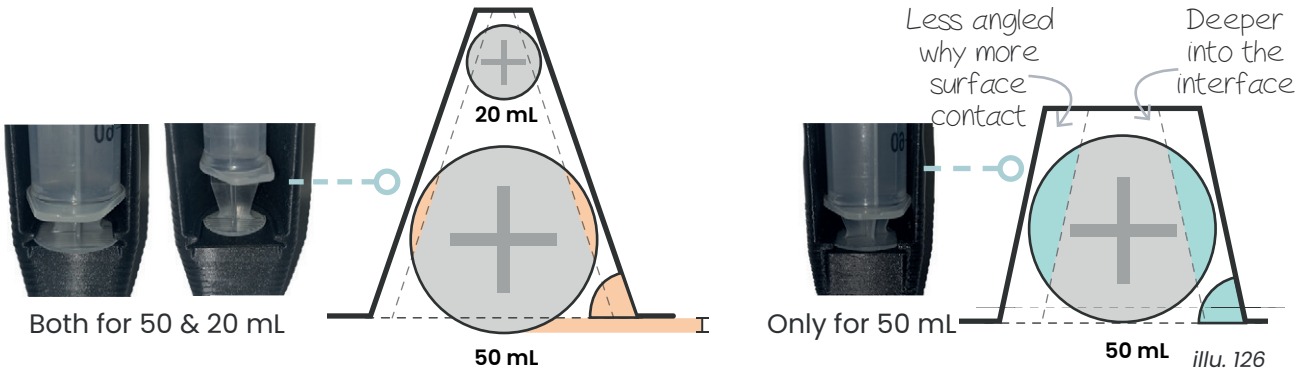
Must be mobile with a weight of maximum 100 g

Must not have a usage which surpass the current accumulated interactions

Making the 20 mL syringe workaround redundant also has potential financial (see page 93) and environmental (see page 94) benefits.

The removal of the workaround involving 20 mL syringes, will also result in the elimination of 20 mL syringes altogether in current typical workflows of medicine mixing. This presented an opportunity for further **scoping by dismissing compatibility with 20 mL.** A sensible trade-off as the 20 mL syringe is rarely used, while the **interface** of the manual handles to the 50 mL syringe could be **designed with much greater precision**, ensuring a more secure and comfortable fit, as seen on illustration 126. These positive consequences which would enhance a fulfilment of the Operational Parameters for Adoption. Thus, this scoping was agreed upon.

Must fit all possible size variants of 50 mL syringes from different brands



illu. 126

The solution, as requested by the occupational therapist (page 22), **facilitates only two-handed use to distribute the strain further**. This will require some nurses to make **slight alterations in their workflow during the extraction of medicine from ampoules.** Some nurses prefer to keep their ring and little finger wrapped around on the syringe's barrel while others hold the ampoule in one hand and the syringe in the other. The former method remains applicable when using the manual handle whereas the latter is not. To accommodate this, it was though that some sort of **ampoule holder would be appropriate**. However, for realistic adoption, the ampoule holder would need additional benefits, which it potentially could offer. For instance, the manual handle would have a **designated station, reducing the risk of it being lost**. The **ampoules would have a specific and stable spot, minimising the risk of spilling** expensive medicine or getting it on the nurses' fingers, which can cause tingling. Also, nurses who use the grip in step 13 illu. 54 could utilize the ampoule holder to divide the strain on three additional fingers by adapting this alternative workflow as well.

Must accommodate current one-handed use ampoule scenarios

Partial conclusion

Based on working prototypes, user-feedback and a systematic requirement-grounded evaluation the project was scoped in terms of system, assignment, solution direction and problem. Regions, medicine mixing, the manual handle and exclusively 50 mL syringes were chosen as the focal points, respectively. This scoping was executed to ensure that the problem was effectively resolved in a single context rather than it being addressed with less appropriateness across multiple contexts. Furthermore, the scoping ensured the greatest impact factor, market positioning and business case given its necessity. Moving forward the primary objective was to develop a reliable interface between syringe and manual handle while combining the control from the 'ball shape' with the strength and ergonomics from the 'trowel shape'. Secondary, to design an ampoule holder to accommodate the current hand positions of some nurses. But first it was necessary to determine the exact dimensions of a market majority of 50 mL syringes.

Design Brief 3

Problem Statement

How to create a professional and adoptable hand tool which diminishes or prevents injuries while aiding the hospital nurses in the extraction and injection of 50 mL syringes during medicine mixing?

Target group

Nurses from the Region. Especially Anaesthesia, Intensive Care & Neurology nurses.

Assignment

Medicine Mixing.

Mission

To develop a working environment related tool for the health care sector for byLink.

Vision

To aid in the paradigm shift of the health care sector's work environment shifting from unhealthy to healthy conditions by a movement of work-related assistive technologies.

Interaction vision

To give hospital nurses a feeling of professionalism through power, control, and comfortability.

Requirements & Wishes

The requirements are categorized into aesthetic, function and construction requirements. Some requirements intersect the categories.

No.	Aesthetic requirements	Source
1	Must look professional and in control	Comprehending the Nurse
2	Must be easy to decode placement of hands and syringe as well as use of any other feature	Comprehending the Nurse

No.	Functional requirements	Source
1	Must be able to aid in extraction and injection	Personal Experiences
2	Must decrease fine motor skills usage	Problem's physiology
3	Must be operational whilst wearing plastic gloves	Extend & Context
4	Must allow a visible mL scale during extraction and injection	Extend & Context
5	Must allow various needles, mini-spikes and venflon to be attached to the tip	Extend & Context
6	Must allow syringe to be rotated 180 degress during Luer Lock attachment and last medicine drop extraction with needle	Extend & Context

7	Must be able to let the syringe be extracted and injected within 360 degrees free movement	Extend & Context
8	Must be fixated to syringe during rotation and air bubble-tapping	Extend & Context
9	Must have a usage which combined timespan of retrieving, attaching, injecting, extracting and replacing that is competitive with the current of extraction and injection	Extend & Context
10	Must encourage to appropriate ergonomic use	Two concepts
11	Must not have a usage which surpass the current accumulated interactions	Two concepts
12	Must be resistant to alcohol as well as water and soap	Extend & Context
13	Must fit all possible size variants of 50 mL syringes from different brands	Two concepts

Both a functional & construction requirement

No.	Construction requirements	Source
1	Must be mobile with a weight of maximum 100 g	Two concepts
2	Must not exceed 5% of the available table area of 0.2 m2, equivalent to 100 cm2	Extend & Context
3	Must be able to overcome forces of up till 73 N during extraction and injection	Two concepts
4	Must not exceed a wholesale price of 1,000 DKK	Potential

No.	Wishes	Source
1	Should allow only two-handed use	Problem's physiology
2	Should fit into byLink's product portfolio.	Collab with byLink
3	Should be reuseable	Collab with byLink
4	Must be ambidextrous	Collab with byLink
5	Should not be certified as medical equipment	Collab with byLink
6	Should include an accompanying ampoule holder for one-handed scenarios	Two concepts

Updated requirements are marked with green

6 Detailing

Through a multitude of iterations, the design is updated and refined simultaneously on functional, problem sliced into ergonomics and interface, as well as constructional parameters in alignment with syringes' sizes and nurses' workflow. The design was subsequently refined aesthetically to fit the visual environment of the context and product identity. All revisions of the design work in consensus towards enhancing adoptability and feasibility. The final proposed design is verified on relevant technical parameters and matured for production. The fourth and final Design Brief concludes the requirements and wishes with an accompanying recapitulation of the solution proposals' specifications.

Dimensions of Syringes

How to ensure the majority of syringes on the market fit?

In addition to scoping the system, assignment, solution direction and syringe size compatibility, a final convergence was in place: **compatibility with syringe brands**. It was confirmed by previously acquainted nurse and Key Account Manager at BD, a mastodont amongst syringe manufacturers, Annette Mølby Nielsen, that there are **no brand-transcending standard dimensions for a 50 mL syringe**. However, the dimensions of existing syringes are entrenched as the slightest alteration would render great financial consequences as **each individual syringe model complies with 16 different EN ISO standards and is compatible with numerous syringe pumps,** which would all need revisions or reprogramming.

Furthermore, it was confirmed that nurses when doing medicine mixing exclusively use 50 mL syringes with Luer Lock, as these are the ones compatible with syringe pumps required for administering the medicine. The compatibility between syringes and syringe pumps is where manufacturers primarily differentiate themselves, with **BD and B. Braun being the leading brands**. They are currently each holding approximately **50% of the Danish, Norwegian, Swedish and Finnish market of 50 mL Luer Lock syringes at Hospitals, while both being major contenders in the remaining Europe**. A tendency which is almost rooted in the Danish quadrennial call for tenders. (Appendix 16)

> *I have been working at BD for 20 years and we have always had syringes in all the regions.*

At first sight all syringes look alike

illu. 127

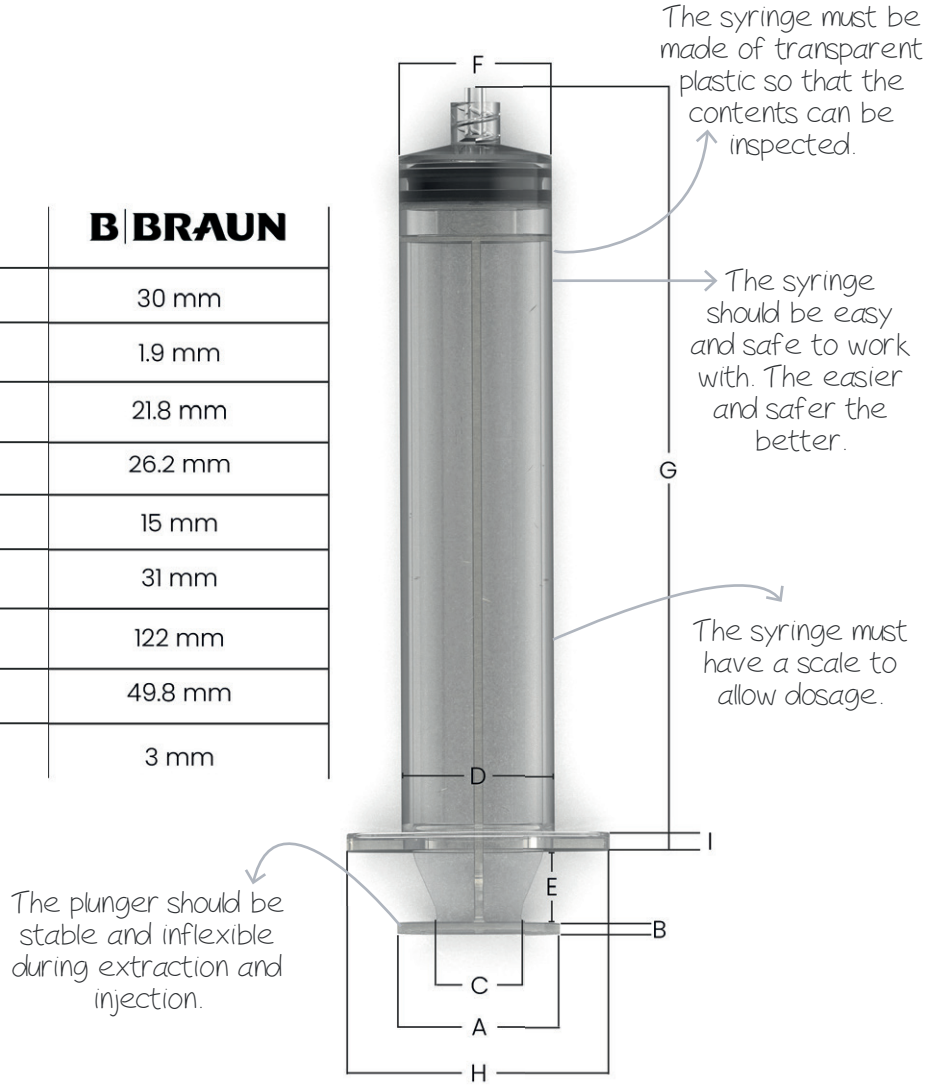
illu. 128

Dimensions and required characteristics

It became apparent that **the solution should be compatibility with BD and B. Brauns' 50 mL Luer Lock syringes to ensure a majority fit within the assignment**. These were meticulously measured and noted as intervals on illustration 129, which has additional relevant required characteristics for 50 mL Luer Lock syringes, originating in the Danish Regions' joint call for tender for 2025 (Appendix 16).

Must fit all possible size variants of 50 mL Luer Lock syringes from BD and B. Braun

	BD	B|BRAUN
A	31.1 mm	30 mm
B	1.9 mm	1.9 mm
C	16 mm	21.8 mm
D	25 mm	26.2 mm
E	12.1 mm	15 mm
F	29.8 mm	31 mm
G	134.3 mm	122 mm
H	50.2 mm	49.8 mm
I	2.6 mm	3 mm



illu. 129 The syringes characteristics

Partial conclusion

The Key Account Manager at BD, a major syringe manufacturer, suggests that the most effective approach to solving the problem is by designing a tool that is specifically tailored to fit syringes, rather than attempting to modify syringes themselves. This should be done through a smaller company rather than big syringe manufacturers as she has seen several concepts perish this way due to their focus being on the patients rather than the health care professionals. The 50 mL Luer Lock syringes made by B. Braun and BD that are compatible with current syringe pumps, currently occupy 100% of the Nordic market and will most likely continue to do so in the future. Hence, these were measured to ensure the interface of the solution being compatible with the majority of the 50 mL syringes in the health care system. Not to say that additional brands does not fit, as the dimensions, after all, are relatively similar. From here the focus returned to the development of the manual handle.

Shape & Ergonomics

How to ensure a comfortable fit?

To ensure a well-designed product, this part of the problem slice focused on detailing the handle's shape and ergonomics through a multitude of iterations. It is detailed parallel to the development of the interface. **To develop an ergonomic shape, which divides the strain from the fingers to the entire hand and encourages a straight pull from the hand to the shoulder, the Build-Measure-Learn Loop, PDCA Quality Cycle and reflection-in action was utilised**. These approaches made the development tangible due to rapid prototyping by 3D-printing handles and evaluating them through self-testing. (Ries, 2022; Dubberly, 2004; Malinin, 2018). To **ensure a good product-user fit the most promising iterations were also tested in the context by the user, who both gave constructive feedback in the moment and after one weeks' use** (Haase, 2022). Lastly **byLink, a hygiene nurse, and a physiotherapist** (DAN: Fysioterapeut) **were also involved to ensure a good product-company fit** (Haase, 2022) (Appendix 12, 29, 36 & 37). The collected considerations of pros and cons of each iteration can be found in Appendix 36.

The wrap shape

After receiving feedback on the 'ball shape', which ensures control of the syringe, and the 'trowel shape' which offers good strength and ergonomics, the **two concepts was merged and the 'parallel wrap shape' arose**.(Appendix 31). The parallel shape to the syringe ensures a straight pull with the entire arm, thus activating the bigger muscles in the upper arm (biceps, triceps and deltoids), which is the recommended working position by the occupational therapist. The 'trowel shape', needing **a grip perpendicular to the axis of extraction and injection, did offer a bit more strength**. However, **studies suggest it is mere 10%** (Seo, 2010). But this extra strength would be at the expense of wrist strain, making the trade-off to better ergonomics straight forward. Whether the syringe barrel's flanges were parallel or perpendicular to the axis of attachment did also have consequences. Being **perpendicular did result in a wide handle**, due to the fixed dimensions of the syringe, as **seen with iteration 3 and 16, which did not fit the average female hand**. Trade-off like these were the returning theme of the development process.

Iterations

illu. 130

The main feedback from byLink:

> *I like this prototype. It really **looks professional** compared to the earlier one ['trowel shape'].*

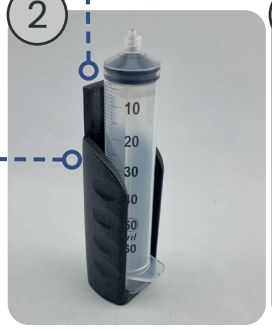
The main feedback from a user:

> *It gives **good control** due to being closer to the syringe and being in the same axis as the syringe. But it is **hard to see the mL scale** and there is **not so much room for the other hand to grab the syringe**.*
>
> Anna-Marie, nurse at Intensive Care at Regionshopitalet Viborg

2

A protruding guide aids the flange

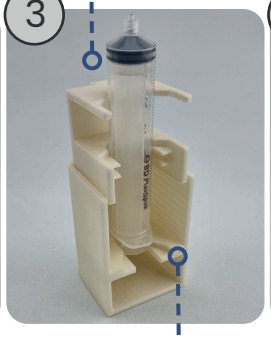
Not comfortable to grab



3

A large linear moving slider, there is attached to the flanges

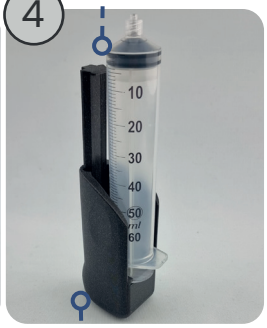
Too big to grab



4

Back to the handy solution with a protruding round bottom

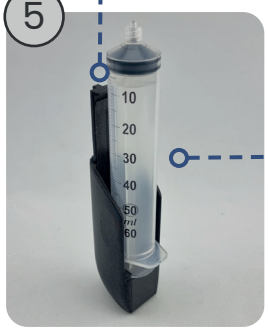
Too big for the palm



5

A linear moving slider, which is attached to the barrel's flange

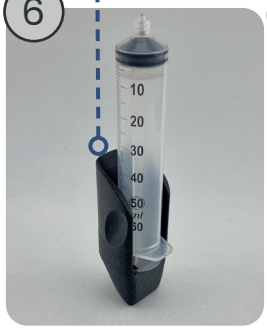
"The slider is not hygienic and will get lost immediately"



6

Making the top curved edge funnel-shaped

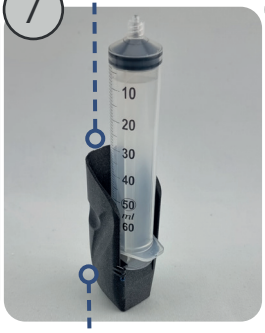
"I cannot use your solution. It is too strenuous on my thumb."



7

Guides the barrel's flange down into the handle

Not the best grip due to friction



8

An imprint shape of the hand for better grip

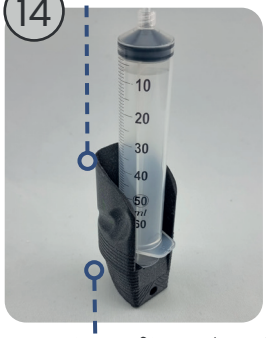
Way too big and unhandy

10

13

"Hmm im missing the upright function! The more I try it [Iteration 7], the more appreciate the feature of it being upright

14



15

Varrios designs which relieve thumb pressure

16

17

"The best one is the beer glass. But it does not fit my hand, and it locks my hand in one position

18

It is often the thumb, the nurses have problems with, why they need to be able to use the handle without the thumb.

"The small wings help a bit, but it is not enough. I can still feel it in my thumb and little finger

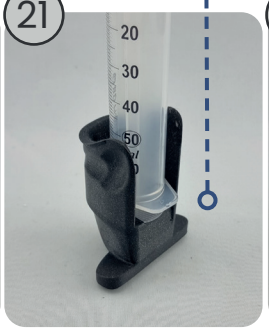
Adding wings, which are formed after the hands' curvature

20

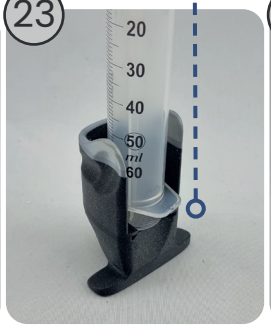
The wings remove the strain from the thumb.

21

Reducing dimensions of the wings



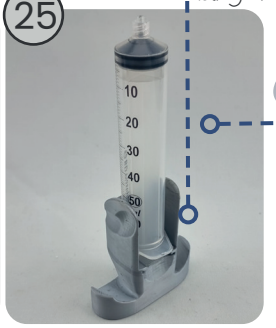
23



25

Return of the larger wings

"It is amazing how big of a different a wing has.



One wing provides the best ergonomics due to more space for the root of the thumb, but two wings fit both left-handed and right-handed. Large wings can inhibit the free mobility of the syringe.

illu. 131

Throughout various interviews it become apparent, that it was relevant to consult with at hygiene nurse as they often are looked upon as the most critical of all nurses. With the development of this concrete solution, its design was reviewed with a hygiene nurse. It should be noted that they are a guiding entity and not a regulatory one.

The main feedback from a **hygiene nurse**:

> *Since the handle is not in contact with the patient's skin, it is **'non-critical equipment'**. That means the nurses **can just clean the handle with a cloth of soap water** after use most of the time. Like they do it now with the syringe pump. [...] But look wise it **needs to have a smooth surface and consistent colour, so it is easy to clean and visually inspect**.*
>
> Irdi A. Dalsgaard, Hygiene nurse in Region Midt

Since the handle is defined as non-critical equipment, it needs to be able to handle a disinfection, as a consequence of being transported into a patient room, why it must withstand heat disinfection in an instrument washer: 80 °C and chemical disinfection with alcohol (70-85%) and chlorine (1000 parts per million).

- Must be able to withstand heat disinfection in an instrument washer at 80 °C
- Must be resistant to alcohol as well as water and soap as well as chlorine

Partial conclusion

Developing an ergonomic shape is a trade-off through and through. But by a multitude of iterations the 'parallel wrap shaped' handle was designed and validated by eight nurses, one physiotherapist, one hygiene nurse and byLink to ensure a good product-user fit and product-company fit. The 'parallel wrap shape' ensures good control due to closer vicinity to the syringe while following the axis of extraction and injection. Furthermore, the shape ensures a straight line between hand and elbow and activate the bigger muscle groups, which is the recommended working position of the occupational therapist and the physiotherapist. The wings help to remove the workload from the thumb, which is the most critical finger, and ensure a solution that both helps the injured and prevents injuries in the fingers. The funnel-shaped top guides the barrel's flange into the handle's centroided void during injection while the rounded bottom creates good surface contact between the palm of the hand and the handle. The flat bottom makes it possible for nurses to place the syringe upright which ensures the needle will not touch the table and get contaminated. Lastly, the recesses for the fingers and the curvature of the shape offer a good feedforward aiding the nurses in decoding the placement of their hand. The only aspect of the workflow the handle does not address is the one-hand-ampoule-scenario during extraction, why an ampoule holder was developed later.

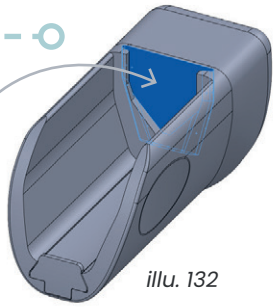
Interface

How to ensure proper syringe fit?

To ensure a well-designed product, this part of the problem slice focused on **detailing the handle's syringe-interface marked with a blue color**.

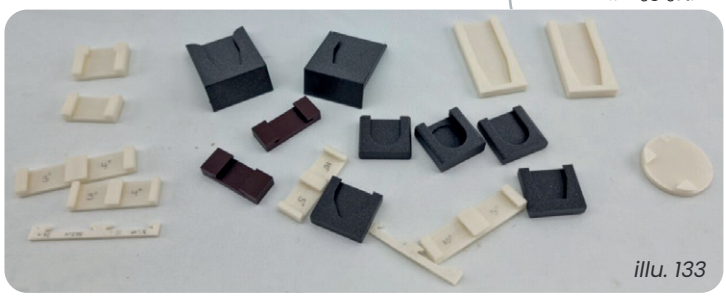
Following the **syringe dimensions defined earlier** for the different 50 mL syringe brands, the interface design could be detailed to **fit the majority of syringes on the market**. Through multiple scoping's it became clear that the handle should **only accommodate 50 mL syringes** as decided on page 65. This made it possible for the interface to be **designed simpler and more optimized for the specific dimensions** of 50 mL syringes, as seen on illustration 126, instead of being a jack of all trades, but master of non.

The interface is comparable to that of syringe pumps



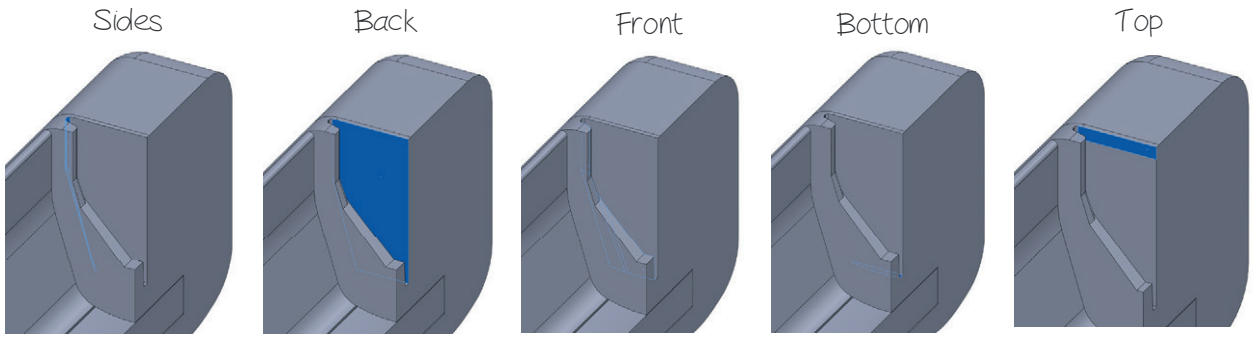
illu. 132

20 iterations in total



illu. 133

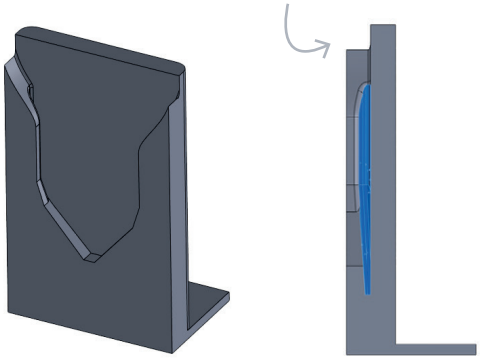
A perspective and a section view of each iteration is depicted to illustrate the design process of the interface. Furthermore, **illustration 134, shows the naming convention used to describe the interface**. The designs were **3D-printed, self-tested, as well as field-tested by nurses** (Appendix 12, 29 & 36), utilizing two methodologies of Design Thinking: Reflection-in-action (Laursen, 2017) and the PDCA Quality Cycle (Dubberly, 2004).



illu. 134

1 Iteration

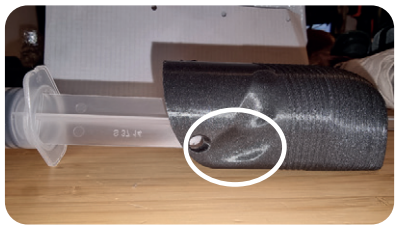
First interface made to fit 20- and 50-ml syringes



illu. 135

This interface accommodated both the 20 mL and 50 mL syringes and was made with **two different draft angels on the sides, front, and back**, that made the **syringes able to be wedged into the handle.** These draft angels also made the **syringes prone to slide out** because it only wedged the syringes into a small section at the bottom of the interface with **minimal contact between the handle and the syringes**. This prob-

illu. 136



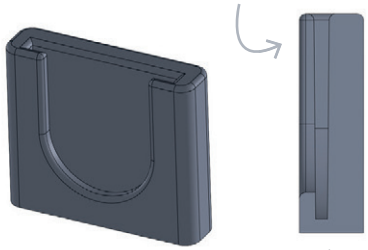
illu. 137

lem **could be solved if the nurses wedged it in more tightly** but in **user-tests this rarely occurred** and when they did the syringe was often too **difficult to pull out** afterwards. Because of this the nurses pointed out that **instead of the stain being in the extraction it was just moved to detaching** the syringe.

Through tests it became clear that the depth-placement of the interface was important. Because the interfaces were designed parallelly with the handle, early handle prototypes, shape iteration 1-3 on page 72-73, had the former placement-depth artefacts from when 20 mL syringes were also in consideration. This meant that the **plunger's thumb rest was protruding out from the interface which caused the handle to consistently** tumble over when being placed with the interface downwards on the medicine table. This was an easy **fix, by just lowering the interface placement** to ensure that the thumb rest could go further into the handle.

2 **Iteration**

Only for 50 ml syringes



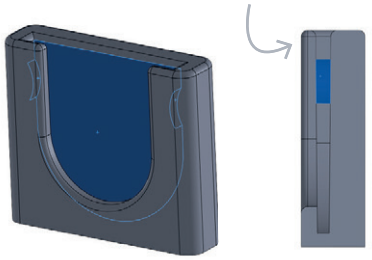
illu. 138

This interface designed only for 50 mL syringes was a simple **open-ended slot made with a draft of 0.5 degrees on both sides, the front, and back and some guiding fillets at the top**. This worked well but the draft angles were **still making the syringes slip out and did not wedge the syringe in as hoped**.

Must have an interface resistant to wear and tear

3 **Iteration**

Side bumps to click syringe in place

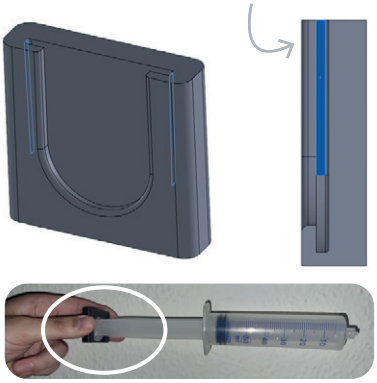


illu. 139

This interface was made similarly but **two 'bumps' were added on each side** at the top of the interface to make **the syringe click into place**. This functioned decently but **the friction of the syringes quickly deformed the plastic bumps** permanently to the point of malfunction destroying their effectiveness. Another **issue was the variation in diameters of the plungers thumb rests** from different manufacturers, where the B. Braun syringe would perfectly squeeze over the bumps, the BD syringe would have to be forcefully pushed in despite a mere difference of one millimeter between them.

4 **Iteration**

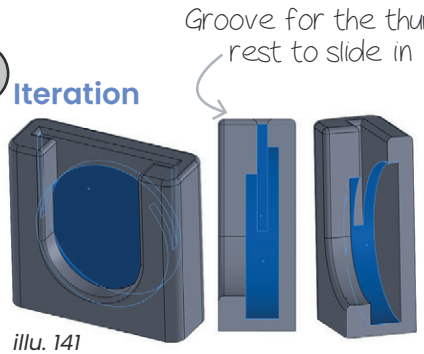
Only draft angels on the side



illu. 140

This interface was similar but with **draft angels only at the sides and was then flat at the front and back to make more surface contact** with the plunger's thumb rest when extracting. This **worked well**, ensuring fixation of the syringes without making it difficult to detach. Furthermore, it was discovered that when **the syringe is fixated, and the front is pulled down by gravity it creates friction because the thumb rest bends in the interface holding it in place**.

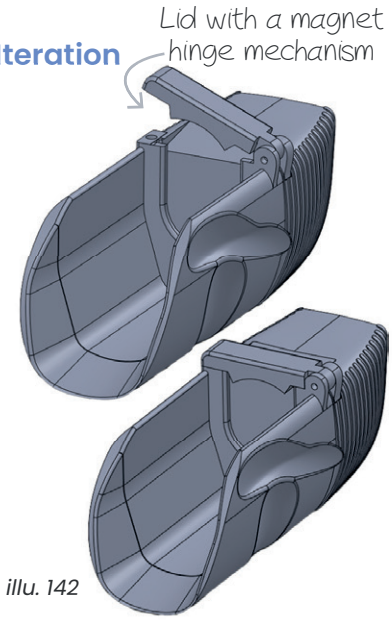
5 Iteration



illu. 141

This interface was made to **test another principle** where the syringe could be **slipped through a narrow slit into a groove** that would **lock it** from going out unless the syringe was intentionally precisely guided out through the slip again. This principle **was decent**, but the backlash of the groove was too severe to get the feeling of control when handling the syringe.

6 Iteration

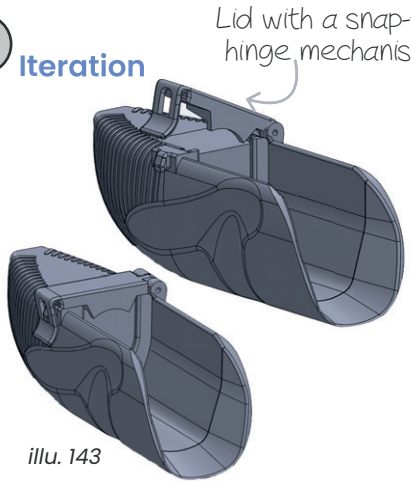


illu. 142

This iteration of the interface was to test if a hinge lid at the top of the interface attached with a magnet would make the syringe **feel more fixed.** However, even though the magnets were **satisfactory in closing the mechanism, they were not strong enough** to make a difference. Furthermore, this design is a bit more **complex** and has the **added cost** of assembly, the magnets and a hinge which is a moving part and generally tends to degrade quicker.

As a side note a **guide groove was added on top** of the handle to help guide the syringe **into the interface**. With this groove it was only needed to approximately aim the syringe at the interface, and it would **slip right in**. This guide groove is detailed further on page 79.

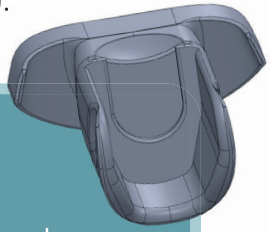
7 Iteration



illu. 143

This iteration followed the same principle, but **the magnet was substituted with a snap fit instead**. This worked a lot better than magnets, but the **narrow plastic hook was a failure point and prone to fatigue**. Secondly this kind of design also **added two interactions** to the nurses' workflow: clipping the lid on and releasing it off when done, counteracting product adoption. These interactions must be **limited to a minimum for the greatest chance of nurses adopting the product.** The user-feedback during field-testing was negative as the hinge felt unnecessary, creating more steps (Appendix 12).

illu. 144



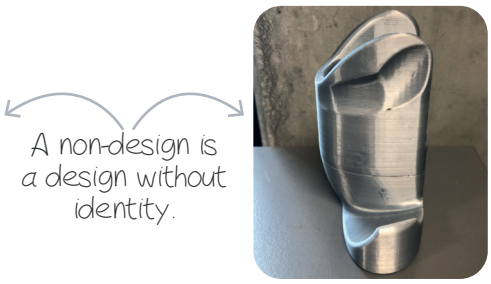
Partial conclusion

It was decided to go with the fourth iteration of the interface because it had the best working principle while also being quite simple with no wedge mechanism that could wear down the plastic interface over time. This iteration was slightly tweaked with different draft angles on the sides and different slot diameters to get the snuggest fit possible while not being excessively tight. With the interface design completed to fit the 50 mL syringes from BD and B. Braun, while also adapted to the time-efficient workflow of nurses, the focus was shifted to the aesthetics of the handle.

Aesthetic Adjustments

How to ensure visual coherence?

After detailing the handle and its features it was clear that the **ergonomics had been the main focus and driving the shape**. To transform the handle **from a non-design to an object with character a style board was developed** to find an aesthetic direction (Appendix 38). This takes the nurses wish to exhibit professionalism by easy decoding and fitted context aesthetics into account.



illu. 145: Design before aesthetics

The direction was based on a mix of the **product language of nurses' equipment** and the **product identity**, with an inclusion of 'a **feminine look** as the far majority of nurses is female.

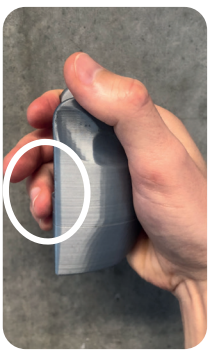
illu. 146

After creating an overview of the common characteristics, it was clear that the design should be **more round, soft and subsequently harmless looking** and comfortable to the touch. Furthermore, it should **be clearer, which surface is an interaction surface** and which is not.

A change in material, colour and surface texture was not possible due to the chosen production method and the recommendation of the hygiene nurse about a smooth surface for easy cleaning and visual inspection. Therefore, the development was based on **clear line flows following the hands' curvature for easy comprehension** of where to grab.

illu. 147: One finger joint on the wing

illu. 148: Two fingers joint on the wing



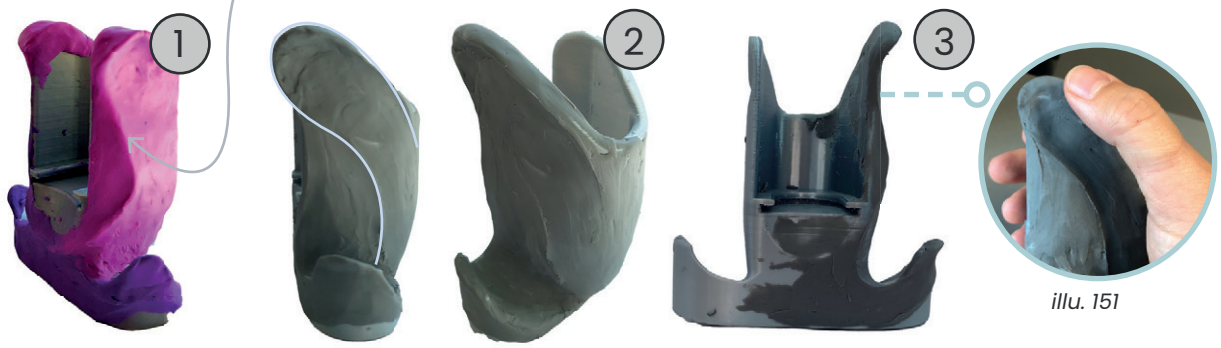
illu. 149: Three fingers joint

illu. 150: Pain in the little finger or big hand

Since nurses have different injuries in different fingers and have different hand sizes and shapes, it was important to make a design, who accommodate various ergonomic grips.

Iteration 1-3

Free form in play dough, clear line flows, that guides and follows the hands' curvature and an extended top, accommodating the thumb



illu. 151

4 Iteration

Feminine form due to tulip associations, but too sharp and sculptural, with the latter being too trend-based for longevity

illu. 152

Affordances

To visually show that the plunger's thumb rest should slide into the interface, different ramps were tested. A square ramp was chosen, as a curved ramp reminded people of a fingerprint.

A place for the finger?

illu. 153

Iteration 5-14

Back to the handy version, but with clear line flows, Same thickness and no negative angles to accommodate injection moulding in the future

illu. 154

Due to making it economically feasible (page 85), the handle winds up with only one 'wing', why it appears slightly disjointed. In future series it could be more appropriate to increase the 'wing's' identity, by coherence and interestedness with the remaining handle or by highlighting its independence as the main visual characteristic.

The main feedback from nurses:

*Super **beautiful and calm design** […]. The **design tells you how to use it.** You do not need a big manual. The same with the standing function.* **No sharp edges to cut your fingers on**. *It **gives 'peace' for the hands**, which is important with all the medicine that needs to be mixed. So, all in all, a super nice design.*

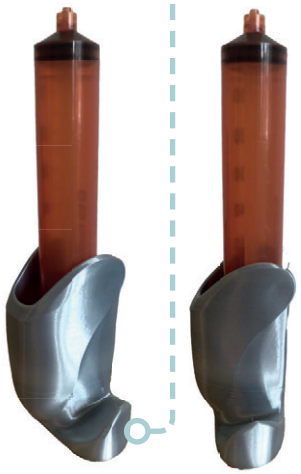
Merethe, Department Manager at District Vesterparken

*I asked all the nurses in my department, and they all said it is **really elegant and sweet** and I totally agree.*

Bente, Nurse at Intensive Care at Aalborg Universitetshospital

I think it fits my hand nicely […] And then it is pretty.

Tracey, Nurse at Intensive Care at Viborg Regionshopitalet



illu. 155

The main feedback from byLink:

*Waooo. So **nice you went back to a small and handy version.** Did you name it and what about a logo?*

*The handle is really nice. **Comfortable and nice to look at**. So elegant..*

illu. 156

Partial conclusion

After detailing the handle it was clear the ergonomics have been the main drivers of the shape. By making the shape rounder, the handle gets a softer and calmer look, which fits nicely into the context and the product language of nurses' equipment. Furthermore, the design offers good feedforward due to the overall shape and the line flow which follows the hands curvature, aiding the nurses in decoding the placement of their hands. A square ramp visually indicates that the plunger's thumb rest should be slided into the interface. All in all, a design that expresses professionalism by fitting aesthetically into the context and being easy to decode for the nurses, which ensures they feel experts in own product and look professional seen from the patient's and their relative's point of view.

Construction, CMF & Validation

How to realise a durable product?

Parallel with the detailing the shape, ergonomics and interface of the handle, the construction and manufacturing were established with accompanying durability analyses and **cost optimisation to ensure that the design could be realised** and not just conceptually in a CAD-program (Appendix 39 & 40). Current applicable construction requirements, see Design Brief 4 on page 87-88, are addressed throughout as a **technical verification of the product**.

Manufacturing Method

Before determining a manufacturing method, the type of material should be decided, as the former is highly dependent on the latter. Firstly, **stainless steel or aluminium were discussed**, as they often are seen in contexts which require **easy disinfection and sanitation**. However, they were **quickly dismissed due to cost and weight**. Further desktop research showed that **plastics could be suitable.** But what kind of plastic and manufacturing method? To get a better grasp of the possibilities a few different plastic manufacturers were contacted.

LiqTech *CNC plastic milling*

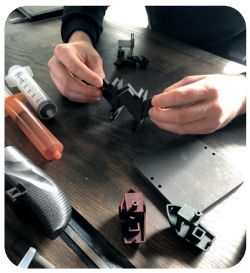
Expert Michael H. Sharff at LiqTech deemed the advanced syringe **interface in the handle too difficult to CNC mill.** While the precise tolerances might be achievable with PEEK (Polyetheretherketone), this material is very expensive, costing over 1,000 DKK/kg.

Vink Plast *Injection moulding ; 3D-printing ; CNC plastic milling*

Bjarne Rysz, a technician at Vink Plast, suggested different manufacturing methods. **Injection moulding requires a minimum order of 3,000 units**, while lower quantities could use FDM or SLA 3D-printing, or CNC milling. The company proposed a CNC-milled prototype, but it was dismissed due to a futile interface.

Podovo *3D-printing*

Nicklas Lassen, from the **3D-printing** company Podovo, suggested that this manufacturing method is **ideal for small production runs.** With **no tooling costs**, the design can **easily be iterated for each run**.

illu. 157

3D printing was chosen due to its low startup cost and the ability to iterate the design during implementation phase 1 (see illustration 39). byLink, a small startup with limited resources, favoured this approach. It would allow them to test the handle, make adjustments based on feedback, and ensure the design was **matured before moving to a production method with tooling costs, such as injection moulding.**

3D-printing Technology

There exist several plastic 3D-printing technologies, all falling under three different technologies, with slightly varying sub-methods (3D Systems, 2024). Three **sub-methods** within each technology were considered:

FDM *Fused Deposition Modelling* *Material Extrusion*

FDM print was suggested by Vink Plast on an Onyx Mark Two printer which prints plastic with Continuous Fiber Reinforcement, which supposedly has the same strength as aluminium (Markforged, 2024). While this sounded intriguing, **FDM prints often have a rough surface with layer lines that can be hard to clean** and with an estimated cost price by Vink Plast at 500 DKK/unit it was **too expensive.**

SLA *Stereolithography* *Vat Photopolymerization*

SLA print would be great for cleaning requirements because of imperceivable layer lines and is also often seen in the health care industry (Formlabs, 2024a). However, **SLA prints are not as durable as either FDM nor SLS prints** (Vollaro, 2024; Team Xometry, 2022)

illu. 158

SLS *Selective Laser Sintering* *Powder Bed Fusion*

SLS print is **great for making many parts in one build chamber** as it automatically **creates its own 'support structure'** by filling the whole build chamber with nylon powder which increases the **packing density,** subsequently decreasing the price. The **layer lines are minimal, great for cleaning** and it has a great structural integrity (Sinterit, 2024). If designed correctly for SLS printing the handle could have a cost price of approximately 200 DKK/unit according to Podovo.

SLS 3D-printing at Podovo was chosen as the startup production method due to the combination of price, performance and vicinity to both the development team and byLink.

illu. 159: SLS printed handle

A packing density is the ratio between units and volume occupied by these units within a confined space.

illu. 160: Evolution of OpenIt

byLink used a similar product development cycle with OpenIt. They started with low-volume CNC milling to refine the design, then invested in injection moulding once the market and design were validated.

Colour, Material & Finish

Podovo, the selected manufacturer, is only 16 km from byLink and SLS prints exclusively in Formlabs Nylon 12 Powder in the colour charcoal grey (Formlabs, 2020). This material, also known as PA12, is suitable for the application as it is often used in the medical industry and **meets the hygiene-relevant constructional requirements** for resistance to alcohol, water, soap, chlorine as well as other relevant liquids like salt water, oil and greases (Shakiba, 2021; AerosUSA, n.d.). It **maintains dimensional stability up to 100-180°C depending on thickness**, thus withstanding the required temperatures of 80°C (3D People, 2024). Resistance to various medicine which the handle potentially could come in contact with are unknown. While the material's resistance to medicines is unknown, byLink's OpenIt, also made of Nylon 12, but with 10% glass fibre, has not shown susceptibility to medicines so far.

The handle could be sold as-is, but there are significant benefits to applying the right surface finish. **Podovo suggests vapor smoothing, a common post-processing technique for SLS-printed Nylon 12**. This process involves melting the surface in a chamber with solvent vapor, **sealing it**. Despite the **additional 30% cost** as offered by Podovo, vapor smoothing was chosen as it offers several advantages for health care applications, including (Appendix 40):

- Shiny surface suitable for health care aesthetics
- 81% less rough surface, enhancing cleaning
- Consistent black colour without speckles
- Enhanced mechanical properties
- 60% reduction in bacteria growth
- Improved moisture resistance

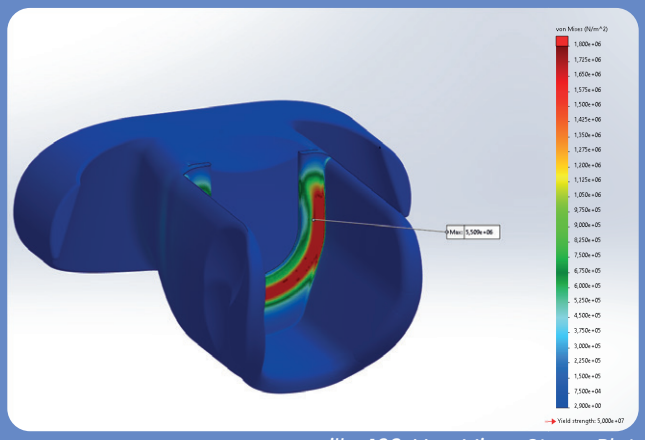
illu. 161: Raw SLS print

illu. 162: Vapour smoothed SLS print

Durability Analyses

To ensure structural integrity, constructional requirements were evaluated, **identifying the interface as the supposed critical point for erosion and stress**. It must withstand wear and tear while accommodate 50 mL syringes from BD and B. Braun. After numerous iterations (see page 75-77), a design with limited wedging utilising a straight surface on bottom and top and a 1-degree inward angle on the sides was developed. The syringes plunger's thumb rest is in tension between the inner surfaces, due to off-axis centre of gravity. With these surfaces, erosion due to grinding is essentially prevented.

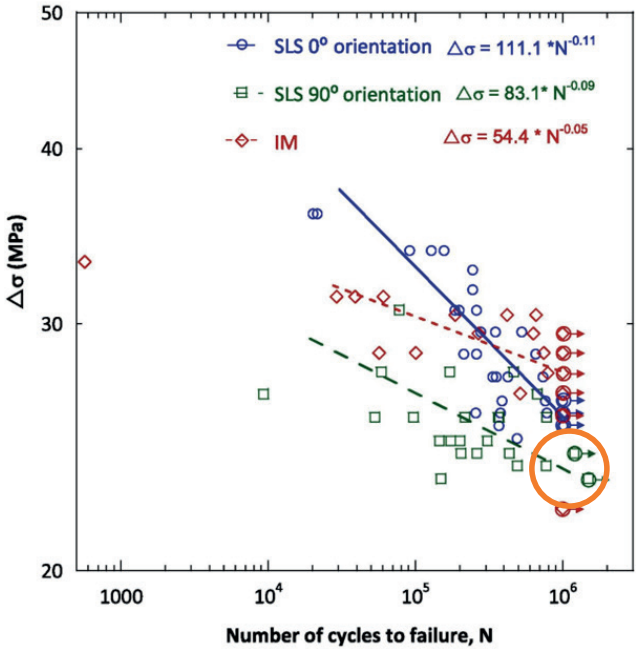
To **verify that the interface could withstand the worst-case scenario of 73 N** with great confidence, **a finite element analysis (FEA) was conducted** by applying said force on the specific surface in question, evaluating stress, fatigue and displacement (Appendix 13, 14 & 40). The FEA was conducted on an older design, Iteration 25 of the shape on page 73, but this does not affect the results as the interfaces is identical to the final version. A custom material based on Formlabs Nylon PA 12 SLS-printable powder was plotted into SolidWorks (Formlabs, 2020). A **convergence study of the FEA**, **identifying an appropriate quadratic element size of 2.4 mm**, was conducted to ensure the used results were applicable.



illu. 163: Von Mises Stress Plot

Stress

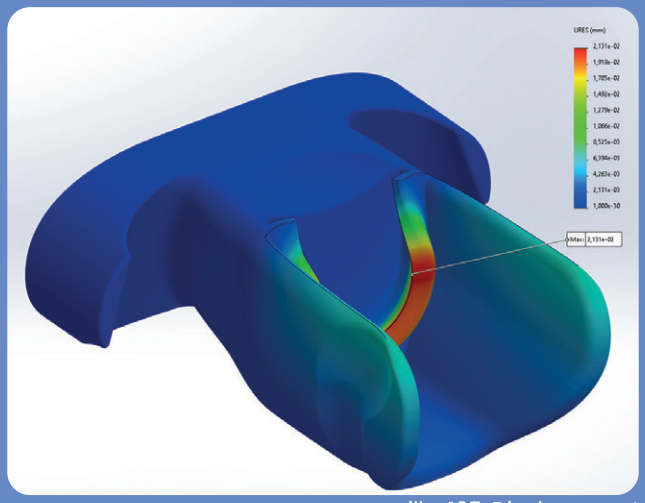
The Von Mises stress plot shows a **maximum stress of 5.5 MPa**, nearly an order of magnitude **lower than Nylon 12's yield strength of 50 MPa**. It could be argued that **material could be saved**, but uniform shell thickness was prioritised over material optimisation for design reasons.



illu. 164: Fatigue of SLS printed Nylon 12

Fatigue

A study on the fatigue of SLS printed Nylon 12 in different layer orientations show it can **withstand a stress of 23 MPa for 106 cycles in the 90-degree orientation**, which the interface will be printed in (Salazar, 2022). This **equates to three nurses using the same handle ten times a day for 91 years** creating 23 MPa of stress each time. Therefore, the worst-case stress of 5.5 MPa from syringe extraction is **low enough to deem fatigue of the interface insignificant.**



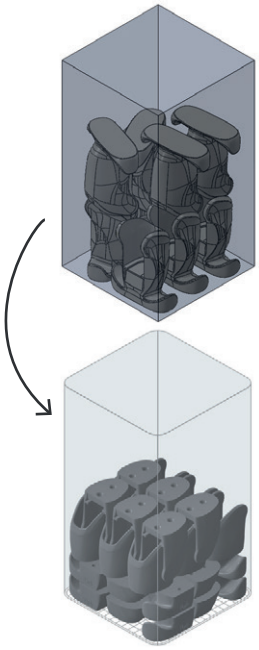
illu. 165: Displacement

Displacement

Examining the displacement plot of the FEA it is evident that the **maximum displacement is 0.02 mm which is negligible and deemed acceptable.**

Design for manufacturing

The additive manufacturing process of **SLS printing has few design** constraints, but those that exist must be considered (Appendix 40). These include part size for optimizing packing density in the build volume, no sharp or pointy edges, as well as tolerances and dimensions of 0.1 mm with the latter also applying to vapour smoothing.



illu. 166 Printing Configurations

Pricing of SLS printing

To reduce unit costs, **the design was optimised for the build volume of Podovo's printer**, the Formlabs Fuse 1+ 30W (W165 x D165 x H300 mm) (Formlabs, 2024b). The original **ambidextrous design with wings on both sides had poor packing density**, resulting in a unit price of 405 DKK. To address this, the handle was **redesigned.** First, **separate right-handed and left-handed versions** were created, improving ergonomics and reducing the unit cost to 325 DKK, which was **still too high**. Next, the design was **split into two parts: the body and the bottom/wing, assembled with M5 threaded inserts and countersunk bolts**. This optimised packing density, and **after 24 iterations, reduced the unit cost to just below 200 DKK, excluding inserts, bolts and vapour smoothing.** The final assembled dimensions are W68 x D52 x H93 mm, allowing 15 handles to be printed at once in a two-layer configuration. This **met the constructional requirements for wholesale price, size, and weight**, with the handle weighing 94 g. (Appendix 40)

M5 threaded inserts and countersunk bolts will be made of **brass and stainless steel, respectively, both resistant to relevant chemicals and heat** (Appendix 40). The inserts are fitted by using a **soldering iron and pressing them into the plastic**, which melts around their knurled exterior. This method allows the inserts to withstand a pulling force of 2,700 N and a torque of 10 Nm, which is acceptable (CNC Kitchen, 2019).

Design Compliance with SLS printing & Vapour Smoothing

Requirements for tolerances and dimensions were continuously assessed to ensure manufacturing compatibility. The final design was reviewed and accepted. (Appendix 39 & 40).

Partial conclusion

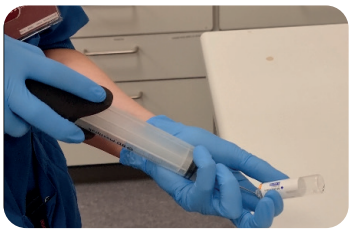
Decisions were made on the manufacturing method (SLS 3D-printing), materials (Nylon 12, brass, stainless steel), and post-processing (vapor smoothing, fitting of threaded inserts). The handle was redesigned to have a single wing and split below the guide chute for cost-effectiveness. This and a durability analysis confirmed compliance with all construction requirements. Next, the focus was on outlining the product fit, business strategy, and future prospects.

Ampoule Holder & Home of Solution

How to accommodate workflows of medicine mixing?

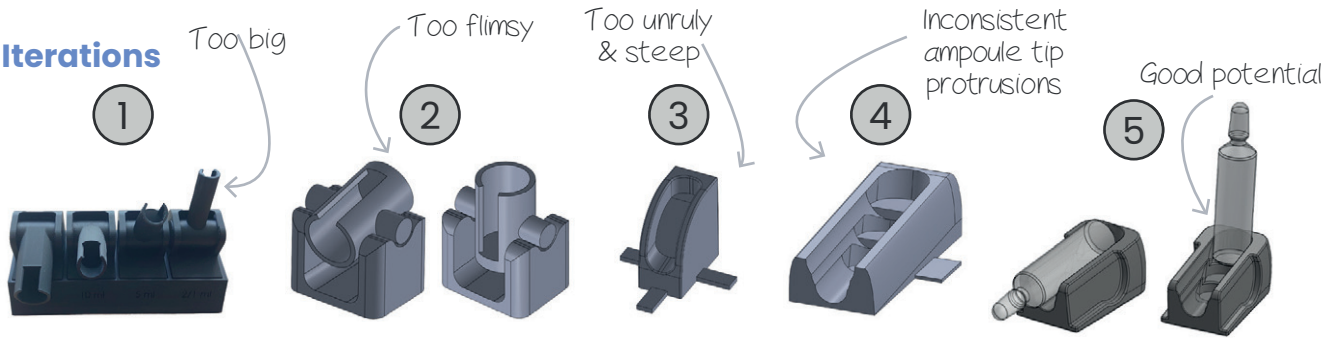
The solution must account for all scenarios of medicine mixing, which includes one-handed ampoule scenarios. Nurses are able to perform this using the handle by holding the ampoule and syringe in one hand, manoeuvring the ampoules position and angle using the thumb and index finger (Appendix 41). This varies from some nurses' workflow, but can quickly be learned, despite being a bit finnicky in the beginning. Thus, this scenario could be optimised in terms of control of both syringe and ampoule as well as strain with an external **ampoule holder**. This would **add steps to their workflow but also offer a home of the handle to reduce risk of it getting lost, which is recurring theme of OpenIt.**

illu. 167 Current technique for some nurse



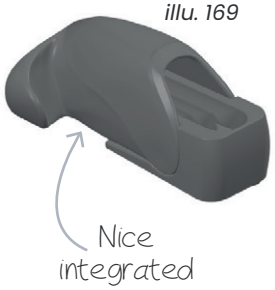
illu. 168 Technique with solution

Iterations



The ampoule holder's development can be **summarized in five main concept** and feature shifts resulting from feedback and self-tests (Appendix 41 & 42).

1: Fixated pivoting mechanism accommodating all ampoule sizes.
2: Self-balancing pivoting mechanism, returning to start position.
3: Groove to pivot the ampoule in with no moving parts.
4: Stationary holes for 20, 10 and 5 mL ampoules to pivot them in.
5: Aligning ampoule tip protrusion for an easy grab post-extraction and cut out for handle blending the surfaces of each, making the holder a home



illu. 169

Partial conclusion

For full transparency it must be noted that the ampoule holder requires further refinement in design, shape, styling, and manufacturing optimisation despite being functional. Long-term feedback is needed to determine if nurses require it or if the, for some, new technique of holding both syringe and ampoule in one hand is adaptable. byLink agreed to initially enter the market without the ampoule holder. If demand arises, the holder can be refined and sold together with the handle as a kit.

Design Brief 4

Problem Statement

How to create a professional and adoptable hand tool which diminishes or prevents injuries while aiding the hospital nurses in the extraction and injection of 50 mL syringes during medicine mixing?

Target group

Nurses from the Region. Especially Anaesthesia, Intensive Care & Neurology nurses.

Assignment

Medicine Mixing.

Mission

To develop a working environment related tool for the health care sector for byLink.

Vision

To aid in the paradigm shift of the health care sector's work environment shifting from unhealthy to healthy conditions by a movement of work-related assistive technologies.

Interaction Vision

To give hospital nurses a feeling of professionalism through power, control, and comfortability.

Requirements & Wishes

The requirements are categorized into aesthetic, function and construction requirements. Some requirements intersect the categories.

No.	Aesthetic requirements	Source
1	Must look professional and in control	Comprehending the Nurse
2	Must be easy to decode placement of hands and syringe as well as use of any other feature	Comprehending the Nurse

No.	Functional requirements	Source
1	Must be able to aid in extraction and injection	Personal Experiences
2	Must decrease fine motor skills usage	Problem's physiology
3	Must be operational whilst wearing plastic gloves	Extend & Context
4	Must allow a visible mL scale during extraction and injection	Extend & Context
5	Must allow various needles, mini-spikes and venflon to be attached to the tip	Extend & Context
6	Must allow syringe to be rotated 180 degress during Luer Lock attachment and last medicine drop extraction with needle	Extend & Context
7	Must be able to let the syringe be extracted and injected within 360 degrees free vertical movement	Extend & Context

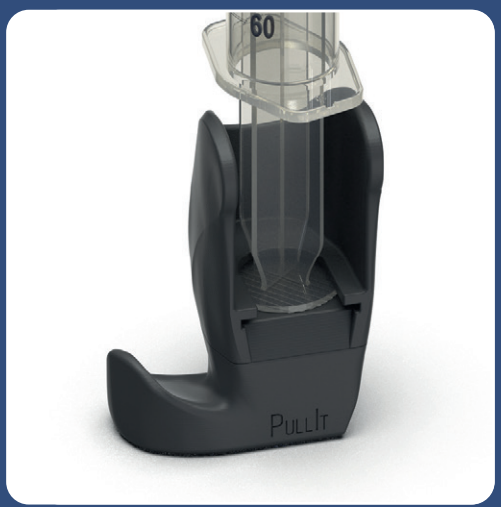
Both a functional & construction requirement

8	Must be fixated to syringe during rotation and air bubble-tapping	Extend & Context
9	Must have a usage which combined timespan of retrieving, attaching, injecting, extracting and replacing that is competitive with the current of extraction and injection	Extend & Context
10	Must encourage to appropriate ergonomic use	Two concepts
11	Must not have a usage which surpass the current accumulated interactions	Two concepts
12	Must be resistant to alcohol as well as water and soap as well as chlorine	Shape & Ergonomics
13	Must fit all possible size variants of 50 mL Luer Lock syringes from BD and B. Braun	Syringe Form Factors

No.	Construction requirements	Source
1	Must be mobile with a weight of maximum 100 g	Two concepts
2	Must not exceed 5% of the available table area of 0.2 m2, equivalent to 100 cm2	Extend & Context
3	Must be able to overcome forces of up till 73 N during extraction and injection	Two concepts
4	Must not exceed a wholesale price of 1,000 DKK	Potential
5	Must be able to withstand heat disinfection in an instrument washer at 80 °C	Shape & Ergonomics
6	Must have an interface resistant to wear and tear	Interfaces & Features

No.	Wishes	Source
1	Should allow only two-handed use	Problem's physiology
2	Should fit into byLink's product portfolio	Collab with byLink
3	Should be reuseable	Collab with byLink
4	Must be ambidextrous	Collab with byLink
5	Should not be certified as medical equipment	Collab with byLink
6	Should include an accompanying ampoule holder for one-handed scenarios	Two concepts

Updated requirements are marked with green



illu. 170

Specifications

Price: 599 DKK exclusive VAT
Dimensions: W68 x D52 x H93 mm
Weight: 94 g
Compatibility: BD & B. Braun 50 mL Luer Lock
Classification: Non-Critical Equipment
Colour: Black
Materials: Nylon 12, Brass & Stainless Steel
Finish: Vapour Smoothing
Heat Resistance: 100-180 °C
Chemical resistance: Salt Water, Soap, Grease, Oil, Alchohol & Chlorine

7 Business

The second to last chapter explores the business case through a Business Model Canvas spread across several sections. It elaborates on the business strategy and supply chain, while also laying the groundwork for a realistic implementation plan. An overview of the triple bottom line and market fit concludes the true potential of the project with additional possibilities for future horizontal scaling.

Business Strategy & Supply Chain

How is the market entry realized?

This section gives an overview of the business strategy and how the product is positioned, reviewing the **customer sales channels and customer relationship from the Business Model Canvas in relation to byLink**. Involvement of **key partners and activities** is elaborated on in two supply chains illustrating the flow of assets during Implementation Phase 1 and 2. (Appendix 43)

Customers

byLink, the investor, partner and coming vendor of the solution has a typical customer segment which the handle is targeted towards in itself, but also through the **strategic product company-fit, following byLinks' six design DNA characteristics**, seen on page 43-44. The requested, **simple, and easy decodable solution solves a relatable and legitimate problem, verified by feedback from numerous nurses, guiding its design and ongoing development. It is locally produced, reusable, and repairable, reflecting both byLink's and hospitals' increasing commitment to environmental sustainability.** Lastly the **competitive pricing of 599 DKK**, is contingent on it **not being classified as medical equipment** which also would **delay its market entry** fourfold and be **too financially heavy for the small startup**. CEO at CE Toolbox ApS, Niels Peter Lindholt, who is an expert in Medical Device Regulations (MDR) verified that the handle indeed is not medical equipment (Appendix 36):

> *That is **not medical equipment. It is just an analog utility.***

Henceforth, the solution shall be known as **PullIt**. This name was chosen as it **describes the main function** "Pull" followed by "It", similar to byLinks' **current product lineup** with OpenIt and DrainIt.

Implementation Phase 1

byLink will start by **targeting B2C** (individual ambassador nurses) and **B2G** (convinced department managers) through a **bottom-up approach** and **word-of-mouth** via workshop, conferences and the **individuals who have partaking in the design** of PullIt alongside **earlier customers** in their vast network. Thereafter they would **cold canvas** department that use 50 mL syringes. The handle will also be able to be bought directly on their web shop if needed (Appendix 43).

The referred **nurse ambassadors** like intensive care unit nurse Bente and anaesthesiology nurse Lise who are already **truly affected by the problem are crucial for the word-of-mouth-marketing**, as they can convince colleagues and department managers to invest in this type of product (Appendix 9 & 6). A proven strategy for byLink and **supported by implementation expert** from Level Health ApS, Tue Lodahl (Appendix 36):

> *Focus on those who want it, and it will promote itself.*

This approach ensures **close customer relationships and subsequent cycles of feedback which the maturation of PullIt is dependent on to reach mass adoption**. The feedback will be converted to **design changes** in the next series, as seen on illustration 171, which is made **possible by SLS printing not having any fixed costs**. Approximately a year after launching PullIt, when quirks and shortcomings of the design have been addressed and enough profit has accumulated, Implementation Phase 2 will be initiated.

Supply chain Phase 1

Goods and services
Money
Information

Vapour smoothing surface finish

Germany based subcontractor

Podovo
Slut med kedelige ingeniører

SLS 3D-print PA 12

RS

byLink
Healthcare Innovation

Installation of threaded inserts and bolts

Packaging

Storage

Shipping

Marketing and sales

Design optimization and development

Feedback loop for maturing the product

HUSTED
EMBALLAGE

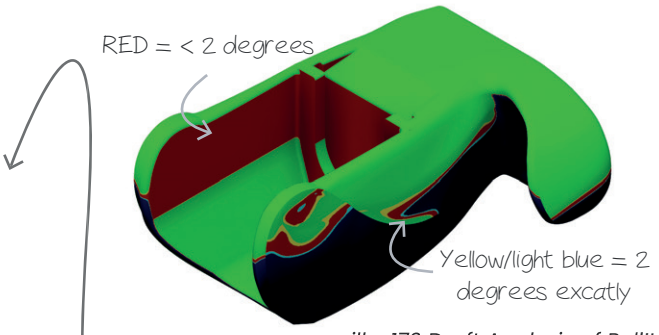
DANSKE REGIONER

B2G & B2C

illu. 171

Implementation Phase 2

Firstly, the design will be **reconfigured for injection molding, reducing costs** and allowing for **colour options** and **ambidextrousness**. This transition will begin once initial shortcomings are resolved and bottom approach has taken hold. Enough department managers requesting Pulllt will prompt **suppliers like Abena to add it to the Regions' product catalogues** making Pulllt be sold increasingly through **B2B**. Abena will also act as a gateway to the **Nordic market** and eventually **Germany, the Netherlands, Belgium, and France**.



illu. 172 Draft Analysis of Pulllt

A draft analysis of Pulllt identifies areas needing redesign for a 2-degree draft angle. Achieving a uniform shell thickness will likely require side action during injection moulding.

Supply chain Phase 2

Goods and services
Money
Information

RAPID® DIRECT

Injection moulding

Adapted design with no assembly or threaded inserts required

Packageing

byLink
Healthcare Innovation

Storage

Shipping

Marketing

B2B

MEDIQ

Sales

ABENA®

DANSKE REGIONER

illu. 173

Partial conclusion

Pulllt, as the solution is named, has a strong user-fit and subsequent company-fit ensured by compliance with byLink's design DNA. A realistic and proven two-phase implementation plan are outlined accompanied by corresponding supply chains. Several tasks are done by byLink. Fitting for a small startup, as this keeps costs down.

Triple Bottom Line

What is the value for the people, planet, and profit?

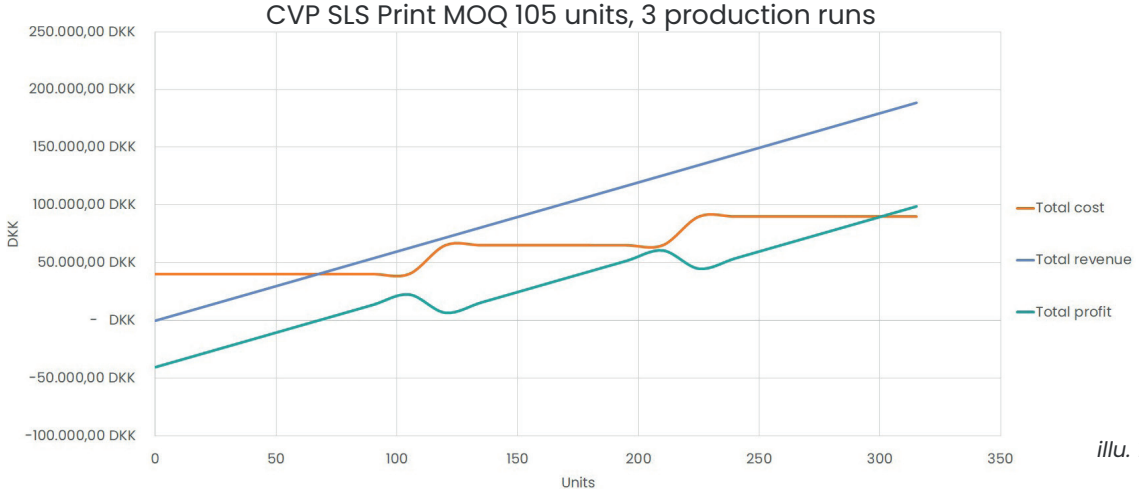
This section addresses the revenue stream, key resources and value of the Business Model Canvas. Pullit aims to achieve true sustainability by considering economic, societal, and environmental factors (Appendix 43). Their efforts **align with United Nations Sustainable Development Goals 8, 3, and 12**, as outlined below (United Nations, 2024a).

illu. 174

Economic sustainability

No product is developed unless there is an **economic incentive** behind it which is why Pullit tries to address the Sustainable Development **goal number 8**, specifically 8.2: *"Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors (United Nations, 2024b)"*

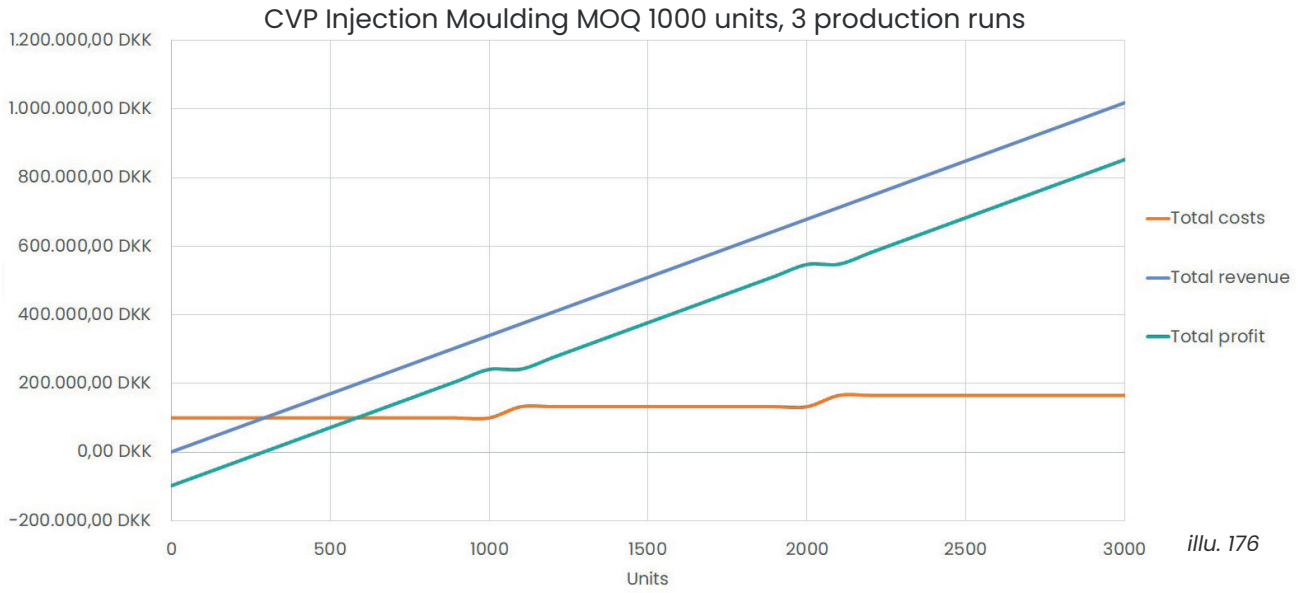
To verify that Pullit have a return on investment for byLink a **cost-volume-profit (CVP) analysis was made** for respectively phase 1 (SLS print) and phase 2 (Injection moulding) (Appendix 44). **The phase 1 CVP analysis was based on order quantities of 105 units each production run**. Based on user feedback, Pullit has a suggested **wholesale price of 599 DKK** and an estimated **cost price of 236.07 DKK** which is a **contributing margin of 61%** (Appendix 4-6 & 8-11). The **breakeven point** using SLS 3D-print as a production method will be **67 units sold which is approximately 2 departments.**



illu. 175

After selling 319 SLS printed units, Pullit has accumulated enough profit, totalling 100,000 DKK, to invest in an injection mould and associated costs for Phase 2. Pullit's design will require updates to facilitate injection moulding. Pricing for the **mould can vary significantly depending on the manufacturing location**. In this instance, a quote for **1000 units was obtained from a Chinese-based company, Rapid Direct, due to byLink already has production there** (Appendix 44).

The new production setup **reduces the unit cost to 33.2 DKK from 236.07 DKK** in SLS printing. With **sales assistance from Abena, which takes a 40% profit** cut, **byLink's contribution margin decreases slightly from 61% to 57%** if the wholesale price remains unchanged at 599 DKK.



illu. 176

units, it begs the question: Why not invest in a mould to begin with? The **reason is that with SLS 3D-printing as a production method byLink can test the market demand, verify the design for a wider audience, and mature PullIt easily because of no tooling costs**, before investing in injection moulding, which is a **business strategy that byLink is familiar** with and is seen in their products like OpenIt.

Additionally, PullIt will address large and avoidable expenses the Danish society faces each year, saving money passively. **PullIt contributes to minimising the number of syringes used as well as nurses that: retire earlier than expected, needs surgery, change jobs because of pain and have sick leave because of musculoskeletal disorders, with just the latter two points being an economic burden of 2.46 billion yearly.** While it **might be hard to pinpoint exactly how much PullIt will reduce these numbers**, everything that can be done to get a better work environment in the health care system should be according to Rubusthedskommisionen, which is a report over the sustainability of the Danish health care system (Robusthedskommissionen, 2023)

Social sustainability

PullIt's introduction to the market could have **positive societal implications, aligning with Sustainable Development Goal 3**, particularly target 3.d: *"Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks "* (United Nations, 2024c). While PullIt is yet to be tested on a wider scale it has been evident during the product development that it **reliefs a lot of finger pain** for nurses like Bente (Appendix 41).

> *I have tried and tested the handle, and it works really well. I actually have nothing negative to say.* ***Everyone thinks that it relieves one's finger and makes pulling up so much easier. And that means both younger and older nurses.***
>
> Bente, Nurse at the Department of Intensive Care at Aalborg Universitetshospital

When listening to nurses that have been in the industry for many years it is obvious that they to a large degree and unjustly **sacrifices their own well-being and health for others**, and serval examples exists, like Lise, that cannot even open a bottle of soda anymore without excruciating pain (Appendix 6). **PullIt can help eliminate one painful aspect of their work, which is one less thing they have to worry about and can stay longer time on the labor market**. With the strate-

gic user-fit, **PullIt optimises the nurses' workflow by 45 seconds** and saves time that they can be used on patients or other duties instead, by liminating the referred 20 mL syringe workaround as well as balancing of syringe to avoid contamination (Haase, 2022)(Appendix 34). This optimisation could **also influence younger nurses to use the product** which as a benefit would proactively prolong the health of their hands. **PullIt removes the need for touching the inside of the plunger and makes it possible to use needles with filters making patient safety better** and making the nurses look more professional overall.

Environmental sustainability

After three years the implementation of PullIt would have offset 15.5 tonnes plastic, 2 ¼ tonnes stainless steel and at least 58.1 tonnes CO_2.

The health care sector accounts for **6% of Denmark's carbon emissions, with 70% of this attributed to medicine and equipment** (Nielsen, 2024). While regions are starting to address this, the possible implications for syringes are supposedly **limited to transport and packaging** (Appendix 16). However, PullIt challenges this notion by offering an alternative that reduces the number of syringes used, aligning with Sustainable Development Goal 12, particularly target 12.5: *"By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse."* (United Nations, 2024d).

By eliminating the referred 20 mL syringe workaround, every **PullIt would save 373,215 syringes per year and just as many needles**. This would result in a positive offset in material and carbon emissions compared to PullIt's manufacturing, saving enough plastic and stainless steel to produce 56,803 handles per year. The carbon emissions ratio is 1:9.2, with **each handle saving 18.6 kg CO_2 per year** when PullIt's emissions are offset based on the proposed 3,125 units sold after three years. This is a conservative estimate, as it does not include factors like transport, labelling of plastic, assembly, packaging, material extraction, or various emissions connected to manufacturing (Appendix 45).

PullIt justifies its material choices and associated carbon emissions by rendering the 20 mL workaround redundant and offering a reusable product. **It is not only carbon neutral, but carbon negative**. However, these calculations are estimates based on various scientific articles (Appendix 45). For a more accurate assessment of its environmental impact, a holistic approach such as a Life-Cycle Assessment (LCA) conducted by a professional using software like SimaPro is needed. This would consider all internal and external environmental processes of PullIt's entire lifetime.

Partial conclusion

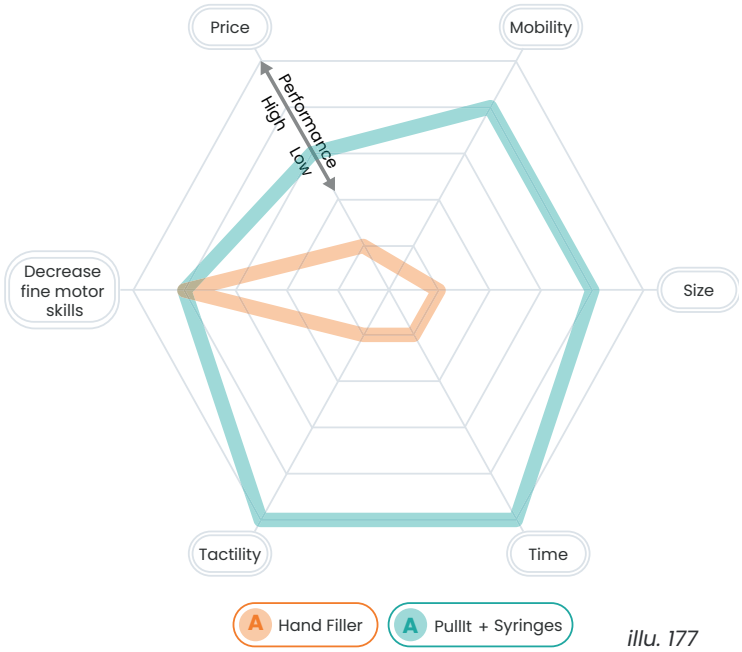
PullIt embodies all three aspects of sustainability. Economically, it offers a profitable business opportunity for byLink and stakeholders. Socially, it assists nurses by alleviating pain, optimizing workflow, and enhancing patient safety. Environmentally, PullIt contributes to responsible consumption and production patterns in the Danish healthcare sector, particularly in syringe usage, while also legitimizing materials and emissions, resulting in a negative carbon footprint.

Market Fit

Is Pulllt competitive?

To assess **Pulllt's competitiveness and product-market fit** (Haase, 2022) for syringe extracting and injecting products, a **modified spiderweb diagram from the Market Analysis** was used for comparison. Discussion with syringe manufacturer BD (Appendix 16) revealed that Pulllt doesn't compete with various syringe designs like VacLok and spring-controlled syringes due to their too high cost as a disposable syringe. Furthermore, **Pulllt is not a redesign but an additive product**, why it is dependent on the syringe. Instead, Pulllt's **competitors** are additive products such as the **Handfiller and air vent mini-spikes from B. Braun**. Note that Pulllt are **still perfectly compatible with the usage of Mini-spikes, and it is recommended to use both Pulllt** and a mini-spike simultaneously for an even greater reduction in finger strain.

Pulllt effectively solves the issue and significantly **reduces the need for fine motor skills, comparable to the larger Handfiller solution** by B. Braun. **Unlike Handfiller, Pulllt maintains tactility and good control**, making it ideal for other assignments such as gastric suction. Its syringe interface design allows **easy attachment and detachment,** optimizing nurses' workflow and **saving time**. Pulllt is **much smaller in size and handier than the Handfiller and fits perfectly onto the medicine mixing table** and into the nurse's workflow, **not comprising the mobility** of the nurses when they use it and transport it.



illu. 177

Furthermore, the **wrap-design almost blends in with the syringe, so the nurses can move the syringe as usual without any inconvenience making this solution much more likely to be adopted**. ByLink plans to sell 0-Series at a low profit margin to quickly enter the market and generate momentum. **With no direct competition, Pulllt fills a market gap**, **priced at 599 DKK**, significantly **lower than the Handfiller's 6,500 DKK**. With Pulllt's profit margin byLink can further reduce the price without losses, facilitating competitive pricing if needed. This strategy applies to SLS 3D printing.

Partial conclusion

Pulllt addresses a gap in the market with no real competition for the 50 mL syringe problem, potentially entering a blue ocean. ByLink can initially price the product with a high profit margin of 61%.

Future Scaling

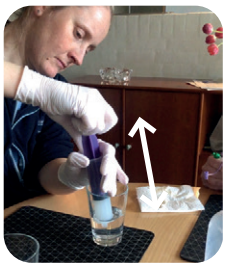
Is Pullit feasible for byLink?

Hospitals are not the only instance where syringes are used, meaning that Pullit's have **the potential to scale horizontally into other work contexts and scenarios**. Currently Pullit is **designed for medicine mixing, excelling in both upward and horizontal syringe extractions** and offers great control and tactility. Due to these features it has received **positive feedback for gastric suctioning and catheter flushing**, where horizontal extraction and injection is common. These assignment require a significant force, precise control and tactile feedback to ensure patient safety. (Appendix 19 & 41)

illu. 178: Variants: tube food, 20 mL, Colours

illu. 179: Upward

illu. 180: Horizontal



illu. 181: Different Grip

Pullit was initially planned to include the **tube feeding scenario** in its design, as outlined in Design Briefs 1 and 2 (Appendix 7). However, it **requires redesigning due to ergonomic issues.** When nurses extract tube food, they sit at a table and extract upwards, affecting hand, arm, and shoulder differently ergonomic wise. **The grip changes**, causing the index finger to improperly slot into the wing which currently is designed for the little finger. Additionally, the syringe tip is submerged, **making it difficult to hold and counter act the barrel while extraction**. This could **be addressed by moving the syringe interface forward on the handle** for better barrel access.

Other **potential markets** for Pullit include nurses in various departments beyond Intenive Care, Anaesthesia, and Neurology; **veterinarians working with farm animals or pets** (VikingDanmark, 2024); **laboratory workers** using a variety of syringes, including 50 mL (Hounisen, 2024); and **hospital pharmacies** mixing medicines with syringes (Sygehusapoteket, 2024). These diverse use cases suggest the **possibility of developing a product family to cover all contexts.** Pullit could be scaled and **redesigned for 20 mL syringes** if demand rises. **Switching to injection moulding in implementation phase 2 could allow for different color** to distinguish between 50 mL and 20 mL Pullits, or to indicate a left-handed version, providing visual feedforward to nurses.

Partial conclusion

Pullit has use cases beyond Intensive care and Anaesthesia medicine mixing, including assignments like tube feeding, which could be accommodated with design tweaks. These changes would likely result in a product family to maintain functionality in medicine mixing. Potential markets such as veterinarians, laboratory workers, hospital pharmacies, and nurses in other departments are yet to be explored. Separate colour schemes for different versions, like a 20 mL or left-handed edition, would provide clear visual identification for nurses creating better affordance.

8 Epilogue

The epilogue summarizes and reflects upon the overall fulfilment and execution of requirements in the proposed solution as well appropriateness and elaborateness of the processual approach and strategy towards the projects itself. A reference list along with a list of illustrations follows this, thus completing the process report of the master thesis.

Conclusion

What is the outcome?

This master thesis culminates four months of work focused on designing a professional, adoptable hand tool for nurses in the Danish healthcare sector. The tool, PullIt, aims to prevent musculoskeletal disorders and provide relief by assisting hospital nurses in extracting and injecting 50 mL syringes during medicine mixing. Developed in collaboration with 25 nurses, various experts, and byLink, PullIt intends to improve nurses' health, safety, and quality of life.

Product adoption and product user-fit have been the most complex and crucial part of the projects' development process. The main focus has been here to ensure a solution that has real-world usability for the nurses. A successful adoption of PullIt hinges on three main factors: enhancement of comfort, preservation of time-efficiency and ensuring safety.

Enhancement of comfort

PullIt is designed to decrease strain and discomfort in the fingers by removing the need for fine motor skills, dividing the forces upwards of 73 N across both hands and into biceps, triceps and deltoid, as endorsed by occupational therapists and physiotherapists alike. The wing and shape of the tool encourage appropriate ergonomic use by affording a straight pulling motion from the hand to the elbow ensuring the shift of strain. PullIt helps injured nurses perform medicine mixing without using their injured fingers and optimises workflow for non-injured nurses by solving sub-problems like syringe balancing. This extends both segments time in the labour market creating quality of life as well as a more robust health care sector. PullIts is designed with a feel of quality and durability, yet lightweight and small, weighing just 94 grams. With a surface area of merely 35 cm2 when standing upright, PullIt occupies less than 5 % of the medicine mixing table. Thus, making it easy to maneuverer while maintaining the nurse's 360-degree free mobility when using a syringe. The product aids in both the extraction and injection processes, fitting 50 mL Luer Lock syringes from the two major brands on the Nordic market: BD and B. Braun, and possible other brands, because of the standardisation of syringe designs.

Preservation of time-efficiency

PullIt's manual, simple and user-frendly use fits seamlessly into the nurses' time-efficient workflow of medicine mixing. Additional interactions are justified by eliminating strain and balance related workaround, making the combined timespan of retrieving, attaching, injecting, extracting, and detaching the syringe competitive with current practices, as 45 second, equivalent to 17% are saved. Thus, allocating more time to tend the patient or other tasks. PullIt's guide chute and interface make attaching and detaching syringes easy, while ensuring a firm fixation

throughout the assignment, including during bubble tapping. The small, wrap-like form factor blending in with the syringe ensures that the mL scale is always visible while allowing rotating during attachment of various Luer Lock equipment such as needles, mini-spikes, and venflon.

Ensuring safety

PullIt's shape aims to ensure cross contamination safety by covering the syringe barrel minimising the risk of touching the flanges of the plunger. With its physical empowerment nurses are yet again able to use filter needles elevating patient safety by eliminating the chance of glass shard from the ampoule in the medicine. As PullIt is an extension of the nurse's hand, it provides the tactile feedback needed when feeling resistance during tasks such as gastric suctioning and catheter flushing, thereby maintaining patient safety. Produced in Nylon 12, with a vapour smoothed finish, the tool is optimised for cleaning with a rounded and smooth aesthetic as fitting for hospital equipment. The surface finish has a consistent black colour, on which speckles can be seen, reduces bacteria growth and is resistant to heat exposure during instrument washing as well as relevant chemicals: chlorine, alcohol, soap and saltwater. Resistance to medicines will be tested through longer use in the 0-series. With a short introduction, it is easy to decode and operate PullIt, directed by the flow lines, guide chute, and interface, with the latter having a visual recognisability with the interface of a syringe pump. When interacting with PullIt it allows for operation with plastic gloves and gives the nurse a professional look and provides them with a feeling of control over the situation. Making them the experts in their own product, highlights their perceived professionalism creating a composed, safe and orderly.

Economic and Environmntal Sustainability

To achieve a 0-series pre-production run of PullIt within four months, collaboration with byLink was essential for access to their industry insights, network and sales channels as investor in and vendors of PullIt. Consequently, PullIt needs to have a good product company-fit and align with byLink's DNA and current product portfolio for this ambition to be possible. The solution is economically feasible for byLink by avoiding medical equipment certification, as verified by a MDR expert, and keeping the cost price low through a two-phase business strategy. PullIt's wholesale price of 599 DKK is a cheap investment for the hospital departments giving it momentum potential at market entry. The initial market strategy and implementation plan involves a bottom-up word-of-mouth approach driven by nurse ambassadors with a focus on work environment improvements. While environmental sustainability is not the primary focus in the health care industry, it has become increasingly important. PullIt aligns with this priority through reusability, equipment savings, and a justified carbon footprint. By making the 20 mL syringe workaround redundant, an implementation of PullIt in the Danish health care sector would annually save 5.25 tonnes of plastic and ¾ tonnes of stainless steel, with each PullIt yearly saving 18.6 kg of CO2.

PullIt arrives at an opportune moment, addressing a pressing and acknowledged need for a better work environment in the healthcare sector with proven interest and presales. It represents a realistic, impactful product that improves nurses' everyday work conditions, addresses significant Danish health care expenditures of 2.6 billion DKK yearly spent on nurses with musculoskeletal diseases, and sets a precedent for future innovations in work environment tool design for the health care industry.

Reflection

What did we learn?

Entrepreneurship, Design Thinking and byLink's influence

As we wanted to realise a product in four months the project had a dual utilisation of entrepreneurial methodologies and Design Thinking. Entrepreneurial strategies such as bird-in-hand, lean-startup, reflection-in-action, build-measure-learn loops and low fidelity prototypes guided large parts of the project to accelerate the process. The bird-in-hand principle was frequently applied, leveraging byLink's and our own networks to connect with various experts and users. This led to the quick rejection of a spring-based solution, enabled prototyping with Arduino normally beyond our skill set as well as kickstarting the continuous user-feedback. Lean-startup approach to business strategies was necessary to ensure a product which byLink had the financial resources to realise. The two-phase implementation plan was made to keep the costs low while testing the product market fit catering to a small company. Collaborating with a larger company with a bigger affordable loss could have changed the business strategy starting directly with an injection mouldable design. Partnering with byLink also had other profound impacts on the solution space. One of the significant decisions, also consequently of the pragmatic entrepreneurial approach, was the premature dismissal of the electrical concept. Due to bad initial user reception in combination with byLink's preference to avoid medical equipment, aiming for faster and more economical feasible implementation this solution was rejected. Despite nurses showing the most enthusiasm for PullIt, the electrical solution might have been more effective in reducing hand strain. This decision illustrates the consequences of entrepreneurial approach where time constraints can be the deciding factor of the project direction and trade-offs are made when comparing product company-fit, user-fit and market-fit. While byLinks involvement impacted the solution space their industry insights and network provided invaluable support, functioning practically like an additional supervisor. Their feedback helped us navigate the industry's nuances and align our design with the actuality of the real world and accelerated the project beyond just a 'proof-of-concept' but to the point of 'proof-of-sale'. The usage of entrepreneurship freed up valuable time to use Design Thinking methodologies when necessary, such as reflection-on-action, user emphasization, and PDCA Quality Cycle at deliberate points to have a deeper engagement in the detailing and realisation of the product. The users were thoroughly understood by a multitude of situated interviews but in particular by meticulously shadowing the specific scenarios. The quality cycle was used in optimisation of ergonomics, interface and price of SLS-printing, producing more than 51 3D-printed prototypes of the handle concepts alone.

The wickedness of product-fit

The design of PullIt seems straight forward but involves significant complexity due to the need of balancing product user-fit, product market-fit, and product company-fit for a sustainable and sound product. Thus, being a prime example of the fact that simple products like PullIt often are the most difficult to get right. Each product fit had unique needs and requirements, highlighting the intricacies of addressing a wicked problem, where all solutions are debateable and a series of compromises. As the problem uncovered and evolved so did the solution space. Meaning the design should be adapted, which at times could feel demotivating and like starting from

scratch. Exemplified by an injured nurse's dismissal of the handle's wrap design making us realise the neglection of those who it could aid the most, resulting in a cascade of design changes. However, this co-evolution is in fact the nature of handling wicked problems.

Participatory user involvement versus expert mindset

Continuous user involvement proved to be crucial and was employed using various user emphasization techniques such as situated interviews, simulated use, acting out and shadowing. Leaving prototypes with users for extended periods of time helped identify practical issues beyond the initial excitement phase of testing. However, our rapid development pace sometimes outpaced the departments' ability to test the prototypes thoroughly, making long-term feedback less influential. When feedback arrived, three to four iteration improvement cycles had already been completed, rendering some feedback obsolete. Our user involvement strategy revealed gaps, particularly in selecting test subjects in the beginning. Testing with younger, less pain inflicted nurses delayed the recognition that the design did not properly address the needs of those with severe pain in the fingers and hand. These nurses will be the primary ambassadors for the product's word-of-mouth, bottom-up marketing strategy, making them the most crucial user segment for byLink to cater for. Future projects should prioritise, and more careful sampling of relevant test-subjects from the get-go to ensure timely, accurate and design effective feedback. In this regard balancing participatory and expert mindsets was essential throughout the project. While byLink's user-driven approach made nurses co-designers, we also acted as experts in validating critical aspects of the design. For instance, we took a conscious decision of not concentrating on nurses dismissing the problem, as we through own research, and supported by external ergonomic experts, knew the problem was inevitable in their future and thus latent. Luckily, we were later contacted by the departments that first dismissed the problem with a newfound interest in the project, as they started to recognise it in their daily tasks. Thus, validating that the existence of a solution would, in itself, create its own demand by bringing attention to the problem. This balance helped maintain a rigorous design process while incorporating valuable user insights.

Realisation equals compromises

Compromise emerged as a fundamental aspect of realisation. Every decision involved trade-offs, teaching us the necessity of balancing various factors to achieve a viable product. Early inclusion of production considerations and construction calculations helped prevent unrealistic designs, though it sometimes led to time-consuming optimisations when designing for manufacturing within the constraints of SLS printing. Time which could have been allocated to problem space exploration. Another example is the decision of splitting PullIt into two to keep production costs low with potential sanitary compromises which should be tested further. Other compromises include: aesthetic design vs ergonomics and non-design; price vs ambidextrousness; fast attachment and detachment vs syringe compatibility; company-fit vs solution space.

This project highlights the importance of balancing entrepreneurial and design thinking approaches, continuous user involvement, and strategic compromises, when solving a wicked and complex problem within the health care sector. While there is still room for improvement in the form of surface modelling, a slightly aesthetically disjointed wing, and data driven verification of strain reduction, PullIt adequately address a real-world problem, and is a small step towards a sustainable health care sector.

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List of Illustrations

All illustration not mentioned below by number are self-produced. As are front and back cover as well as the picture of the design team and chapter covers.

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60
ml
50
40

PullIt

no strain no pain

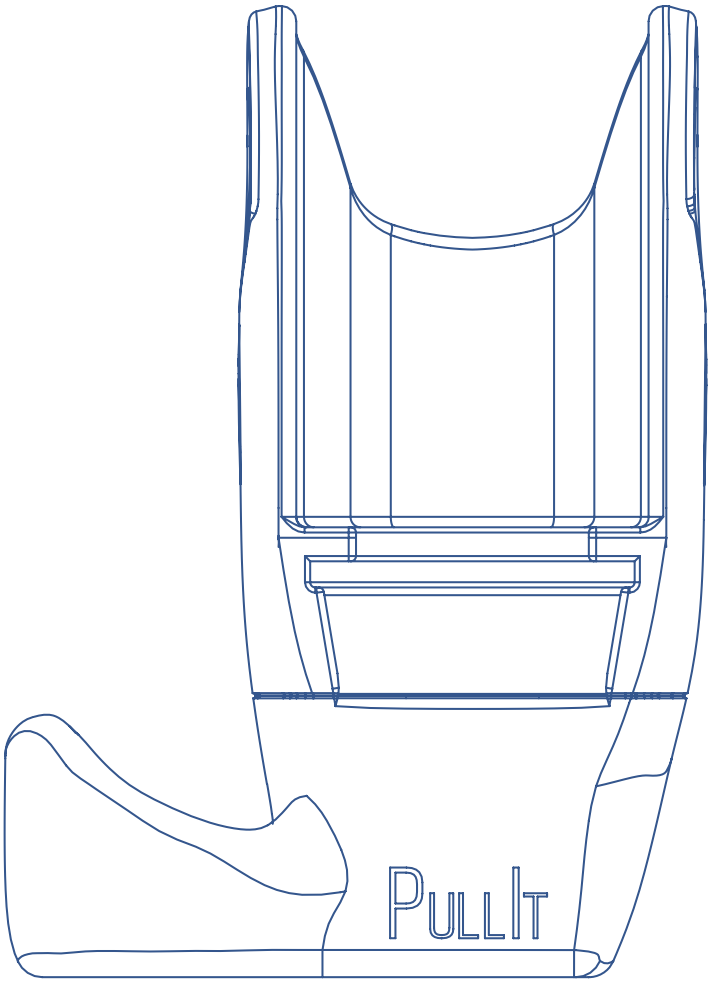
Technical Drawings

ma4-id1 June 2024

Jens Øbro

Sophia Rytter Møller

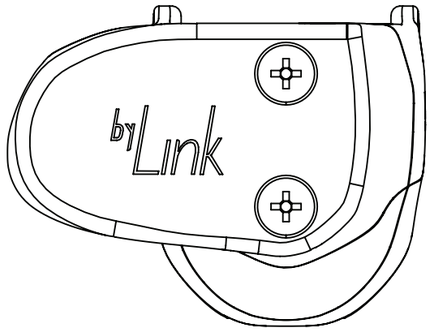
Christoffer Agesen Valsted

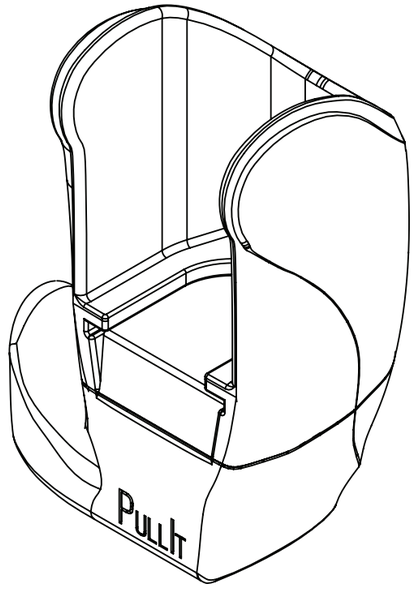


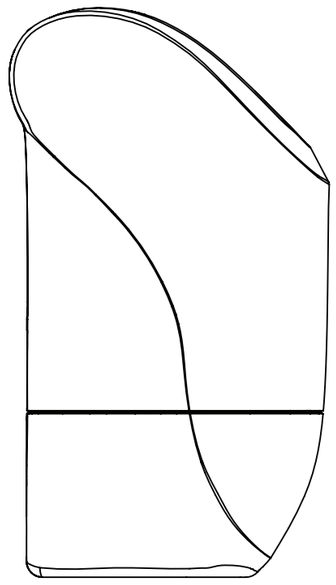
Introduction

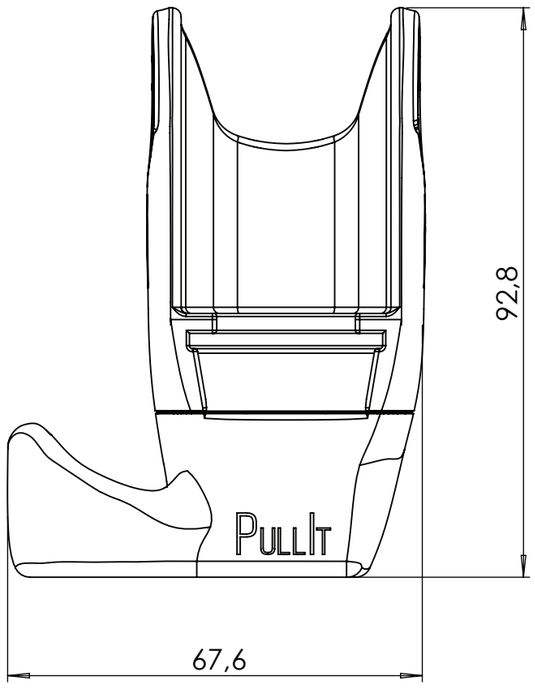
This folder contains technical drawings of the product Pulllt. These drawings include assembly, exploded view, section cuts, BOM, etc. These drawings are meant to be used as way to conceptualise the product proposal and not used for manufacturing it. For manufacturing, because of the complex surfaces, an SLS printer will be used which requires an STL-file exported from CAD-software.

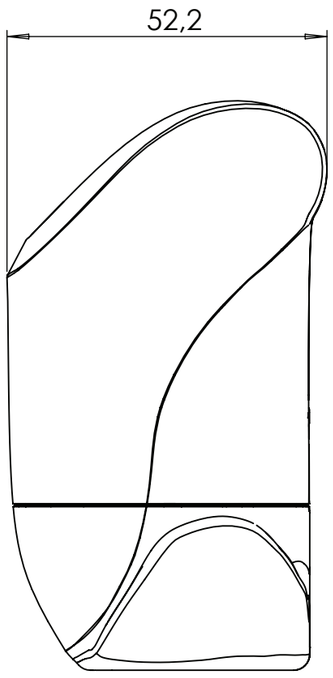
Drawing overview

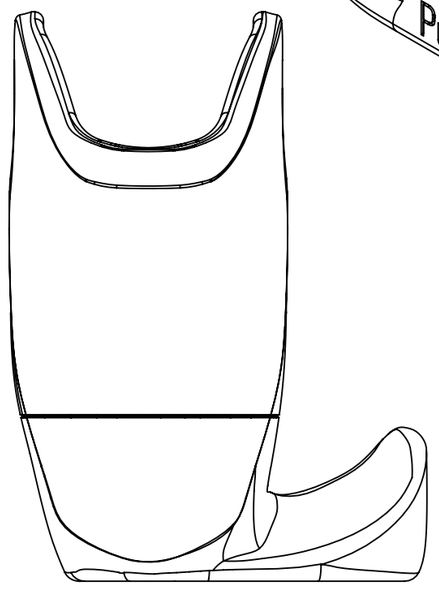


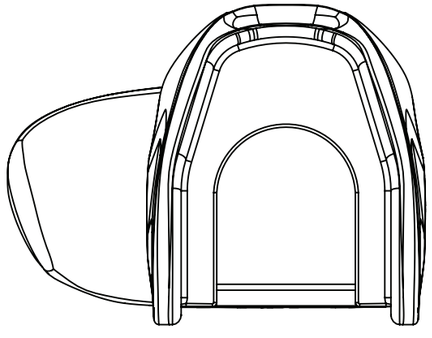




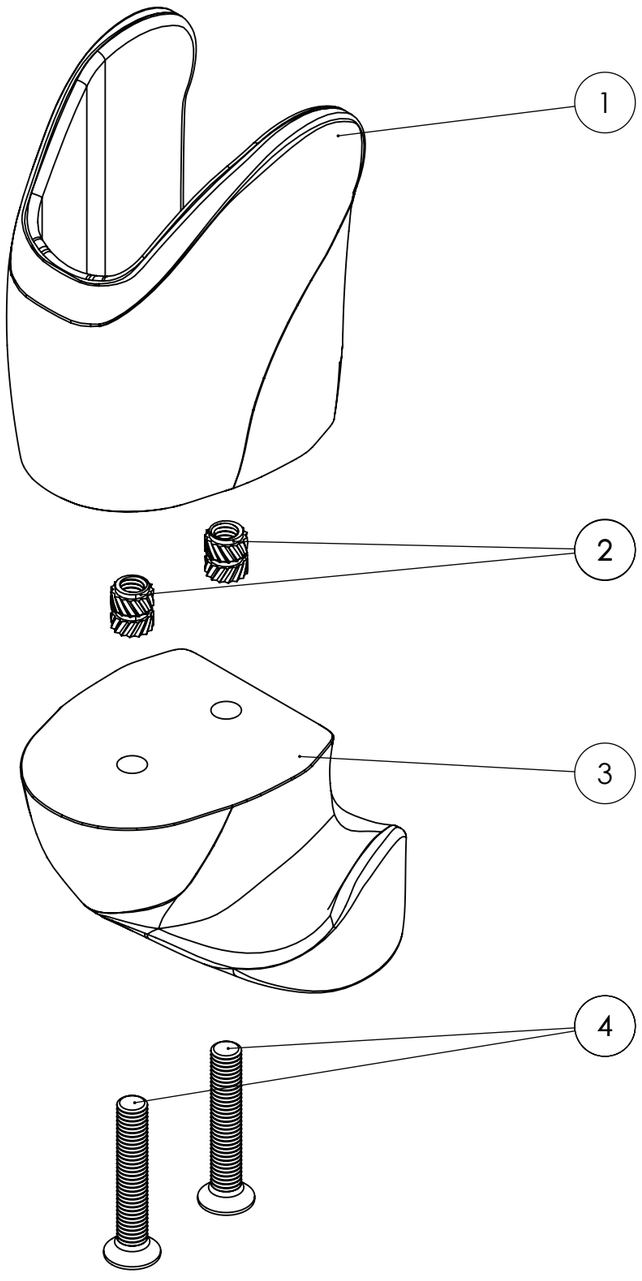






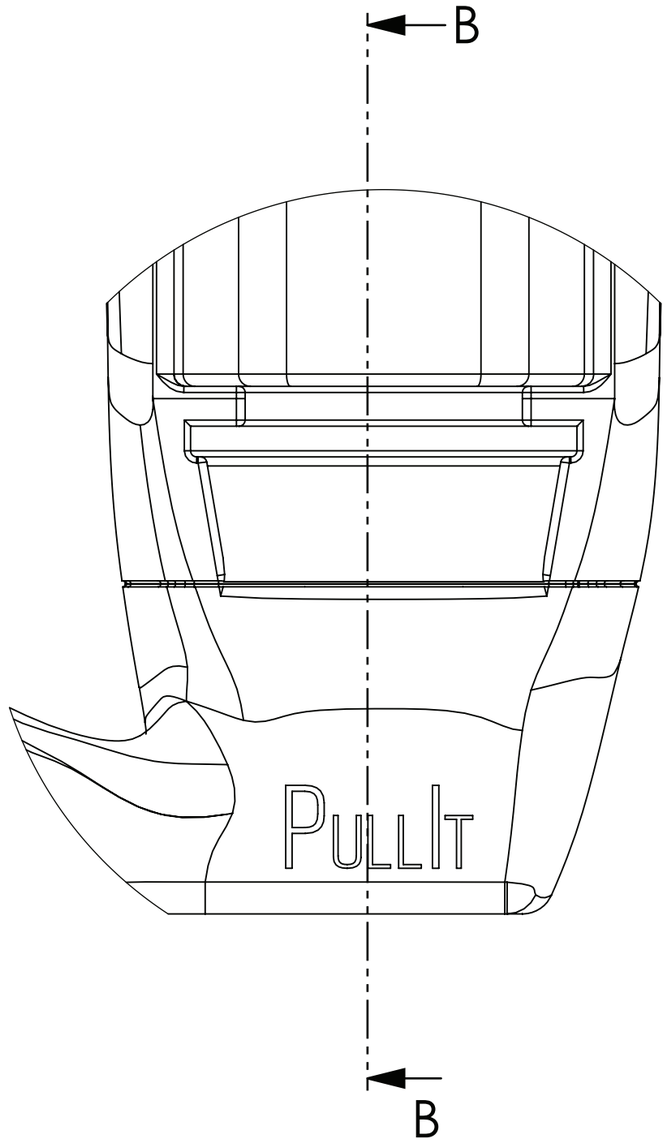


FINISH: Vapour Smoothing	DO NOT SCALE DRAWING	REVISION 1
	PullIt	
DATE 28-05-24	TITLE: PullIt Assembly	
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm		
MATERIAL: Nylon 12 SLS	DWG NO. 1	A3
WEIGHT: 94 g	SCALE:1:1	SHEET 1 OF 6



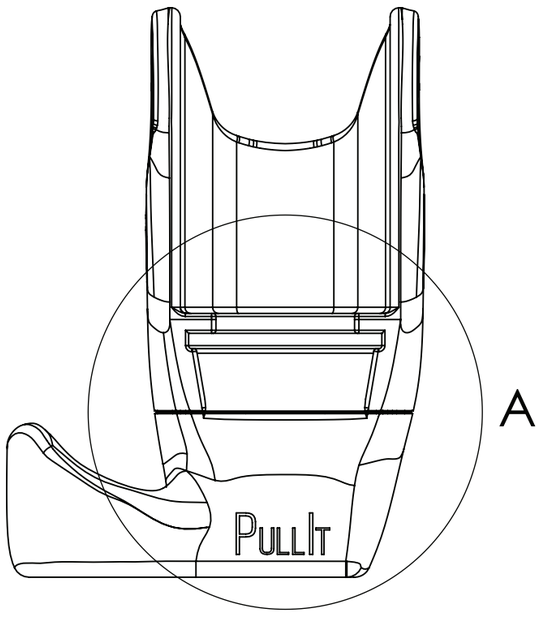
ITEM NO.	PART NUMBER	Material and finish	QTY.
1	Pulllt Body	Nylon 12, Vapour Smoothing	1
2	Threaded Insert M5 Ø7mm L8mm	Brass, Natural	2
3	Pulllt Wing	Nylon 12, Vapour Smoothing	1
4	Countersunk flat head Phillips Bolt M5 x 30mm	Stainless Steel A4 316, Naturel	2

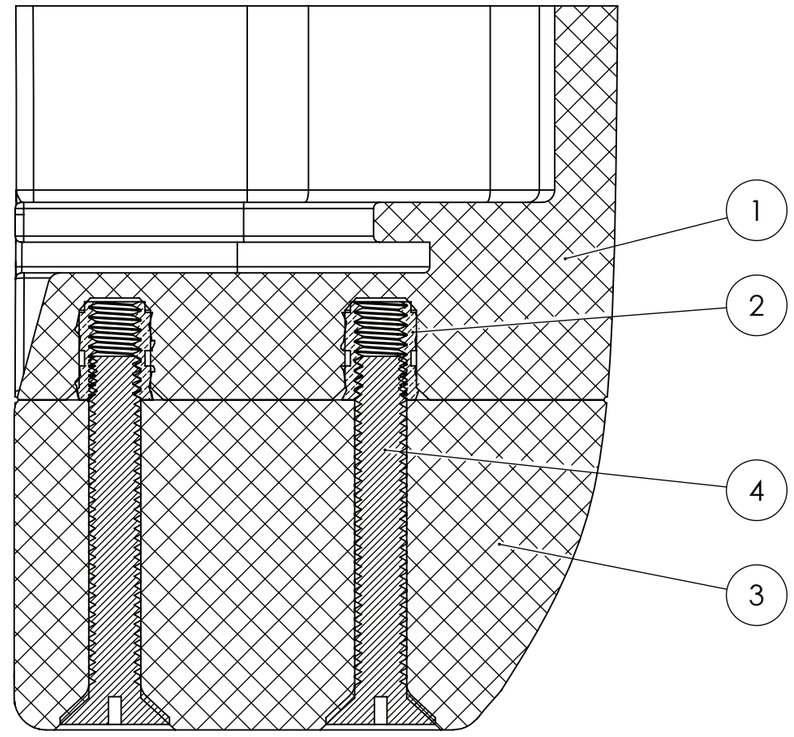
FINISH: -	DO NOT SCALE DRAWING	REVISION 1	
	Pulllt		
DATE 28-05-24	TITLE: Pulllt Exploded View and BOM		
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm			
MATERIAL: -	DWG NO. 2		A3
WEIGHT: 94 g	SCALE:1:1	SHEET 2 OF 6	



DETAIL A

SCALE 2 : 1





SECTION B-B

SCALE 2 : 1

FINISH: -	DO NOT SCALE DRAWING	REVISION 1
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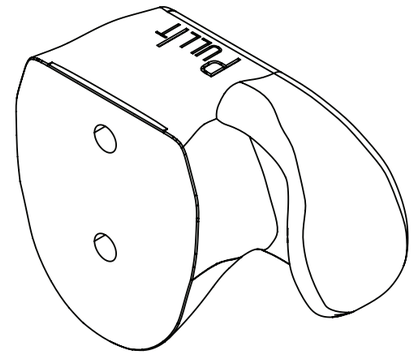
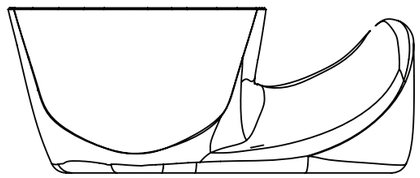
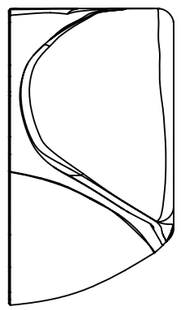
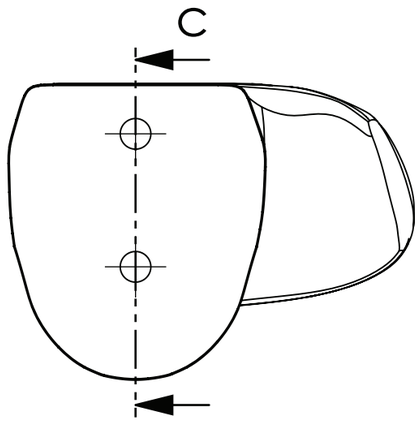
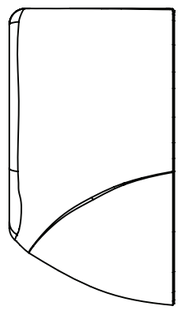
DATE 28-05-24	TITLE:	
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm	Pullit Assembly Section Cut	
MATERIAL: -	DWG NO. 3	A3
WEIGHT: 94 g	SCALE:1:1	SHEET 3 OF 6

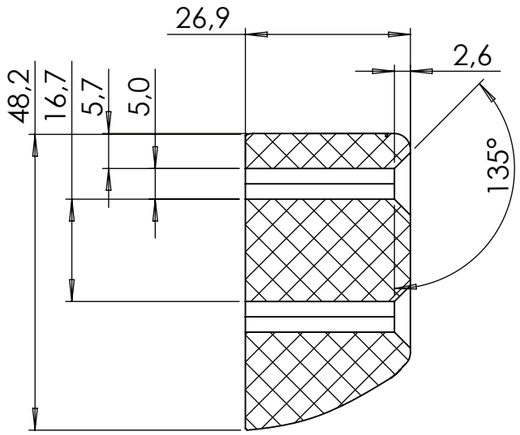




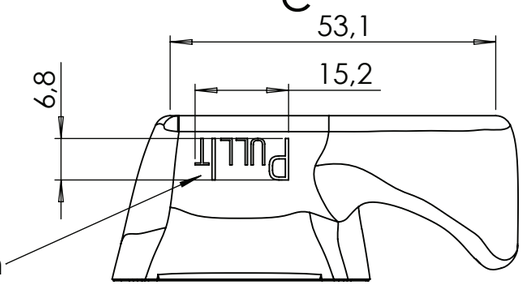


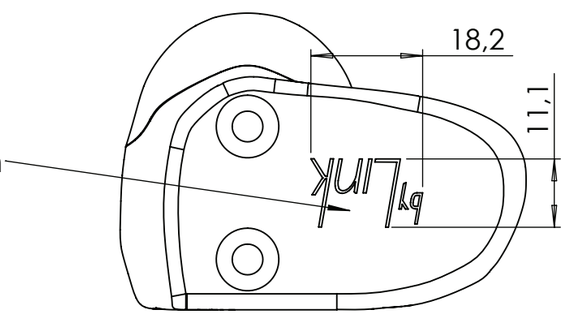




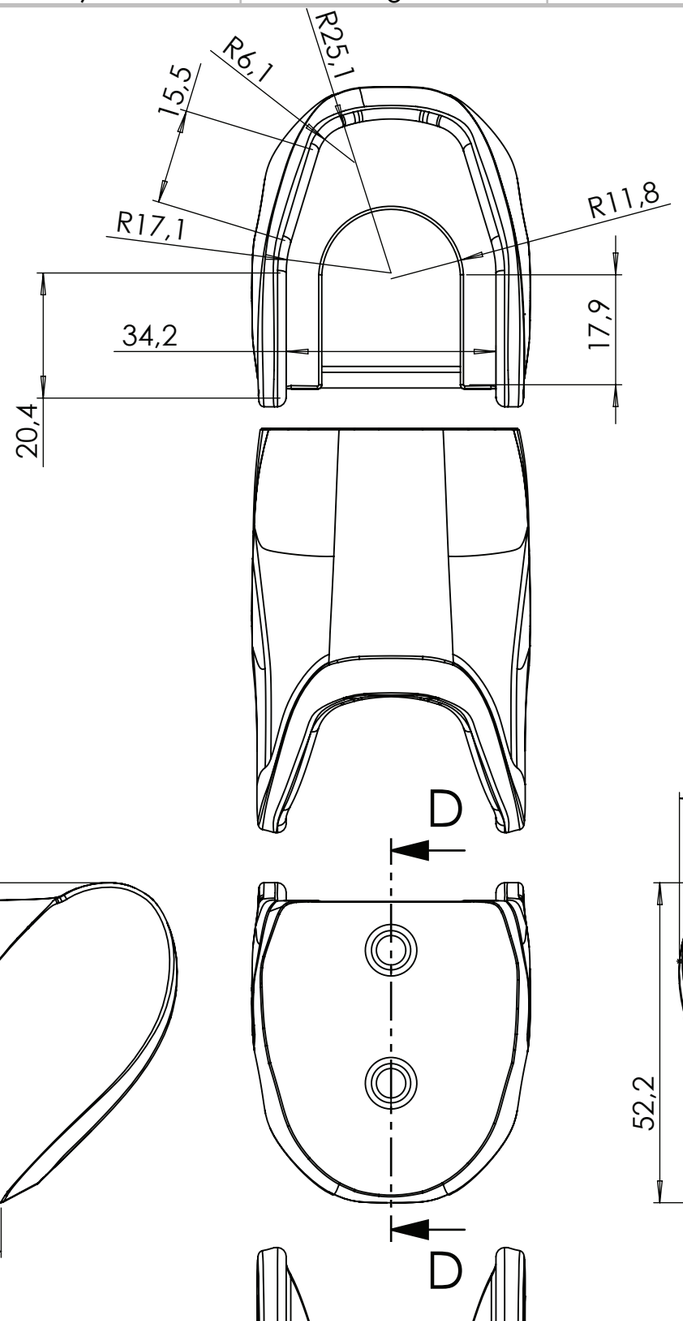


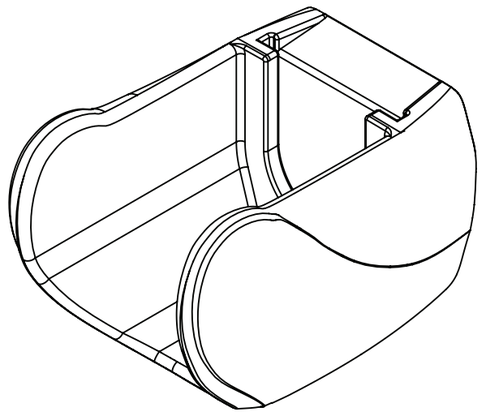
SECTION C-C

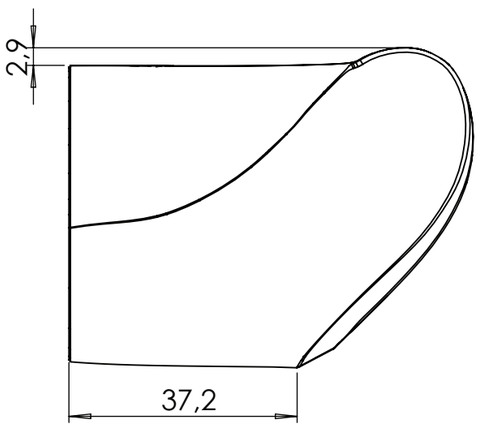


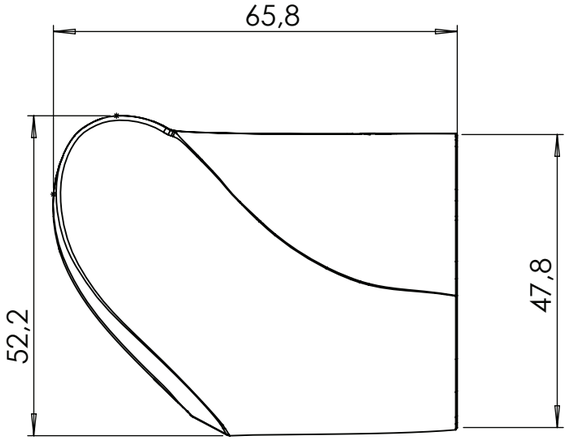


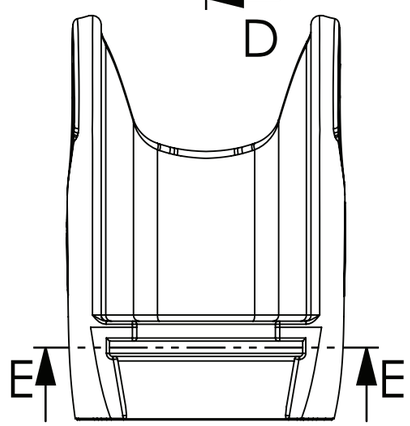
FINISH: Vapour Smoothing	DO NOT SCALE DRAWING	REVISION 1
	Pullit	
DATE 28-05-24	TITLE:	
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm	Pullit Wing	
MATERIAL: Nylon 12 SLS	DWG NO. 4	A3
WEIGHT: 45 g	SCALE:1:1	SHEET 4 OF 6

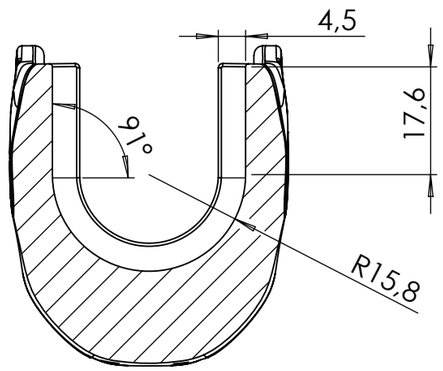




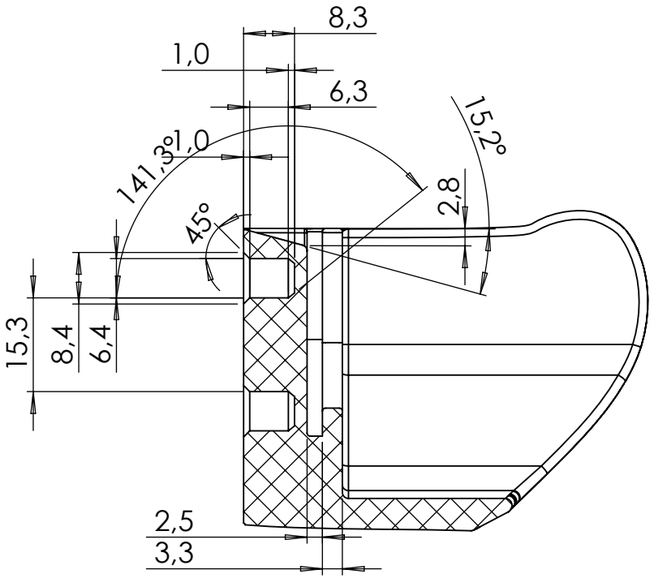






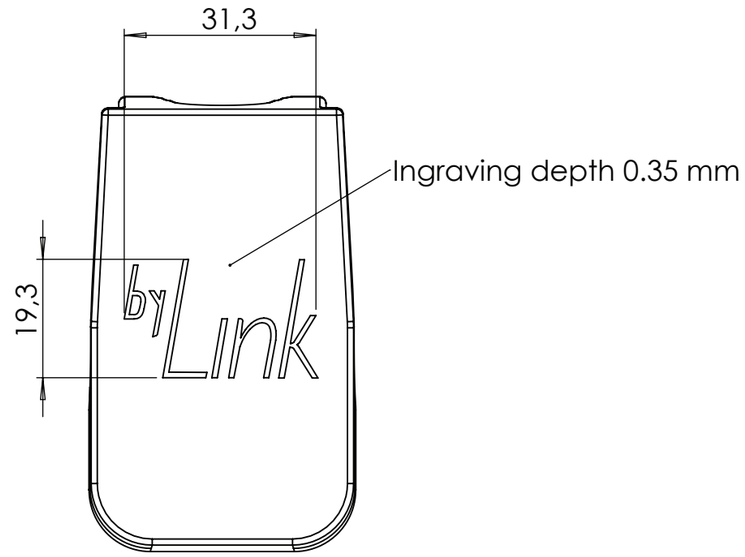


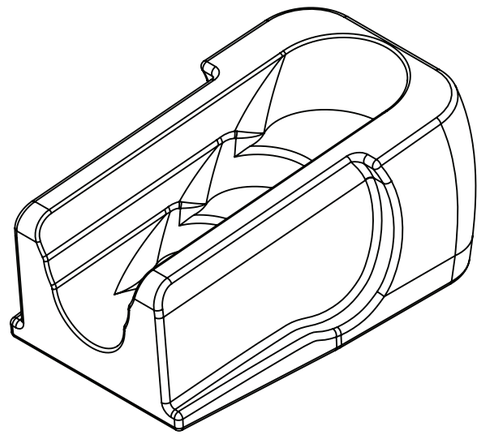
SECTION E-E

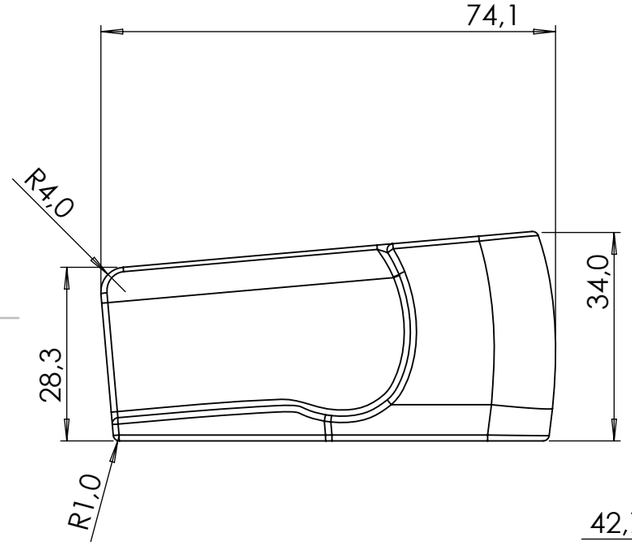


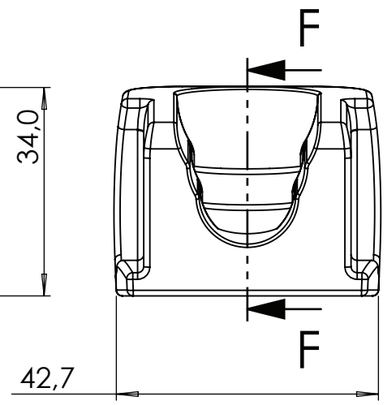
SECTION D-D

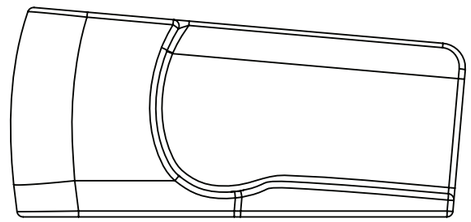
FINISH: Vapour Smoothing	DO NOT SCALE DRAWING	REVISION 1
	Pullit	
DATE 28-05-24	TITLE:	
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm	Pullit Body	
MATERIAL: Nylon 12 SLS	DWG NO. 5	A3
WEIGHT: 44 g	SCALE:1:1	SHEET 5 OF 6

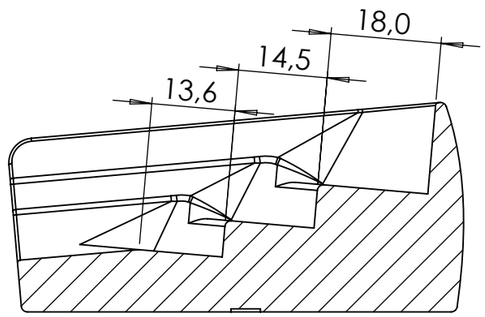




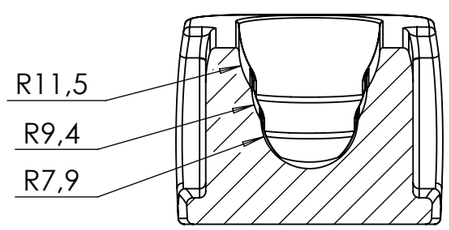




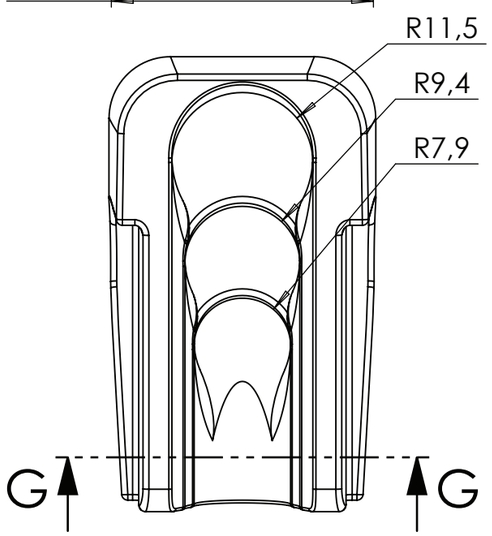




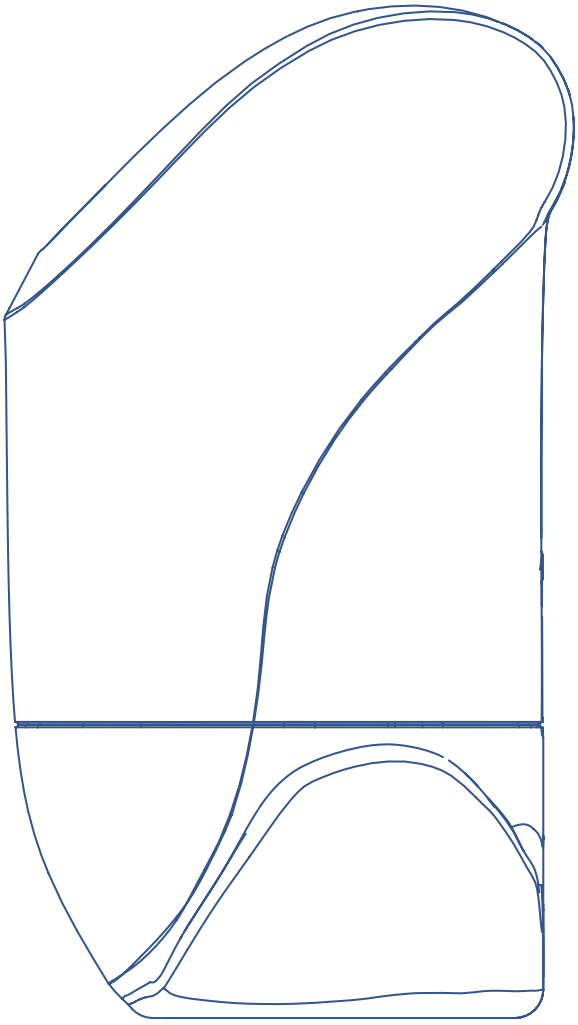
SECTION F-F

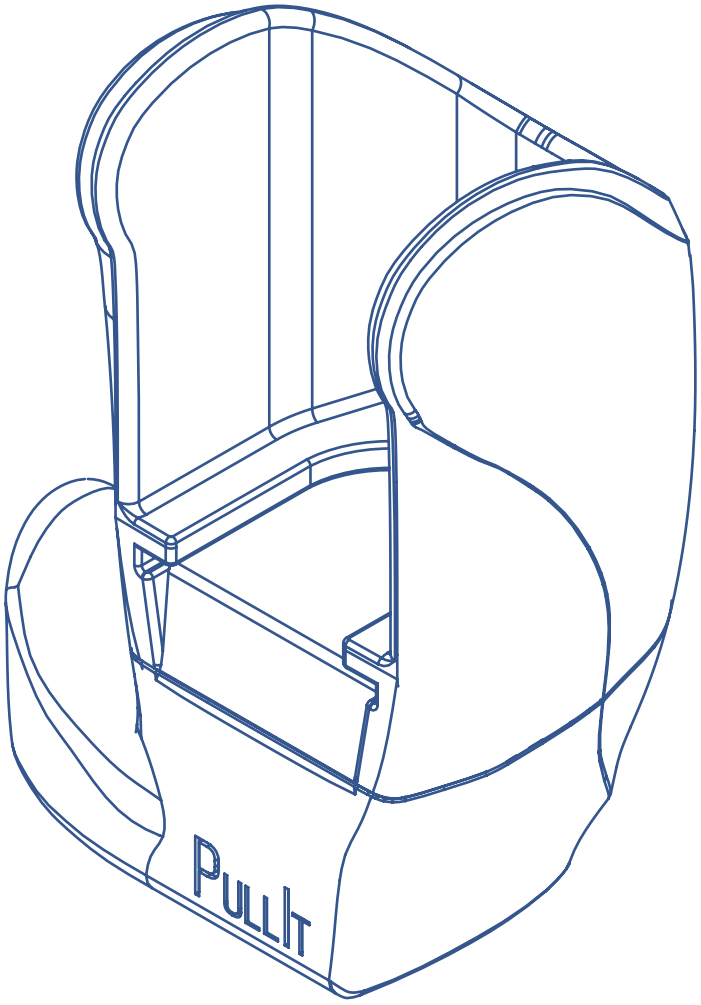


SECTION G-G



FINISH: Vapour Smoothing	DO NOT SCALE DRAWING	REVISION 1
	Pullit	
DATE 28-05-24	TITLE:	
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS TOLERANCES: ± 0.1 mm	Pullit Ampoule Holder	
MATERIAL: Nylon 12 SLS	DWG NO. 6	A3
WEIGHT: 51 g	SCALE:1:1	SHEET 6 OF 6





by Link