SPORT BRA

FOR COMBAT AND CONTACT SPORTS

Project title:

Sport bra for combat and contact sports

Design discipline:

Industrial Design

Theme:

Sport equipment, performance, ergonomics

Diploma candidate:

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Supervisors:

Hilde Angelfoss
Stein Rokseth

ABSTRACT

According to recent studies — exercise induced breast pain is a common problem, at a degree that it affects athletes` performance or even perceived as an obstacle for participating in activity for some women. (1, 2)

Adding to that frequent physical impact and higher probability of injury in contact sports, makes it a good opportunity to look, how can I as a designer create favourable conditions for women to pursue their passion with confidence.

The research and development of the project is based on existing sportswear designs, biomechanical considerations, and athlete feedback to identify key design features necessary for enhancing comfort, support, and protection during high in contact physical activity. Through iterative design process, project integrates experimentation in materials and ergonomic principles.

This project aims to develop a sport bra that not only minimizes discomfort and potential injury risks but also enhances athletes' confidence and performance. The outcomes include functional and visual models, sewing pattern, visualisations, and reflections for future development.

CONTENT

BACKGROUND

BREAST STRUCTURE

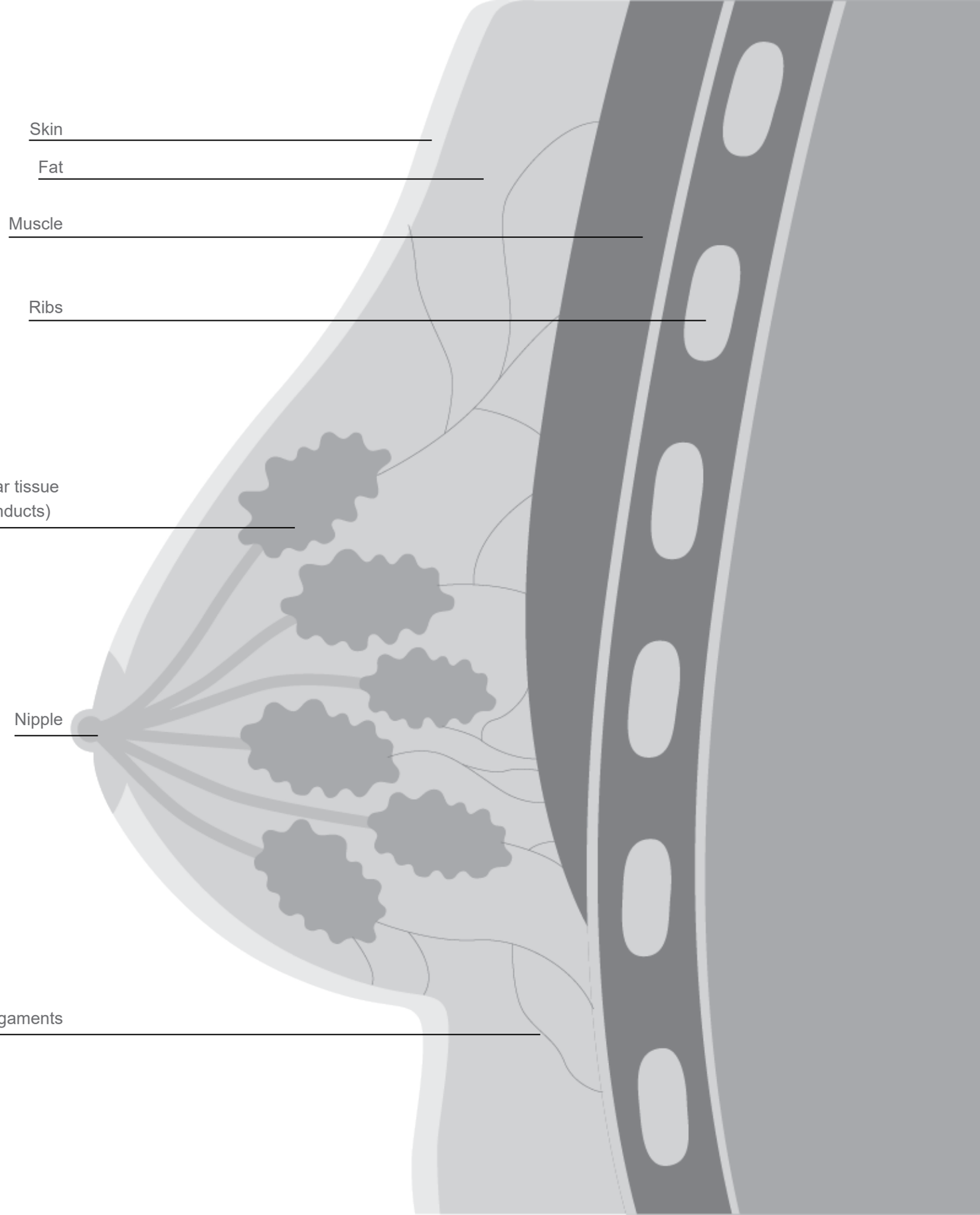
Naturally breasts have little support structure. It is mostly supported with some ligaments, fat and skin tissue. When muscles and skeleton lay underneath this mass.

Low muscular and skeletal support of the breast has two major outcomes when it comes to physical activity:

First is breast movement that appear during intense activity and can cause discomfort or breast pain.

Second is vulnerability of breast tissue to direct impact and as a result possible injury.

(2. https://keepyourbootson.co.uk/wp-content/uploads/2023/07/Breast-Health-v2.1-July-2023.pdf)



BREAST MOVEMENT

“Indeed, for female athletes, a well-fitted and supportive sports bra should be considered an essential piece of sporting equipment”

(1. Biomechanics of Breast Support for Active Women, 2020)

A good support provided with a bra is truly important for comfort and respectively performance of the athlete.

Multiple sources point at the problem that big percentage of active women face problem of breast pain during exercise. In some cases, it even perceived as an obstacle to participating in activity. (2. https://keepyourbootson.co.uk/rugbysafe-toolkit/women-girls-healthcare/)

In the study about assessment, advising and customising sport bras was found that:

1) 51 % of women experienced breast pain

2) after bra assessments athletes often reported enhancement in their performance. (3. Research in Sports Medicine, 2023)

Which shows that properly fitted supportive bra can improve women experiences with sport.

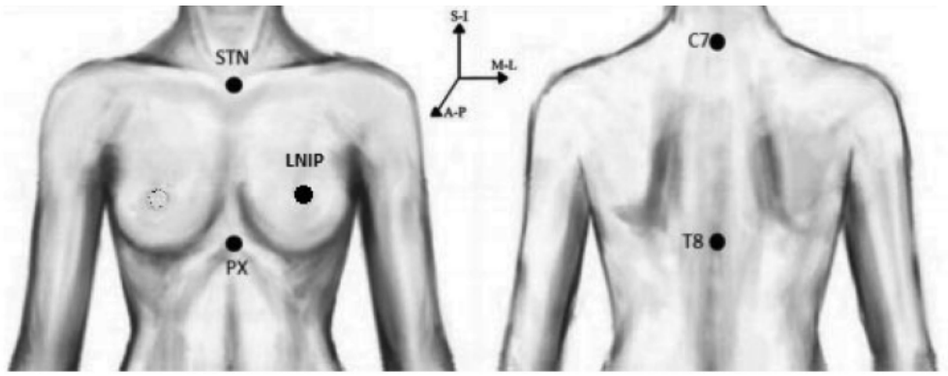


figure 1. A configuration of sensors, used for measuring breast movement in biomechanics research

And what are the reasons for this problem remaining so major?

There are several factors contributing to this. One of them is lack of knowledge and education on the topic. Another one is poor standardization of bra parameters. And one more factor is inadequate bra designs — area that this design project will be focusing on. (1. Biomechanics of Breast Support for Active Women, 2020)

BREAST INJURIES

Breast injuries have been considerably underreported previously, however more recent studies show, that about third part of female athletes' experience breast injury during their activity.

In study about the occurrence, causes and perceived performance effect of breast injuries in elite athletes 36% (n = 182) of the participants reported experiencing breast injury and only 10% of these participants (n = 18) reported their breast injury to a coach or medical professional. (4. J Sports Sci Med. 2019)

WHAT ARE BREAST INJURIES?

Most of the injuries are caused by a friction, often from ill fitted bra. However, it also includes bruising and hematoma.

WHY IS THAT A PROBLEM?

First and foremost, as it was mentioned before, experiencing any trauma or injury have considerable effect on performance of the athletes.

Second, trauma to the breast can have several possible complications such as hematomas, oil cysts or fat necrosis. Those are lumps formed from scarring tissue during process of healing.

Some people can experience tearing or direct injury to the mammary ducts, which could affect the future or current flow of breast milk. These are rare, but potential, complications associated with breast trauma.

Important to mention, according to American Cancer Society, that these lumps do not increase risk of cancer. (5. https://www.medicalnewstoday.com/articles/322817)

However, they need to be distinguished from other lumps on the screening tests.

Designing a bra that would fit perfectly for any kind of activity will be nearly an impossible task, as different sports will have different sets of requirements to a product. And after advising with my supervisors, I decided to focus on one or similar direction disciplines.

Seeing the possibility of injuries in combat or contact sports, I decided to narrow down my scope specifically to combat and contact sports, as design in this area could have the biggest impact.

According to statistics of breast injuries, combat and contact sport is the area where this design project can have biggest impact, including not only fit and comfort but also impact protection qualities.

SPORT REGULATIONS

In the sample of the study about occurrence of the injuries only 3% of participants used padding protection. Therefore, it was important to find out, what official sport regulations say about impact protection.

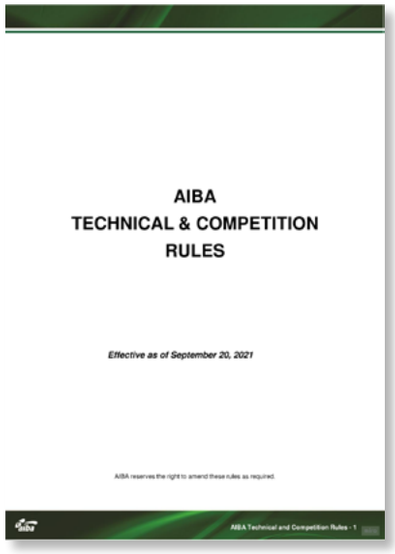
My finding was that regulations differ significantly in different disciplines: for example, in boxing competition rules it is allowed but not obligated, whereas such sports as kickboxing, karate, muai thai and fencing have an obligatory requirement to wear approved breast protection during competitions.

The next step is to reach out to user, gather their insight and identify requirements, user needs and areas to focus my ideation on.

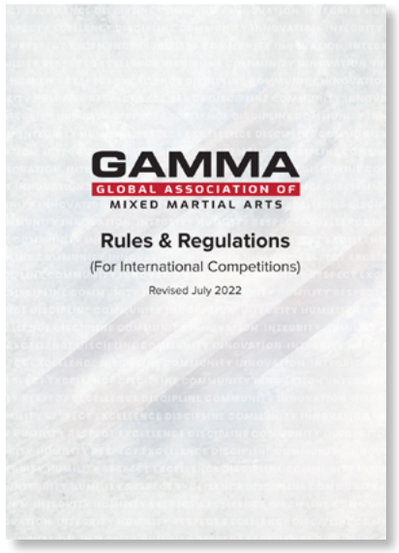
Breast protection is mandatory for female competitors (https://wako.sport/wp-content/uploads/2022/10/WAKO-Rules-25.10.2022.-revision-3.pdf)

The use of chest protection is mandatory for all Female

Athletes competing in an Senior division to guard against hematoma formation within soft tissue areas of the breast. (https://muaythai.sport/muaythai-rules/)



Women and Girl Boxers may use a breast protector and/or a cup protector during a Bout (https://www.iba.sport/wp-content/uploads/2021/09/AIBA-Technical-and-Competition-Rules_20.09.21.pdf)



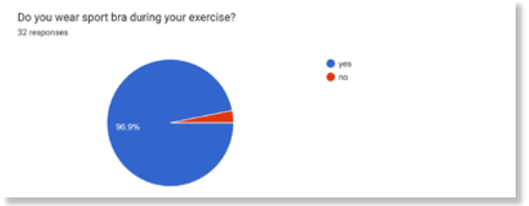
Female athletes shall wear a short sleeved (above the elbow) or sleeveless form fitting rash guard and/or sports bra(s). No loose-fitting tops and/or breast protectors shall be allowed. (https://www.dli.mn.gov/sites/default/files/pdf/official_unified_rules_MMA.pdf)

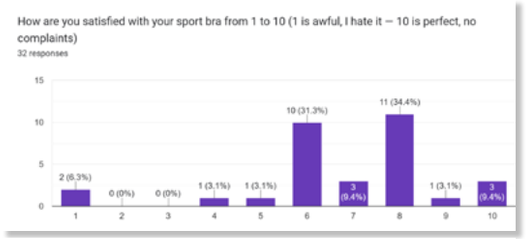
RESEARCH

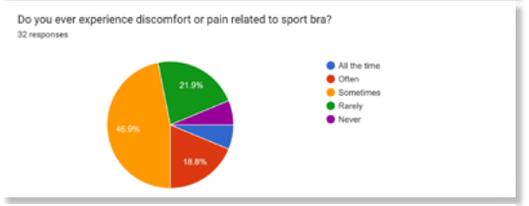
GENERAL USER SURVEY

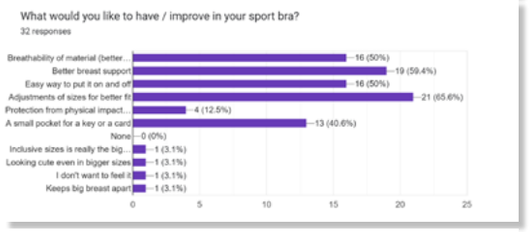
One of my observations was that there is no such thing as combat sport bra exists. And even professional athletes mainly share market with a wider consumer. Therefore, it was valuable to gather wider user group opinions for wide analyses of current products available, user experiences and preferences.

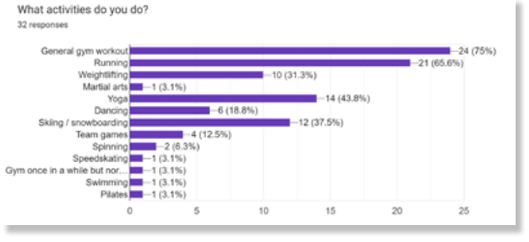
For my own investigation of user experience and to cover a bigger sample of feedback on bra fitting and breast support, I have created a small survey and placed link posters in the locker rooms of the gym that I often go myself, and at the School of Architecture and Design.











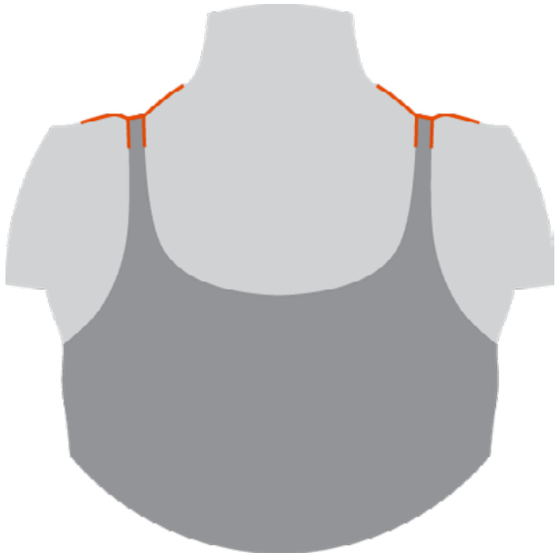
Questions included bra sizing and sport disciplines participation, as well as product preferences and general satisfaction.

Those questions allowed me to see the relation between activity intensity, body characteristics and experiences.

Survey also included open questions about favourite features or models, what users consider when purchasing, and what can be a cause of bad experience with wearing a sport bra.

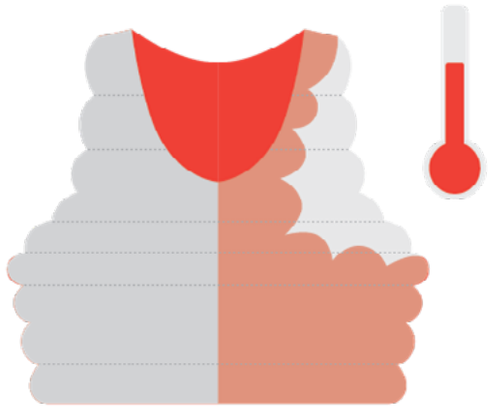
IDENTIFIED PAIN POINTS

Based on 32 responses, 5 most common among answers pain points were identified:

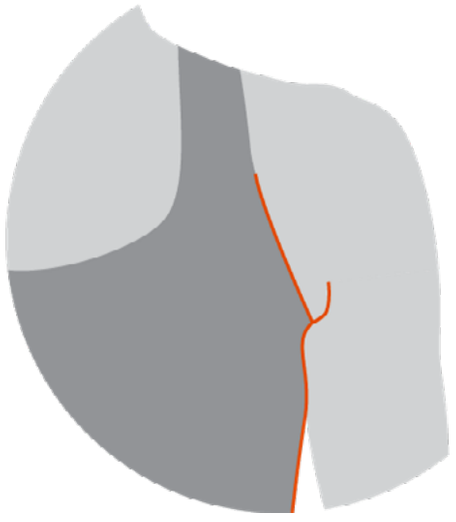


Narrow shoulder straps

Temperature regulation

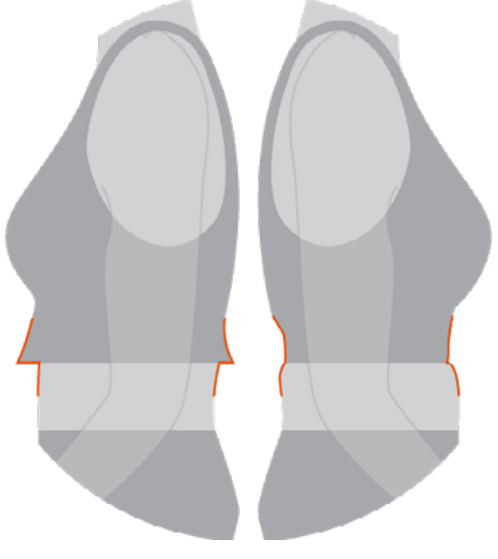


High arm cutout



Putting on and taking off bra with high compression

Proportion of the dimensions
bust / chest



USER INTERVIEWS

For collecting user insight more specific to this project, I have contacted multiple athletes from combat sports individually or through sport associations.

As a result, I got to interview 4 athletes in person, and 7 have answered my questions in written form.

11 women in total from various disciplines and various levels. Including sports with no obligatory breast protection such as boxing and taekwondo and sports with compulsory breast protection for all female competitors, such as fencing and kickboxing.

Questions included multiple general questions like sizing, preferred brands and characteristics, bad experiences with bra, opinions about protection, breast sensitivity, regulations in sports etc…

Multiple findings from athletes' interviews were corresponding with findings from the first user survey which I conducted earlier within much wider user group. Of course, a lot of new insight was also received.

SOME OF INTERESTING FINDINGS:

- A favourite bra is used for many years (5-10).

- Bra with adjustments contain hard elements: those can hurt when receiving an impact.

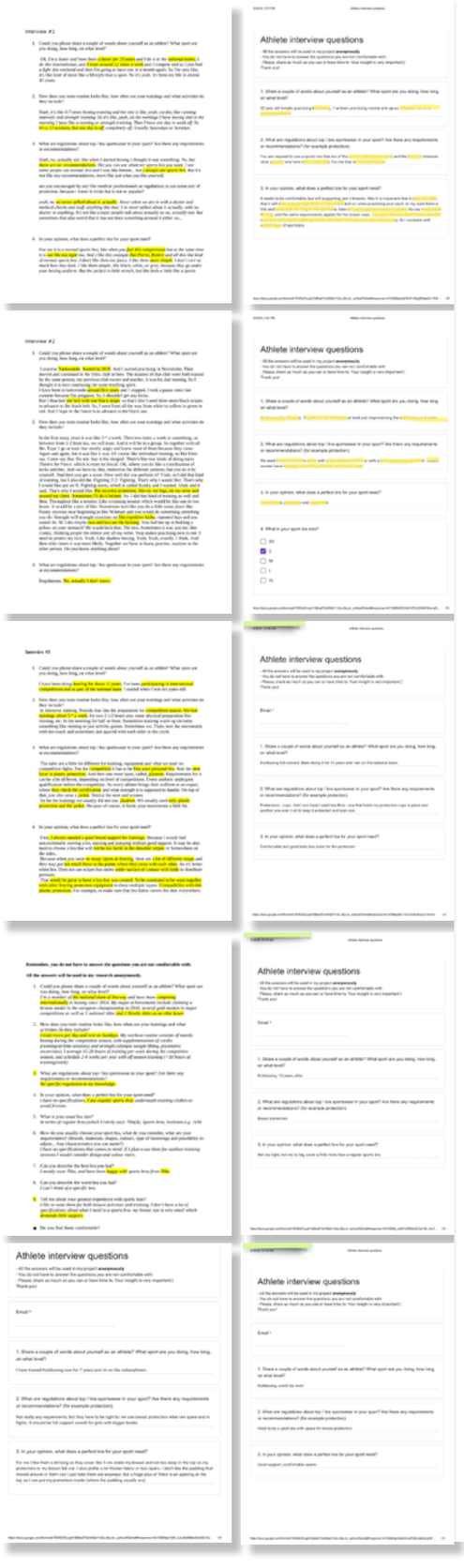
- Sensations in breasts are very individual. Someone finds it more sensitive – others do not.

- Large bust size is more prone to discomfort from movement, without good support. But they are less sensitive to direct blow.

- Surprisingly, a smaller bust sizes are more sensitive to impact (possibly, also due to lower percentage of fat tissue in breasts).

- Without obligatory requirement, very few people are aware of protection options; However, they would consider using it, if there was more information and more good and available options.

- Training routine include multiple activities and most of them do not require protection. It can also be used and removed during the training.



REFLECTIONS

REFLECTIONS ON USER INSIGHTS:

Judging from feedback of users who have not dealt with obligatory protection, I am certain that it will be valuable and encouraging to provide a good product option for those, who will be interested in exploring those options.

And for those who have it as a compulsory piece of their professional equipment. It valuable to provide a qualitive alternative to improve their experience.

I believe a good design, that accounts for compatibility of protection and bra for diverse training routines, can attract more users and be encouraging for more athletes and active women to use protection in activities that include a lot of contact, even when it is not obligatory.

Photo — A protection configuration used by one of the surveyed athletes. A protection cup inserted in a bra. (The pocket however does not fit the whole shape

MARKET RESEARCH

An important part of my research was investigating products and features available on the market.

That included exploring different bra models, their components, features and elements, materials. Especially drawing my attention to models and brands that athletes named as their preferred or favourite in the interviews.

In this way I have gathered a good number of examples and ideas, that I can later use in development of sports bra for combat and contact sports, by sorting out and modifying some of the features, according to constrains of the project.

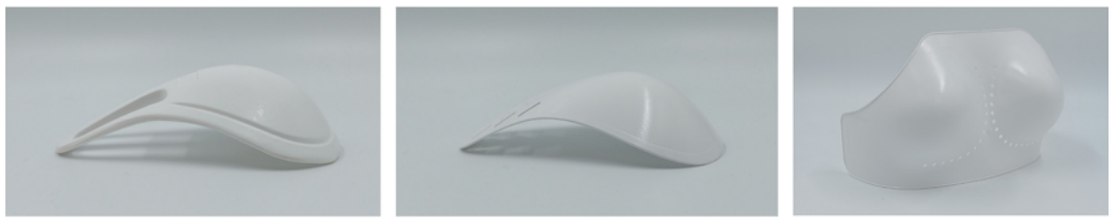
MARKET RESEARCH

Exploration also included breast protection products. After some research however, I have found that there is no big diversity in this area on the market. Even within different brands, product configuration is same. The choice comes to 3 available options:

1st is so called maxi-guard: a one-piece moulded plastic chest plate.

2nd are two separate moulded plastic cups.

3rd is an alternative for the same separate cups but moulded with different, softer, and flexible material, which however results in an increased thickness of the cups.



For the better understanding of current protection options designs, I have purchased 3 major options: maxi guard from Hayashi and QP protection cups in classic material and softer option.

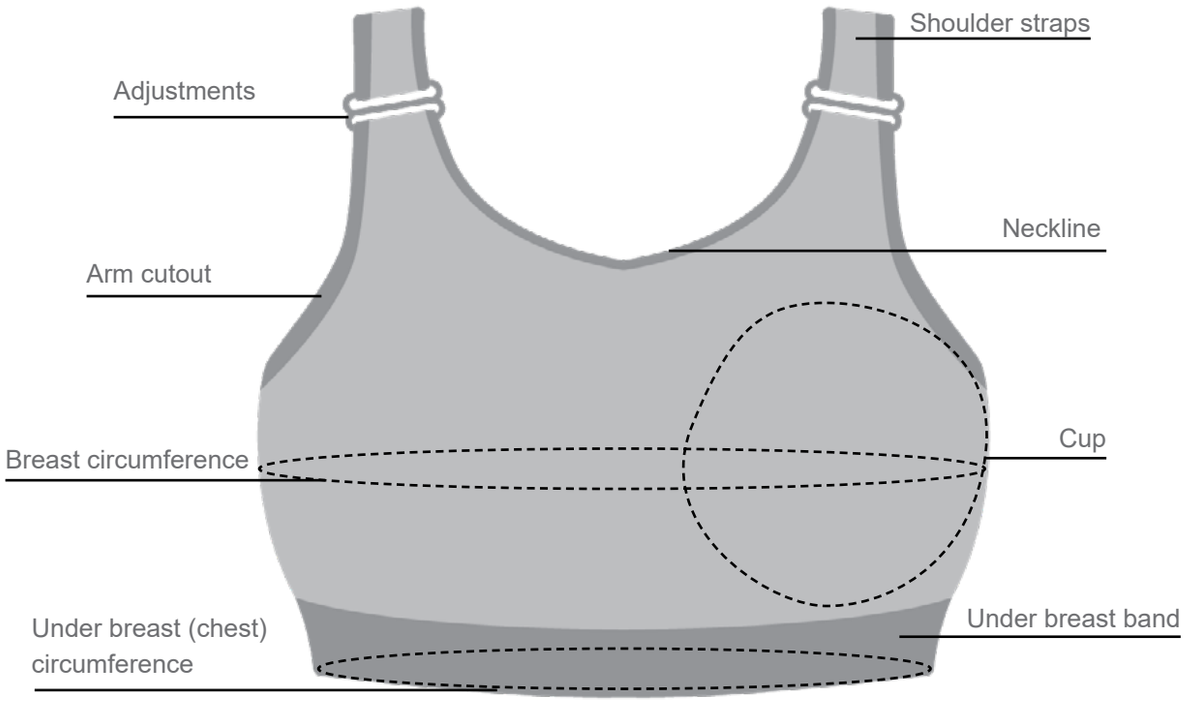
This experience gave me better understanding of user point of view.

Personally, I have experienced discomfort connected to sizing charts: models have only 5 sizes (XS, S, M, L, XL) and according to my measurements and brand sizing charts — my size is S. However, being on the top edge of S size — some of the dimensions were clearly tight, such as under breast circumference.

MARKET RESEARCH

TERMS AND ELEMENTS

Key elements, terms and dimentions in a sports bra, that are important to know for development of sewing pattern.



BRA CLASSIFICATION

In general any sport bra can by categorised as one of these three types:

(13. “The Sports Bra Fitting Guide”)

ENCAPSULATION

Classic wired bra. Provides separate cups for the breasts. It is known for good support.

COMPRESSION

Popular sport bra. A tight tank top, put on throught head. It is comfortable but less supportive.

HYBRID

Mix of first two types. No wires, but it provides encapsulation with shaped cups.

IDEATION

SKETCHING

Based on research done and gathered user insights I have identified my key focus areas, and Which gives me an exact input for ideation.

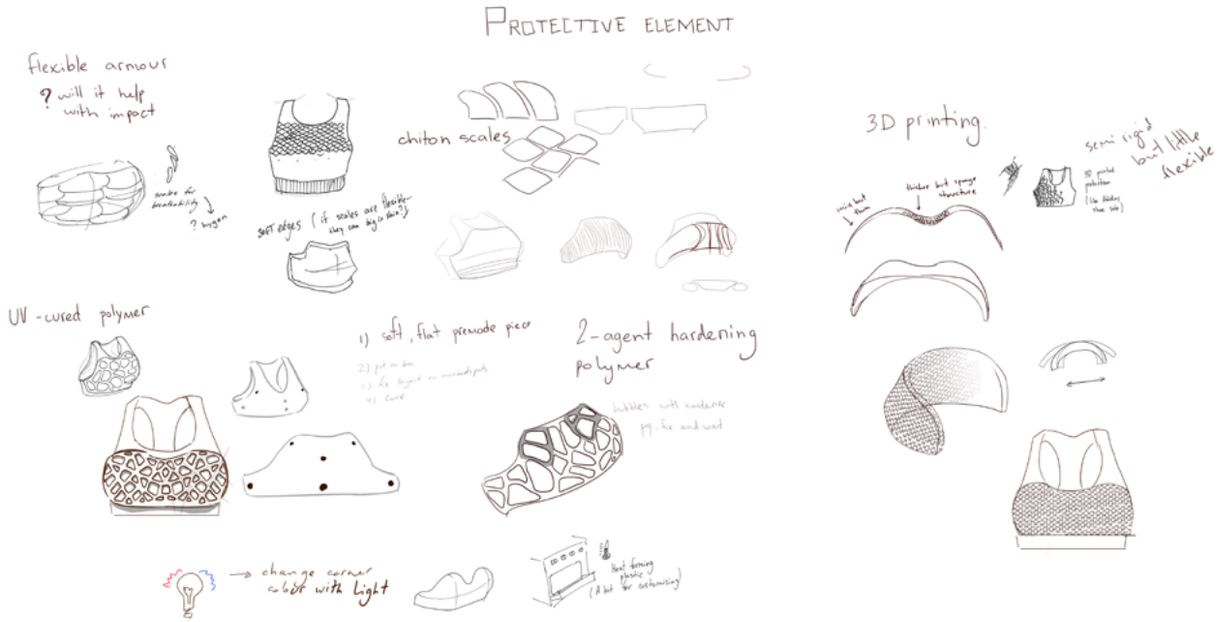
After certain number of sketches, I start to see how most of the possible solutions can be categorized in a certain way. I have categorized sketches into:

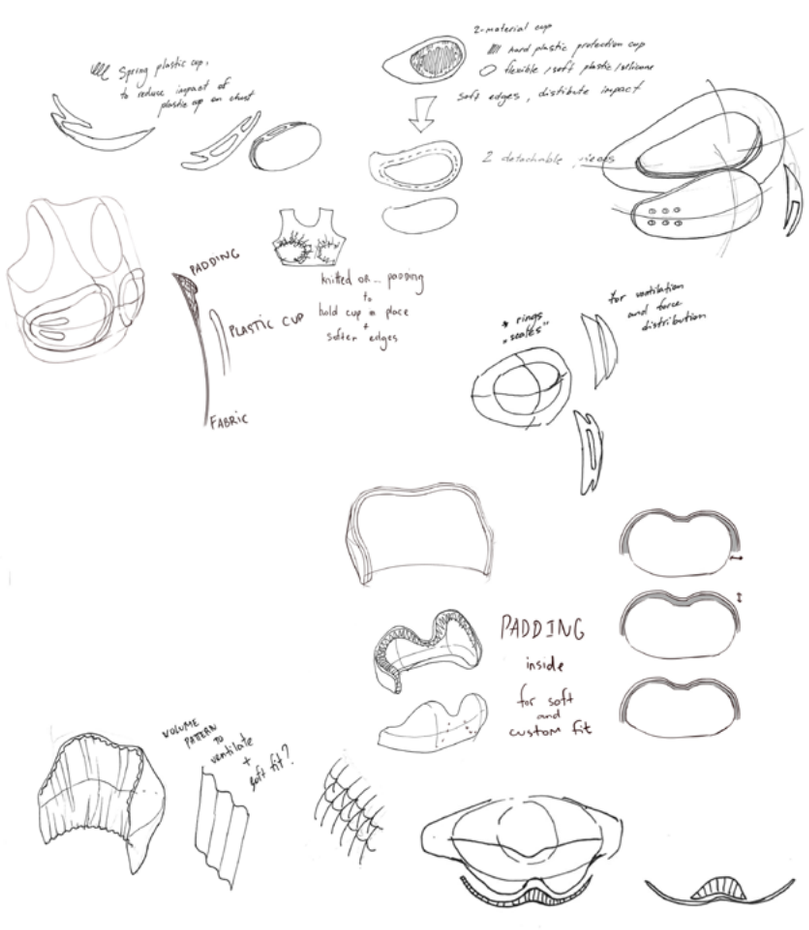
protection solutions

adjustments and fit solutions

padding for fit and ventilation

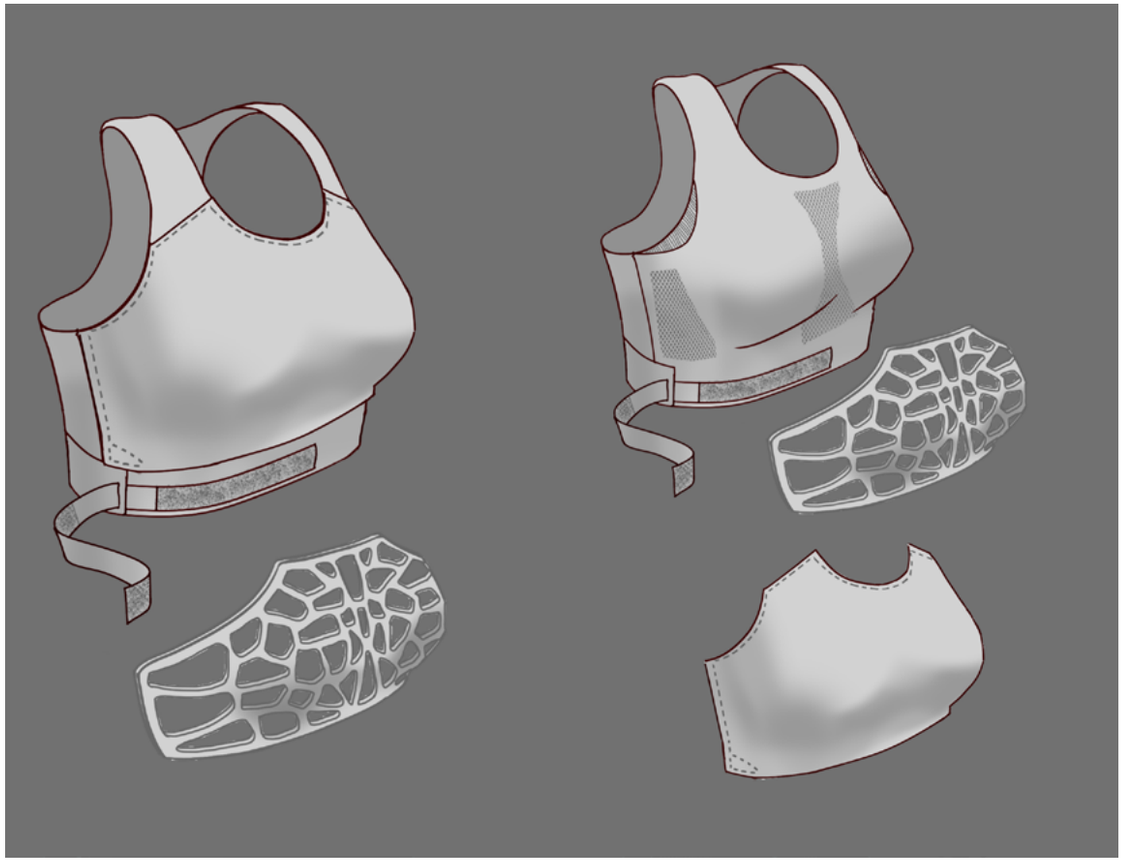
Those are not mutually exclusive and therefore can be mixed to for future concepts.



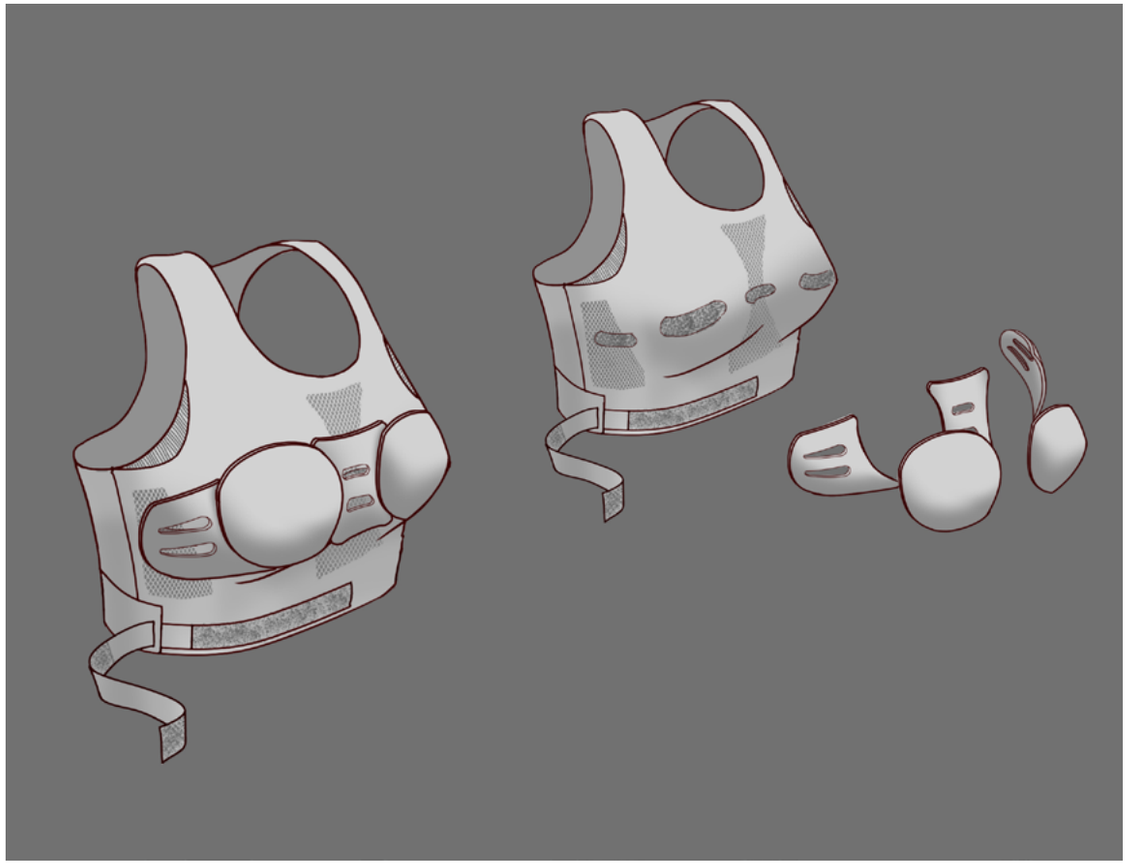


CONCEPTS

From sketching I have concluded 3 main directional concepts. Which means that they represent 3 possible directions to proceed with in further development, which will include further exploration through more sketching, prototyping, and testing, to find the most efficient combination of features and materials.

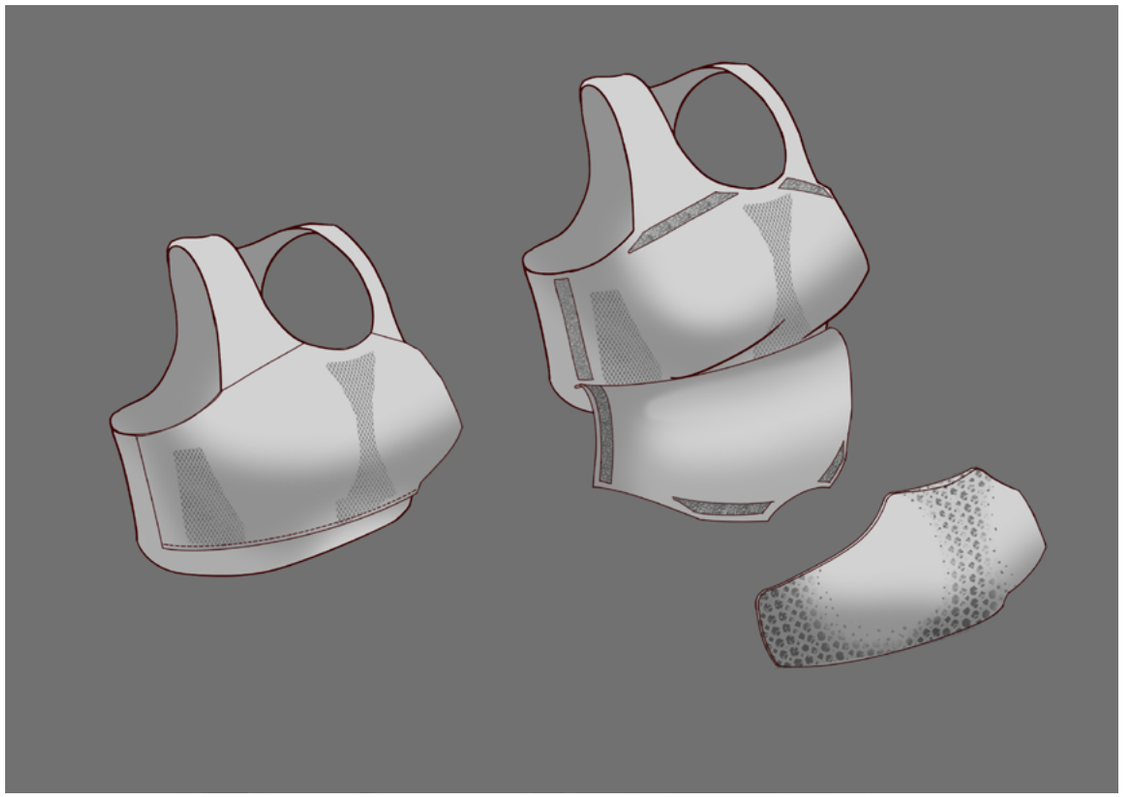


First concept direction is about using UV curing polymer for custom shaping and hardening the protective shell. Taking as an example new technology for casting and fixating broken bones. This concept potentially includes producing a soft flat layout, that will be fixed to a bra of a user and cured with UV, which will create a hard protection, shaped personally to user, by a user.



Second concept direction involves experiments with separation of traditional protective shell into multiple pieces. Which will give a protection additional flexibility, due to flexion between pieces. It might as well fit more comfortable due to this flexion and provide additional ventilation between plastic pieces. However, the more piece it will be divided in - bigger chance to lose in impact distribution qualities.

CONCEPTS



Third concept direction involves exploration of 3D printing technologies as methods of production of protection (protective shell). The idea is that 3D printing might have several benefits:

1) Possibility to produce wider range of sizes, for better fit. since adjustability of digital file for printing is much higher, compared to need of production a separate mould for each size for injection plastic moulding.

2) Possibility to use more flexible material or control flexibility with structure of 3D print. For example, using solid structure abound breast tissue, that need most rigid protection. And using certain hole pattern on the edges, which will make these edges much more flexible, where not much protection is needed but shape will be softly distributing impact from breasts tissue to these edges.

3) Except for the flexibility and soft fit, these structures will create much better ventilated and breathable protection, compared to any moulded plastic solution. `

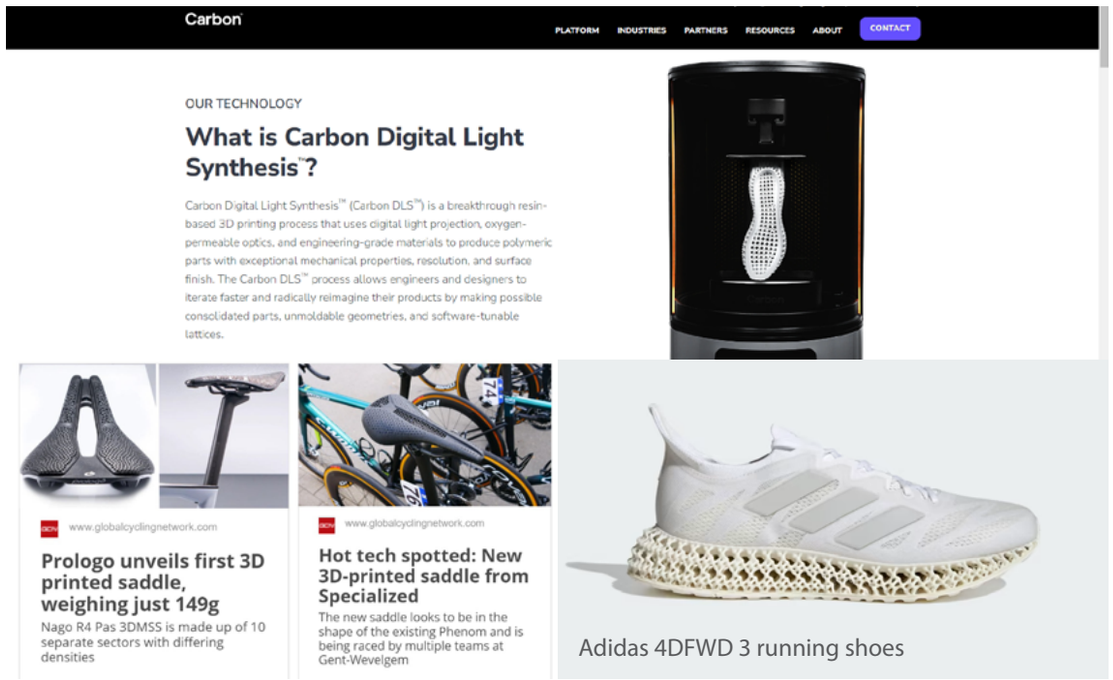
CONCEPTS

These 3 concepts went through a process of evaluation of their potential to take one direction in development phase.

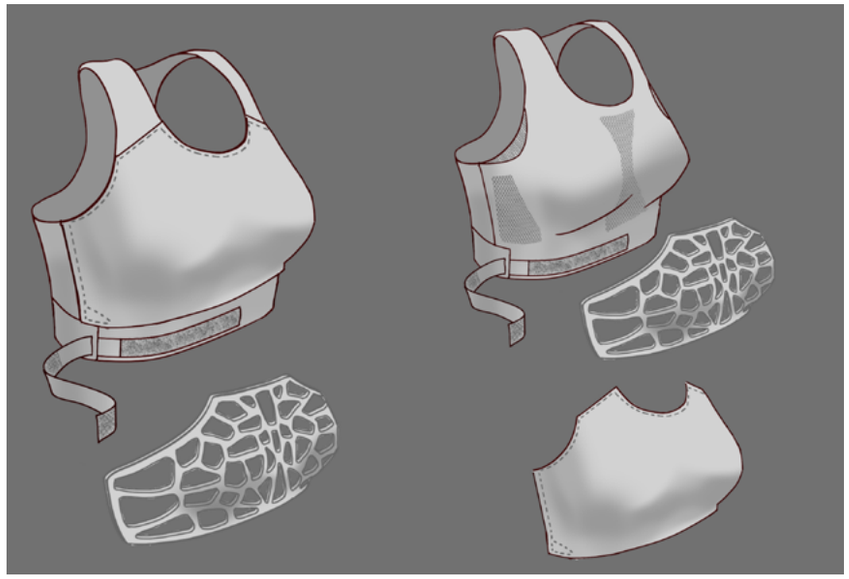
Before making a final decision, I had a conversation with Isil Potaloglu who has been working several years in Adidas sports bra development. I received a lot of useful input and information sources, that I will later apply in bra development. Besides that, additional professional insight was useful for making a decision.

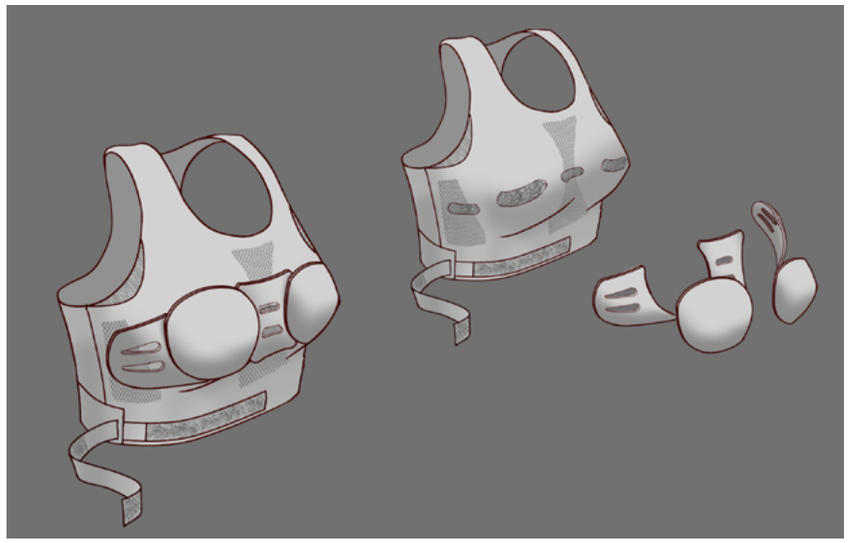
For further development will be used a combination of separate protector cups and 3D printing technology for controlling structure and flexibility of the protection.

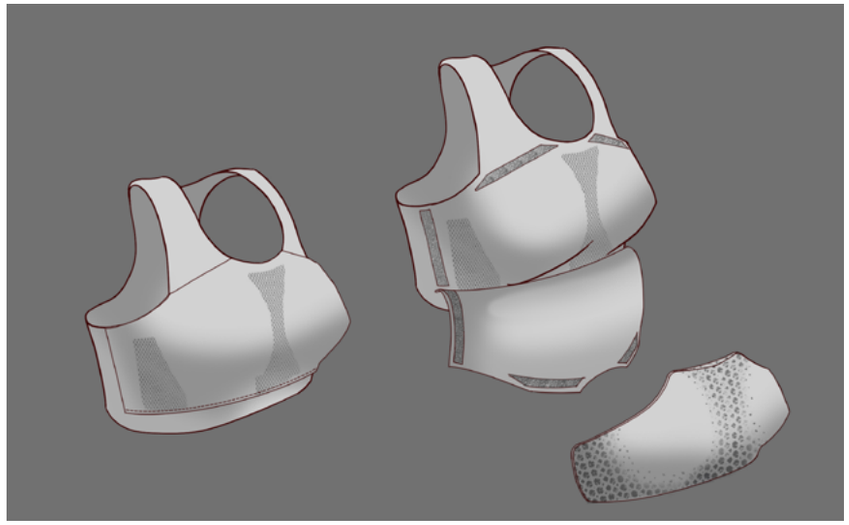
What makes it additionally promising — is that we have examples in the industry, where 3D printing technology was successfully used in production scale. Like Adidas 4DFWD running shoes. (10. https://www.carbon3d.com/carbon-dls-technology) (11. https://www.globalcyclingnetwork.com/tech/news/prologo-unveils-first-3d-printed-saddle-weighing-just-149g)



Adidas 4DFWD 3 running shoes







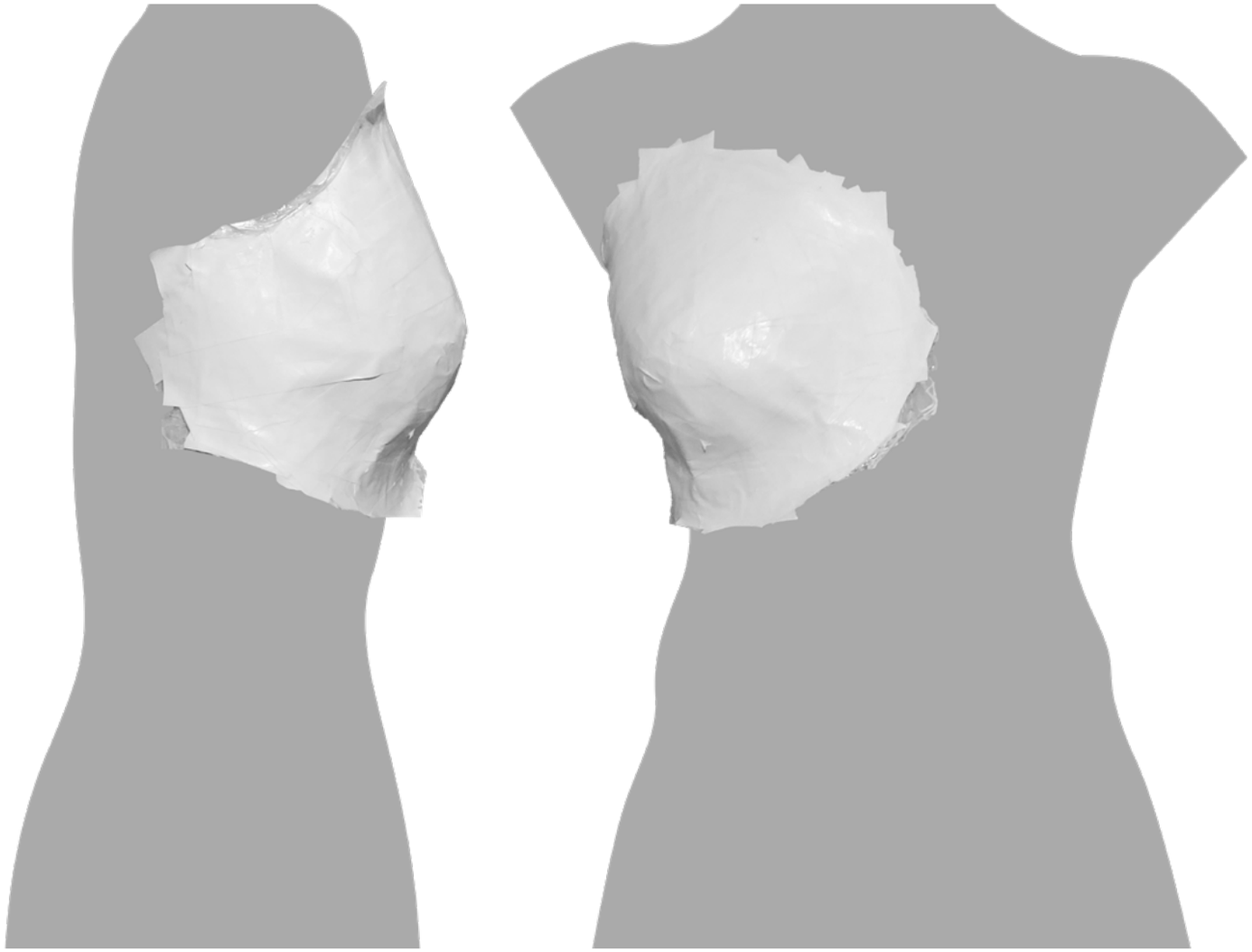
DEVELOPMENT

SHAPING PROTECTION

ANATOMICAL BASE:

For a comfortable fit of the protector, it was important to recreate natural body curves in protector shape. For this purpose, I used papier mâché technique, to create a cast from a model`s body.

Even though the initial idea of this approach was creating multiple papier mâché shapes, to compare and decide where is ergonomically the best border of the shape will lay; in the process I realised that creating multiple casts will be rather inefficient and time-consuming process. Therefore, I decided to transfer the first cast in digital format and use as an anatomical base for further iterations and shape exploration.



SHAPING PROTECTION

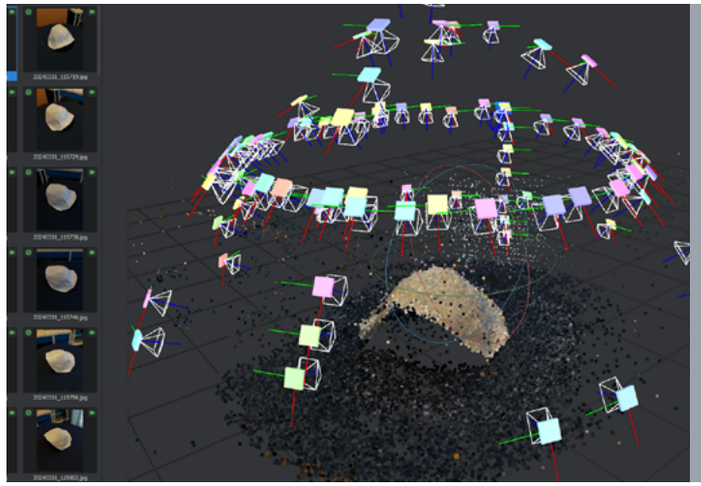
3D SCANNING:

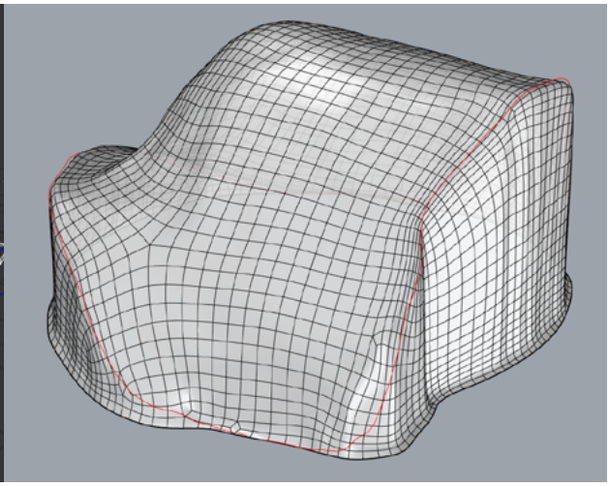
I used an open-source photogrammetry software Meshroom, to create a 3D scan of the cast base I have created earlier with papier mâché.

Produced by Meshroom mesh I have imported in Rhino CAD software and used mesh tools for a little bit of refinement and deleting extra mesh pieces of environment, produced by a software. Later converting a refined mesh into surface for convenient further iteration work.

MESHROOM

Rhinoceros





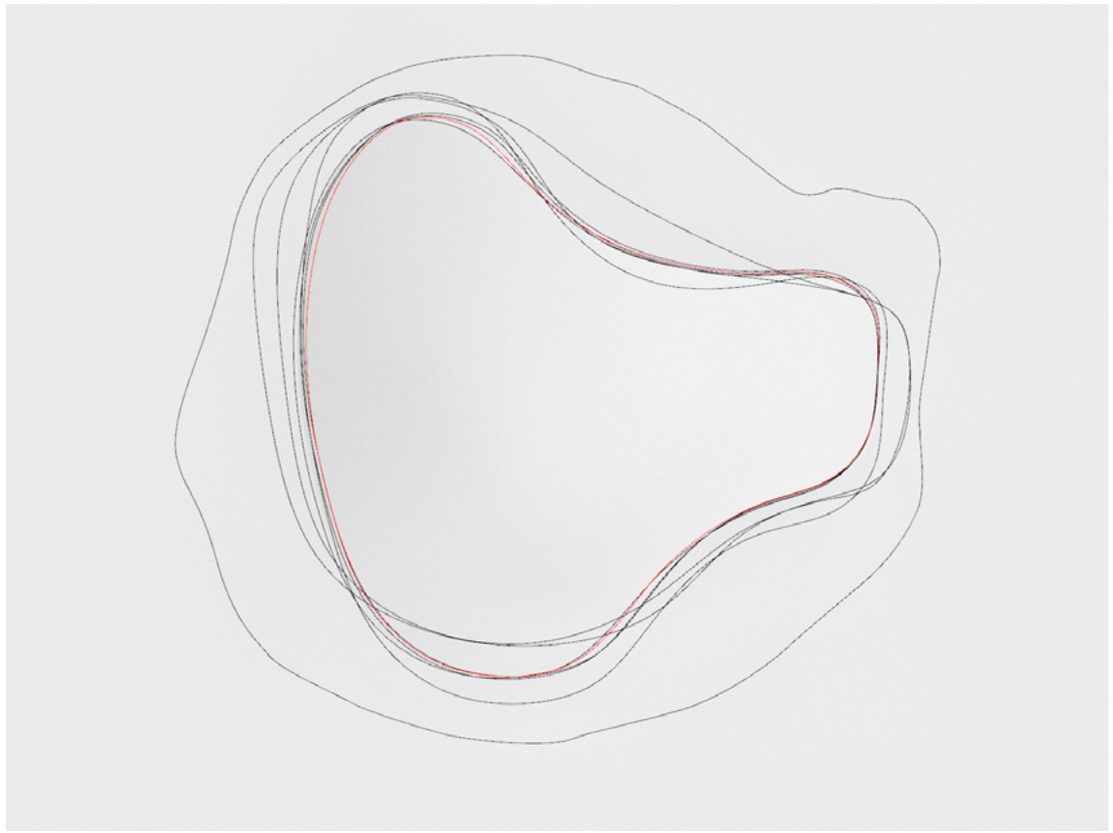
SHAPING PROTECTION

SHAPE ITERATIONS:

In the next step shape was iterated in CAD. I was exploring the position of borderline of a base that was created. Through these iterations, protector gained “wings” as extended from breast tissue edges. Wider surface of contact around breast tissue will ensure soft distribution of impact.

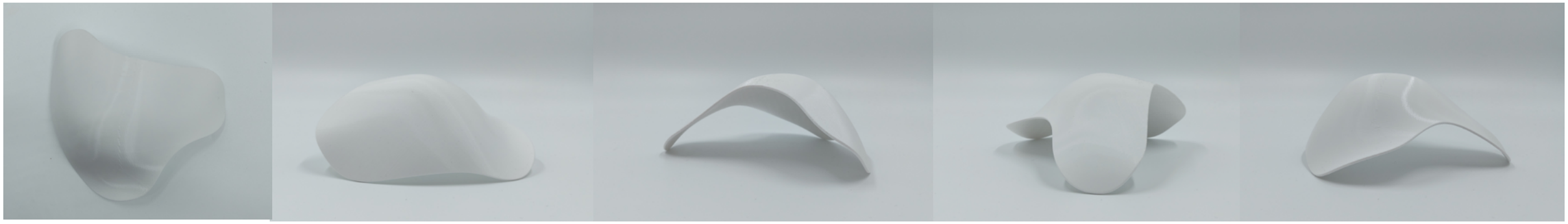
Each iteration was 3D printed and tried on before making a next one. For this phase I have used PLA material, on Ultimaker printers. This material is not intended for achieving properties I need for results in this project, such as flexibility of the edges. However, it is a good way to quickly test an overall fit and dimensions of the shape.

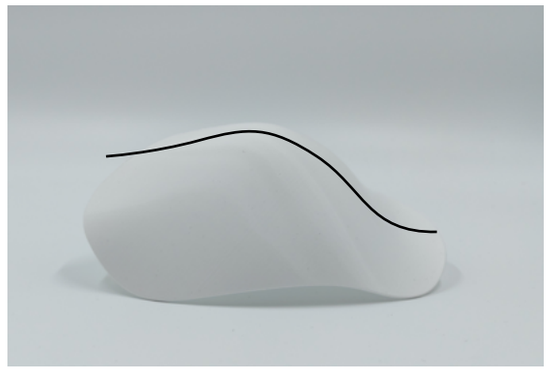
Of course, during shape iterations I have also smoothened the shape and some curves and concavities to make it a more universal fit and not a copy of particular body curves.



SHAPING PROTECTION

As a result, was received surface, that flows along body, with edges looking out of the body, rather than inwards. Which creates a greater contact surface and soft impact distribution.





VISUAL EXPLORATIONS

After consulting with my supervisors, it was decided to give more exploration to visual characteristics of the bra.

Explored shapes included different silhouettes of the product, neckline shapes, certain mimicking patterns of muscle tissue, or skeletal protection, also more abstract shapes with softer and roundish expressions or, on the contrary more rigid looking shapes like squares and rectangles or sharp corners.

VISUAL EXPLORATIONS

After certain number of options, this design appeared to be the best option to proceed further, because:

Pocket is located on the outside of the bra, so that protectors can be easily reached and taken out without need to use changing room and removing bra. Pocket layer is not covering the whole bra, in that way leaving cutouts and openings that contribute into several functionalities:

1) no unnecessary surface is covered, it will contribute to cooling

2) shape has a strong visual identity of the product, creating interesting outlines and visually showcasing different layers and texture materials, which also leaves space for playing with colours and finishes later in the process

3) a central top opening can be used as a marking of separation of the pocket opening

4) outline of the pocket layer follows closely the outline of the protectors and creates an additional fixation for the protectors, by matching the “wings” shapes and keeping them in place, not allowing excessive sliding around.

DEVELOPMENT OF THE BRA

I used CLO3D software for developing sewing pattern. It gives possibility to create a digital pattern, simulate it and make multiple iterations without need to sew each one. This tool helped me to make this process much more efficient compared to alternating pattern multiple times physically.

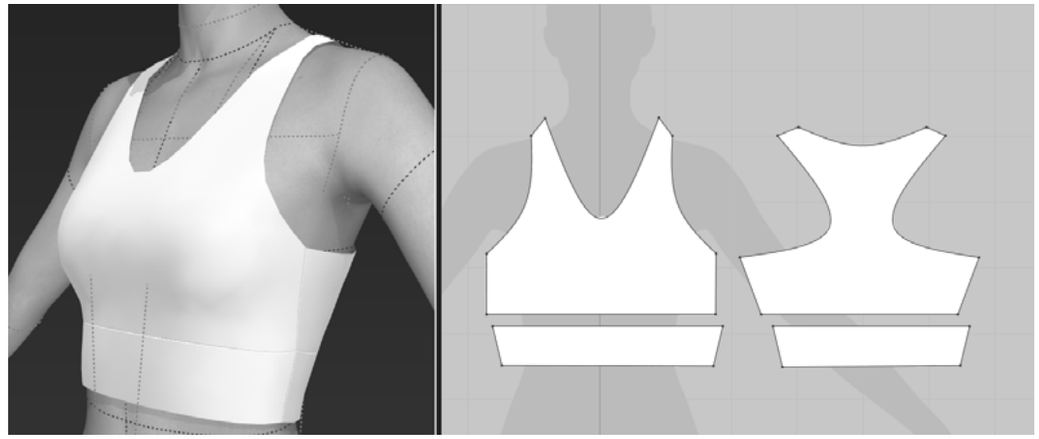
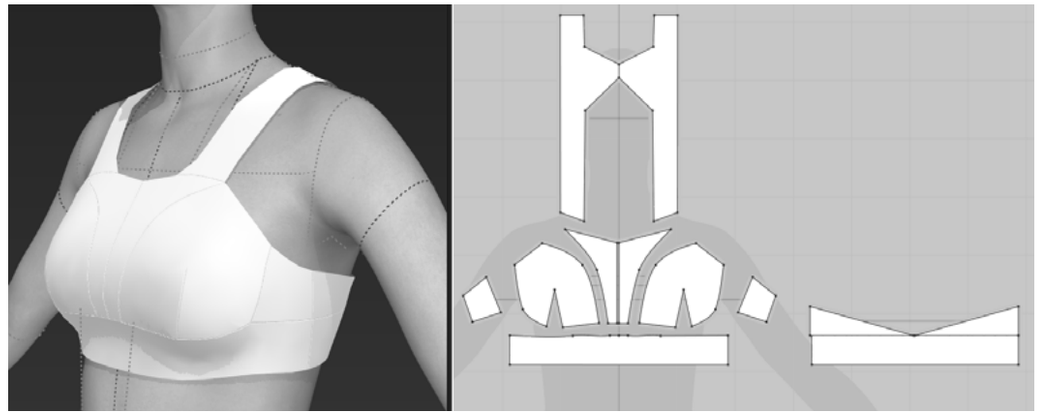
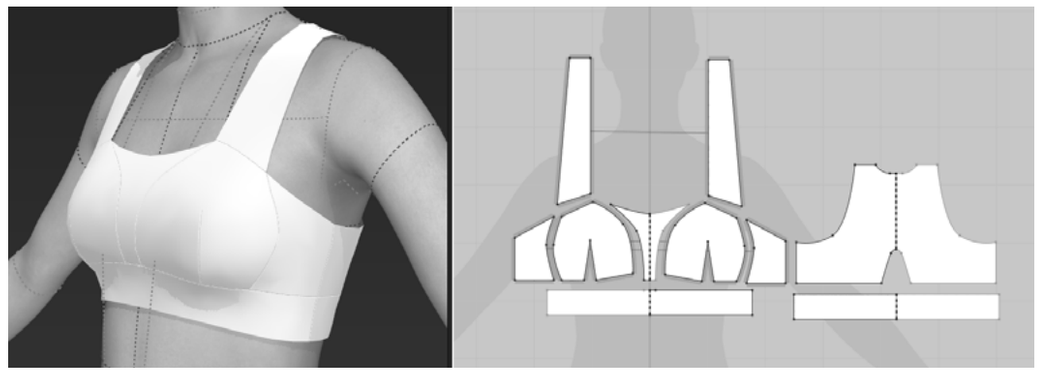
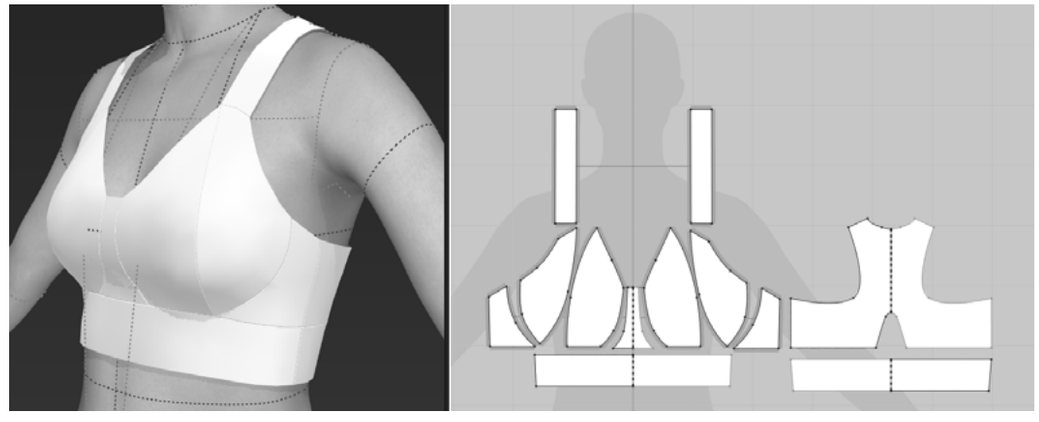
The goal is to create a hybrid pattern of the bra, meaning a combination of encapsulation and compression type of bra.

I have started the development of the pattern from first, base layers, as they are closest to the body and are main for providing support. It was important to find suitable dimensions and shapes, and then, based on this layer move on to the next one.

To ensure that dimensions are correct and to see how pattern will behave in physical material, I created simple prototype. Pattern was printed and cut out from the textile that correspond in content material with ones that are often used in sportswear as they are known to be moisture wicking and well stretching, a mix of polyester and elastane.

After sewing the prototype and trying it on, I have adjusted dimensions and developed the pattern further.



DEVELOPMENT OF THE BRA

In the next step the pattern has gained more details:

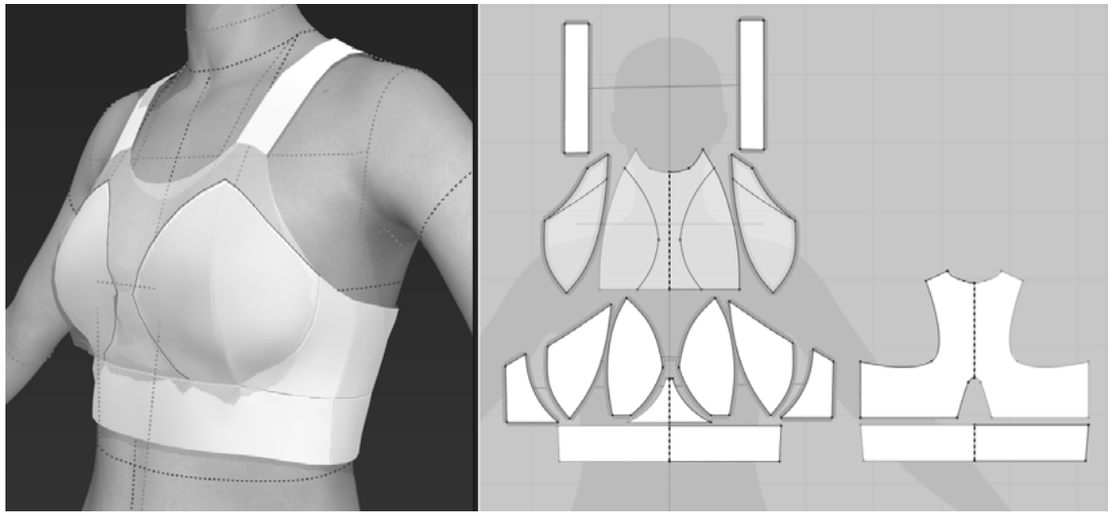
I have noticed that the cups that are supposed to be produced from the foam and provide encapsulation cover a lot of skin, and yet do not cover enough to become a soft barrier between skin and protector.

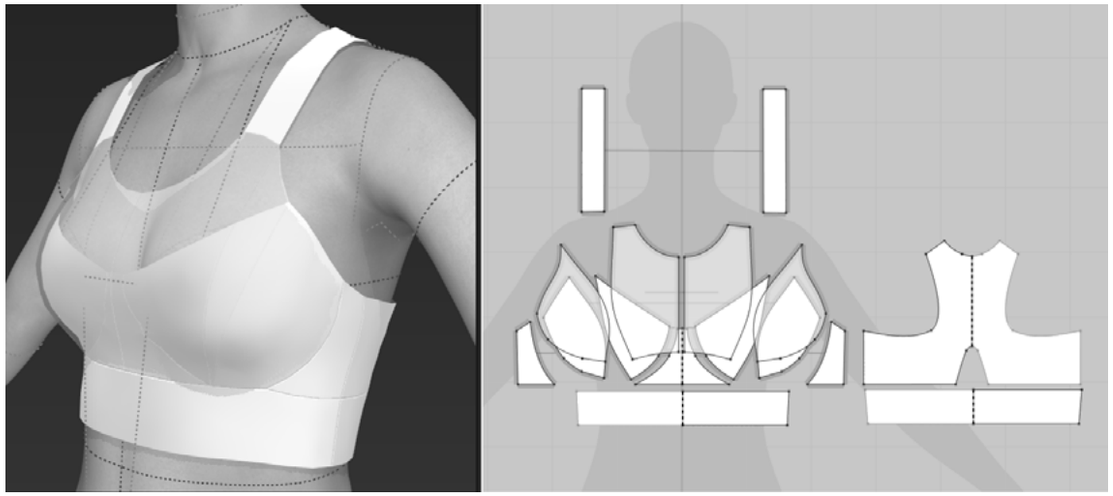
Therefore, in the next pattern iteration, the size of the encapsulation foam cups was reduced. Instead, smaller surface cups were interconnected with a layer of mesh, which can have a good ventilation even with bigger surface, sufficient surface to become a soft underlay between skin and the protector.

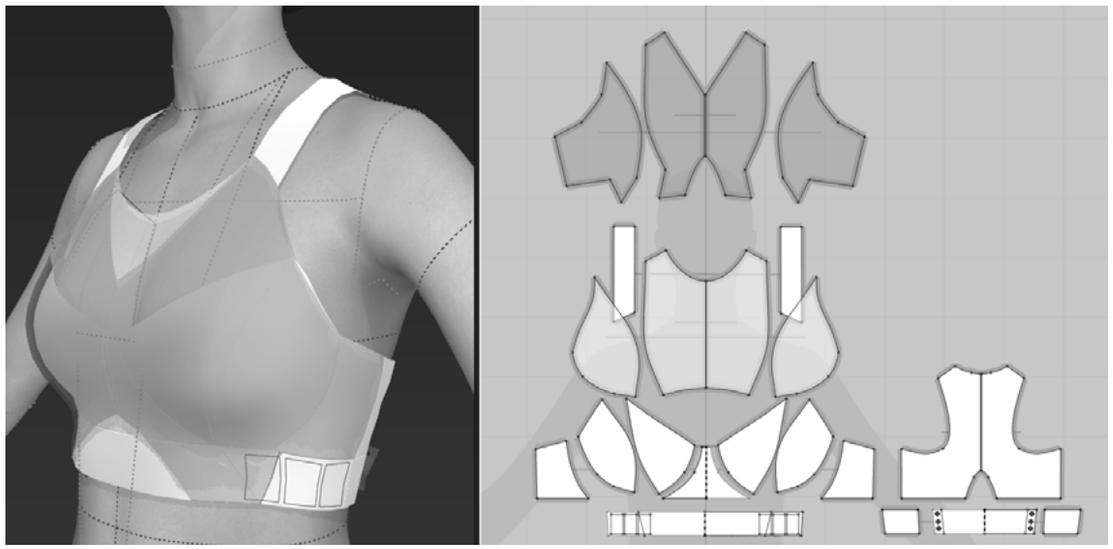
The final layer is a pocket for protector insertion.

In development of this pattern, I have implemented my research findings. For example, the width of the shoulder straps should not be less than 35 mm. (12. Sports Med 2015) And no hard elements were used in the product, as multiple athletes mentioned that any small hard elements, like strap adjustments, can hurt when being pushed in with a blow.

One of the challenges was implementing size adjustments in the design, without using a single hard element.







DEVELOPMENT OF THE BRA

SOFT ADJUSTMENT DESIGN

From user interviews I have learned that tightness of the under-breast chest band is crucial for good breast support. Therefore, it was important to implement adjustment in this area, that will result in 2 important functions: adjusting band tightness for best fit and compression and make it more comfortable for putting on and off.

Figure 2. Sport bra from Shefit

A common practice in similar sport equipment is velco fasteners and adjustments, as it is easy to use and to adjust the fit quickly, buy just pulling Velcro strap.

The challenge occurred when I tried to remove a hard plastic connection element, that normally enables this easy pull adjustment feature. However, one of key findings was that any hard element can cause discomfort or even injure an athlete under the physical impact.

On the other hand, when plastic element is removed from the textile, tension causes fabric to stretch and potentially get worn out too fast.

To solve this, I combined Velcro and lace fastening solutions. Lace`s small width will need only a small opening in the connection fabric piece, and few of them will distribute the tension more evenly, preventing excessive stretch and be more robust (just like any other lacing works, that we see in shoes, can deal with quiet decent force load)

The lace ends however are interconnected with normal Velcro piece, that will serve as fastening between surfaces.

In this way we are preserving an easy pull and stick (fasten) feature of Velcro adjustment, but also removing any small hard elements that are potentially harmful.

DEVELOPMENT OF THE BRA

Choice of materials and prototyping:

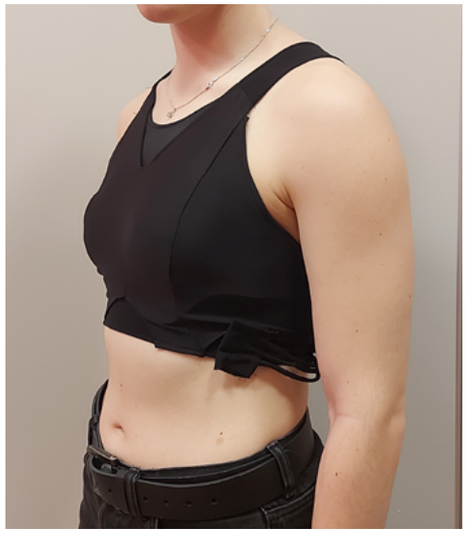
After prototyping base layer all in one stretchy textile, I came to realisation, that equally stretchy material everywhere will not contribute to proper support, as to achieve encapsulation effect, front part needs to hold shape well and consistently.

Therefore, front parts of the patterns where later made in low to non-stretchy textile, but with back pattern parts made in well stretchy material, that will compensate for rigidity of the front, still allowing to breathe and move torso freely, without being limited by textile stiffness.

USER TESTING

I got in contact with a young woman, who is doing kickboxing, not on a professional level, but participating in competitions. Which makes her familiar with wearing breast protection. I have invited her to come and try on the prototype.

We went thoroughly through each step of interaction with a product, including putting on and taking off, adjusting under breast circumference, inserting the protection in two possible ways, and basic movements or positions typical for sport, such as holding your guard up. Describing and observing the experience.



USER TESTING

From this testing session I learned several important things:

Protector shape sits well and comfortably, and wings as planned, create a soft feel for the edges, except for upper “wing” that appears to be directed too much inwards and still create some pressure on skin.

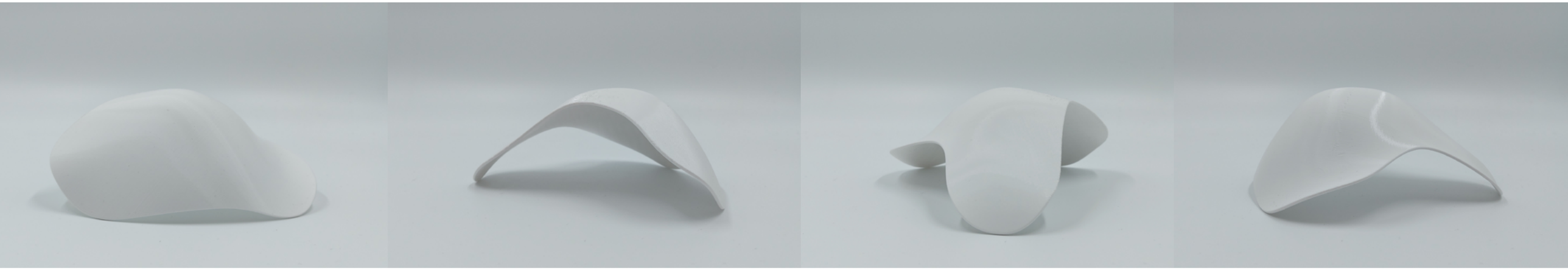
Since during this testing was used PLA hard plastic protector prototype to test overall fit of the shape; unsurprisingly, it was noticeable during movement that rigidity creates discomfort. This however should be eliminated with implementing the structures and adding flexibility to future prototypes.

Current position of the Velcro is in the way of elbow movement. When the elbow is constantly sliding against the edges of Velcro, it creates a risk to roll or even open the Velcro, as well as possible contact with scratchy and rough Velcro surface.

It was obvious that position needs to be moved either back or front. Positioning further back will make adjustment inconvenient to reach, therefore Velcro will be moved forward.

In comparison, insertion through the centre is more convenient and intuitive then through the side opening, therefore it is obvious that pocket entrance should be in the centre.

PROTECTION DEVELOPMENT



After user testing, I found that the upper edge is curved too much towards the body and users perceive it as hard and uncomfortable, therefore I have adjusted the curve to move it further away from the body surface.

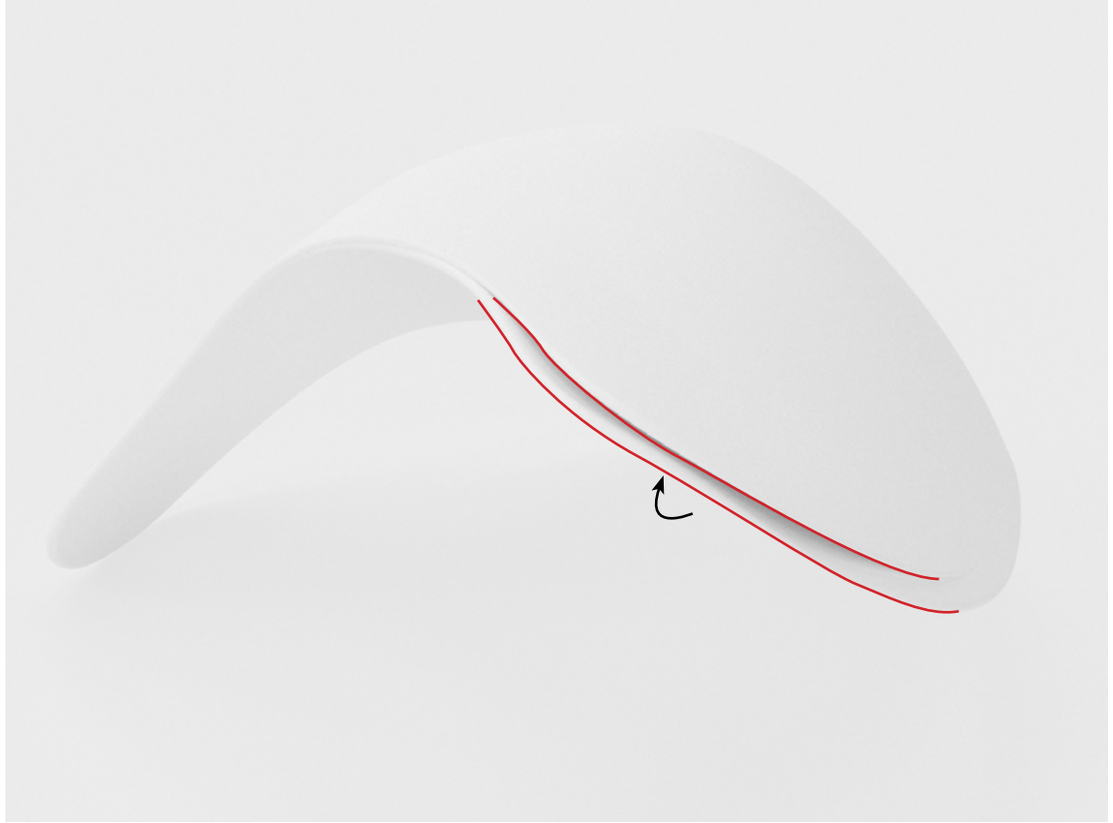
After user testing, iteration to protector shape were done. And when comfortable fit was ensured in overall shape, it was time to develop a structure inside this shape and print next iteration.

After couple small tests I have realised that PLA filament will not be a suitable material for further prototyping, and to achieve more adequate results, I need filament that have more suitable qualities such as flexibility and strength.

To get some insight on possible solutions in this area, I have contacted Ricardo Simian, a PhD fellow at The School of Architecture and Design, who is working with 3D printing.

After the conversation with Ricardo Simian, I decided to build my experimentation and prototyping based on two materials: TPU filament for FDM printer and nylon powder for SLS printer.

Both are present in the school workshop facilities. And TPU is a flexible material that will give the product desired softness. And even though nylon is quite rigid, it can give good protection qualities and could flex as well with certain shape parameters.



PROTECTION DEVELOPMENT

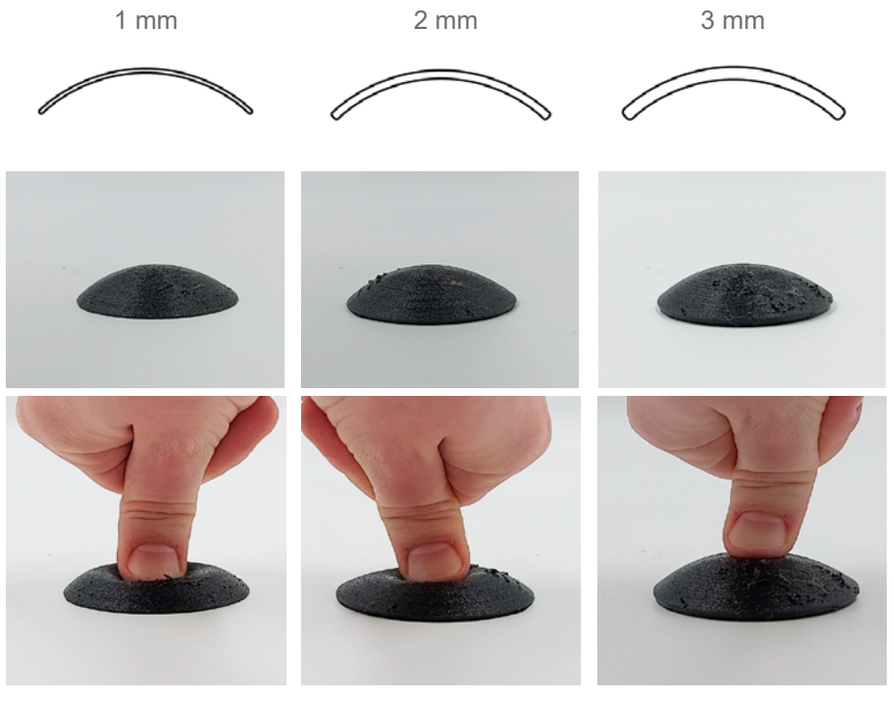
TPU is a flexible material, respectively, there was no doubt in achieving good flexibility in the areas intended to be soft.

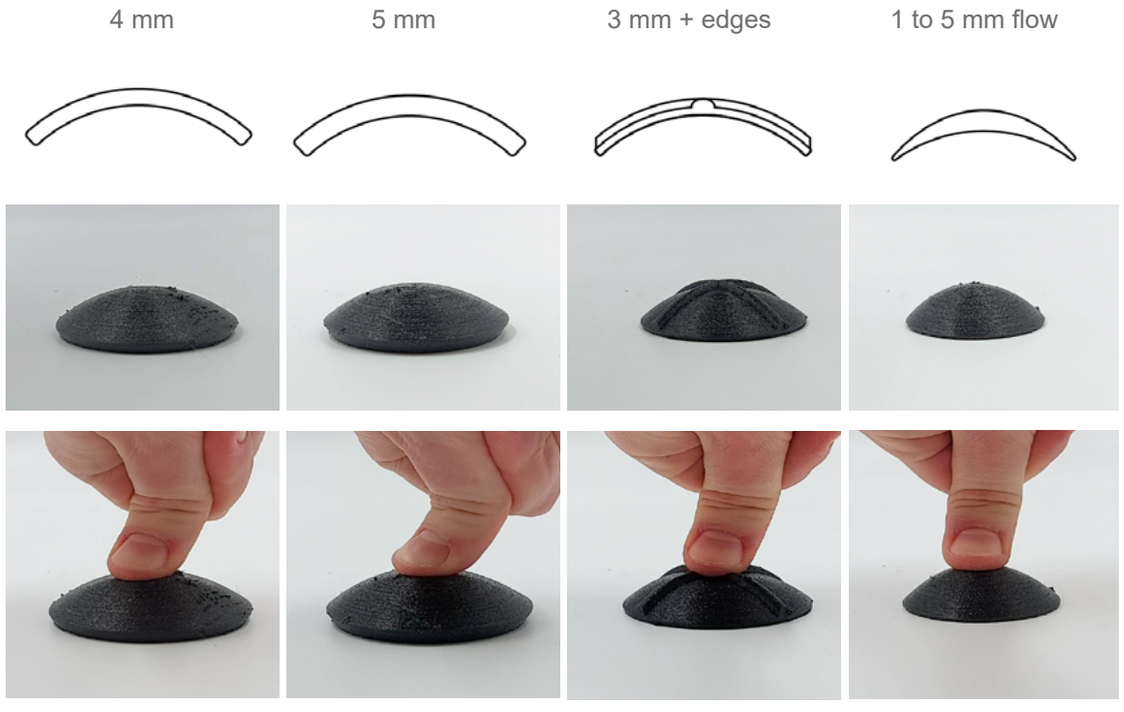
On the contrary, the challenge with TPU or similar flexible material is to make sure that product has enough rigidity in the centre, around breast tissue. So that it can distribute impact through whole surface and provide protection.

It is hard to predict, how material will behave. Therefore, after consulting with Ricardo, I have conducted a small test for exploring how rigid TPU filament can be.

For testers, I have modelled several circular shapes and printed them to learn how material will work with different thickness.

Testers were made convex to imitate convex shape of protector around breast tissue, as I am certain it will also help to make shape stronger. Each shape was made with thickness from 1 to 5 mm, one tester had edges, and one more had various thickness with 1 mm in borderline and 5 mm in the centre.





PROTECTION DEVELOPMENT

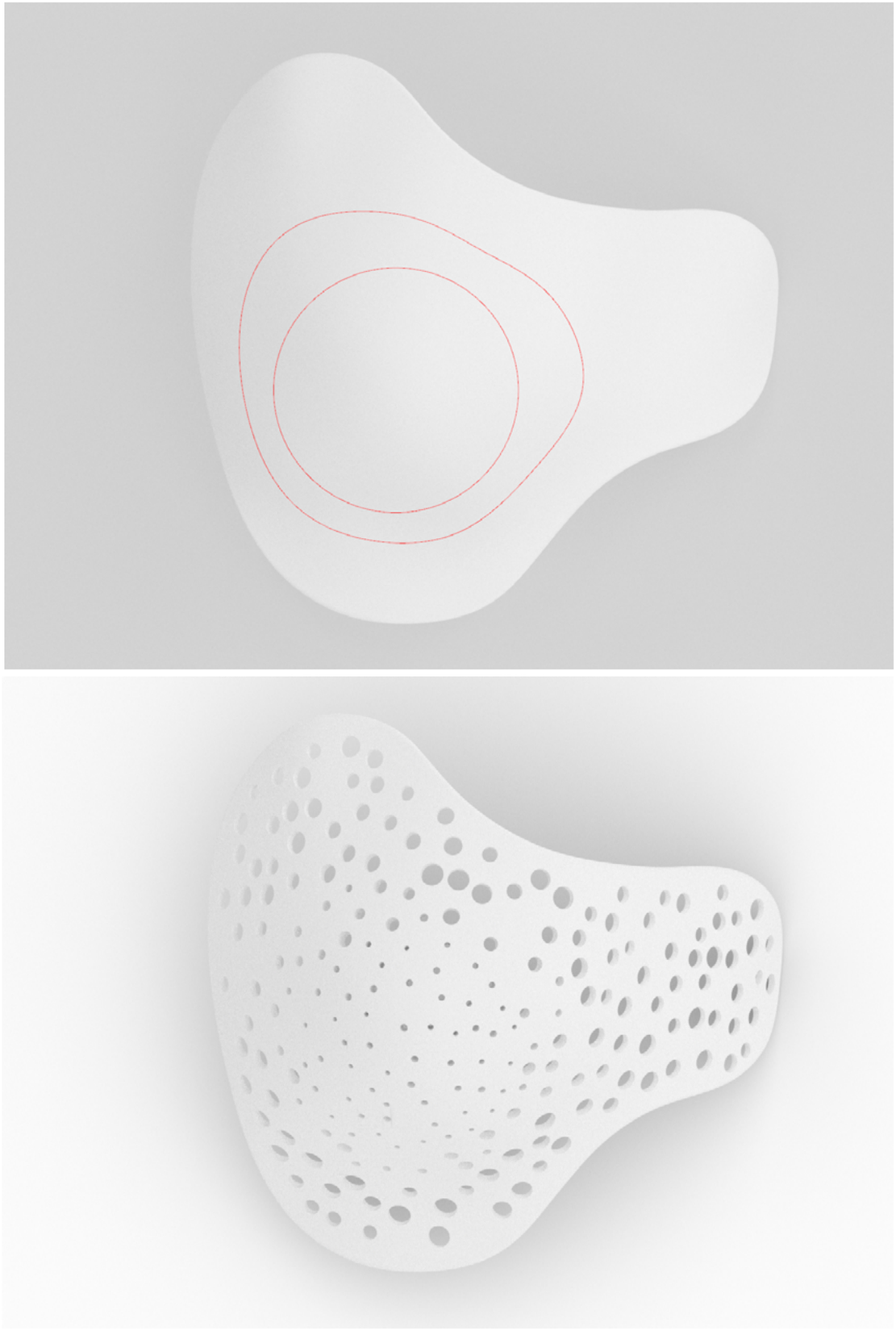
Seeing quite a reassuring result with TPU print testers - I proceed with protector shape that has variable thickness, creating a flow from 5 mm in the central area around breast tissue and ceasing down to 2 mm thickness in the outlying areas.

For creating geometry inside of protector shape, parametric modelling was used. With grasshopper plugin in Rhino software, I have separated protector surface into 3 areas for different pattern density.

As a pattern for TPU print I chose circle as a classic and simple pattern, that also will be possible to print on FDM 3d printer.

Within 3 areas of protector surface that I have divided earlier, I have a control over density of pattern and radius of the circle. Bigger radius of circles which will contribute to flexing properties of the border area.

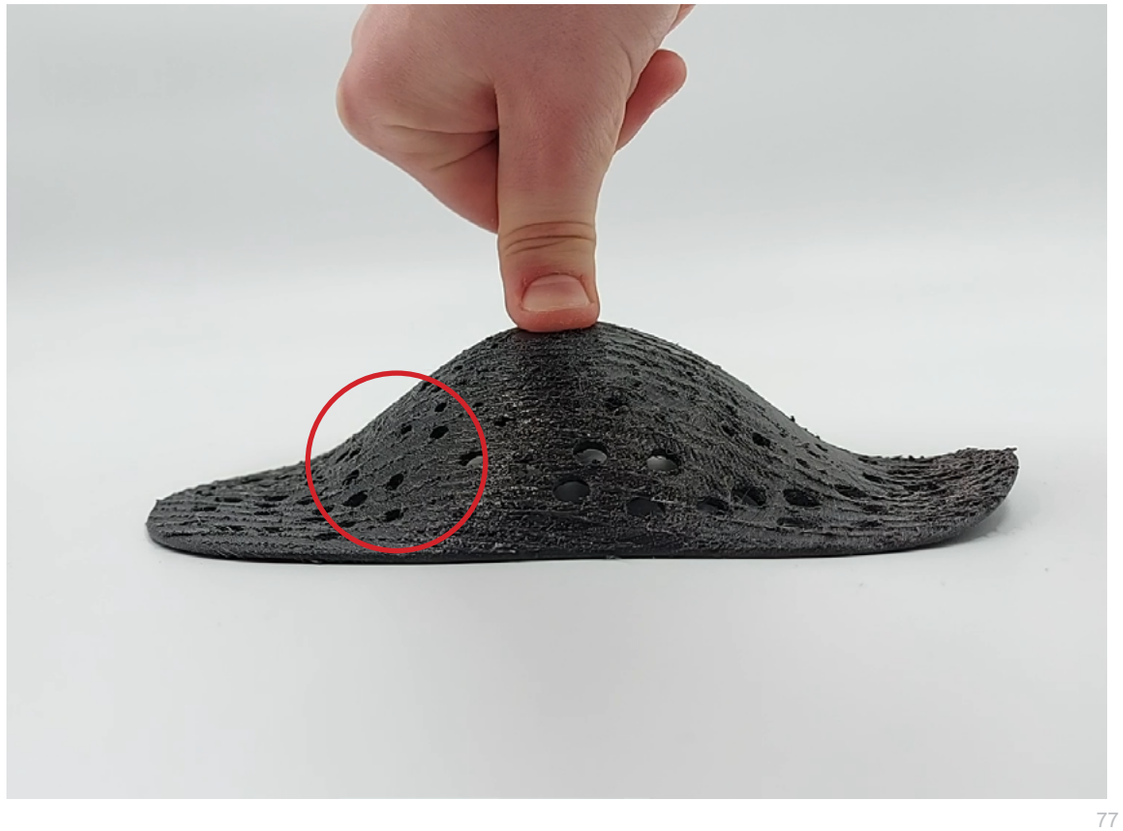
Next step is to print it in chosen filament and see the results.



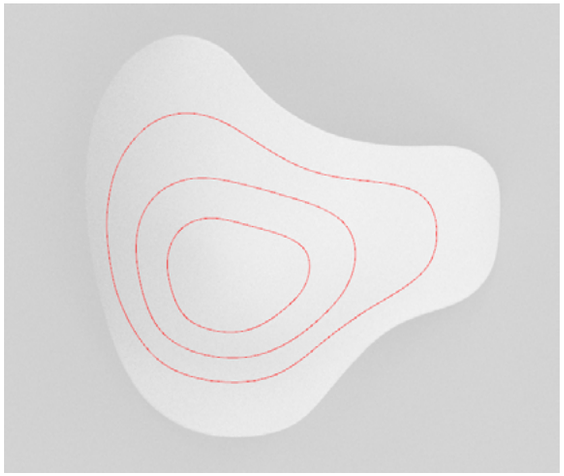
PROTECTION DEVELOPMENT

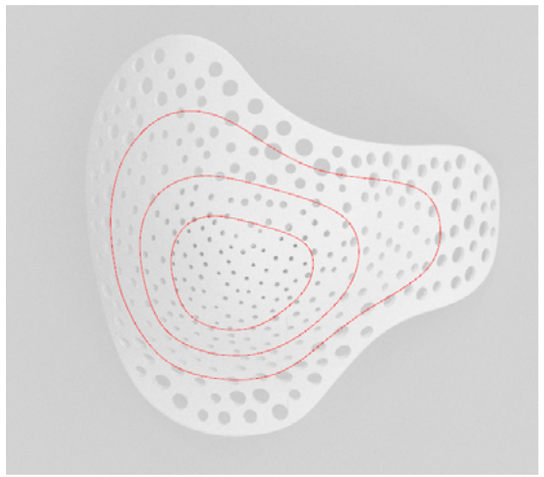
The first TPU print unfortunately failed before being finished. However luckily for me, the most essential part was printed enough for me to analyse the results.

By applying pressure to the prototype - I saw that flexibility of the border area is good and central part is promisingly rigid. However, in the top part of the protector the flexion area lays too close to the breast tissue - it needs to be moved further. So, some adjustments to the structure are to be done before restarting the print.



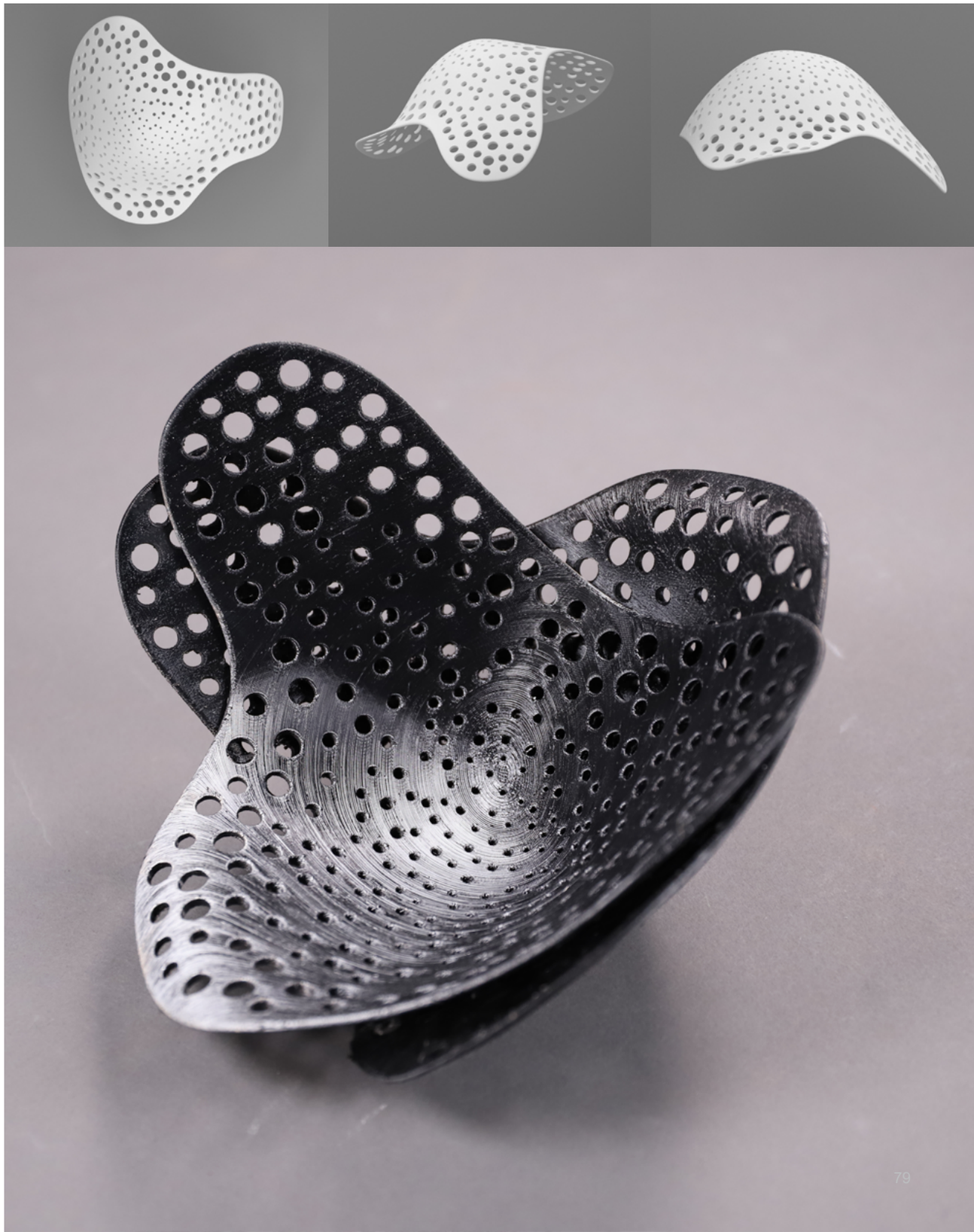
PROTECTION DEVELOPMENT



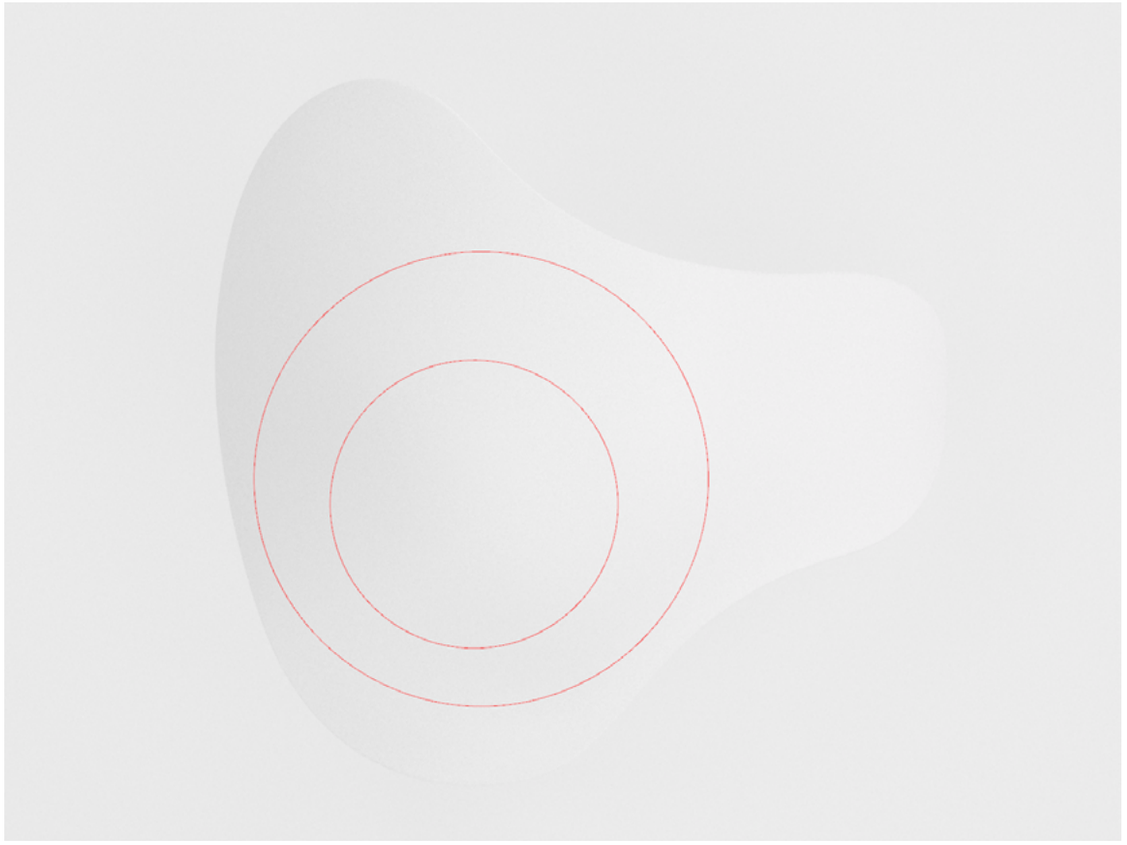


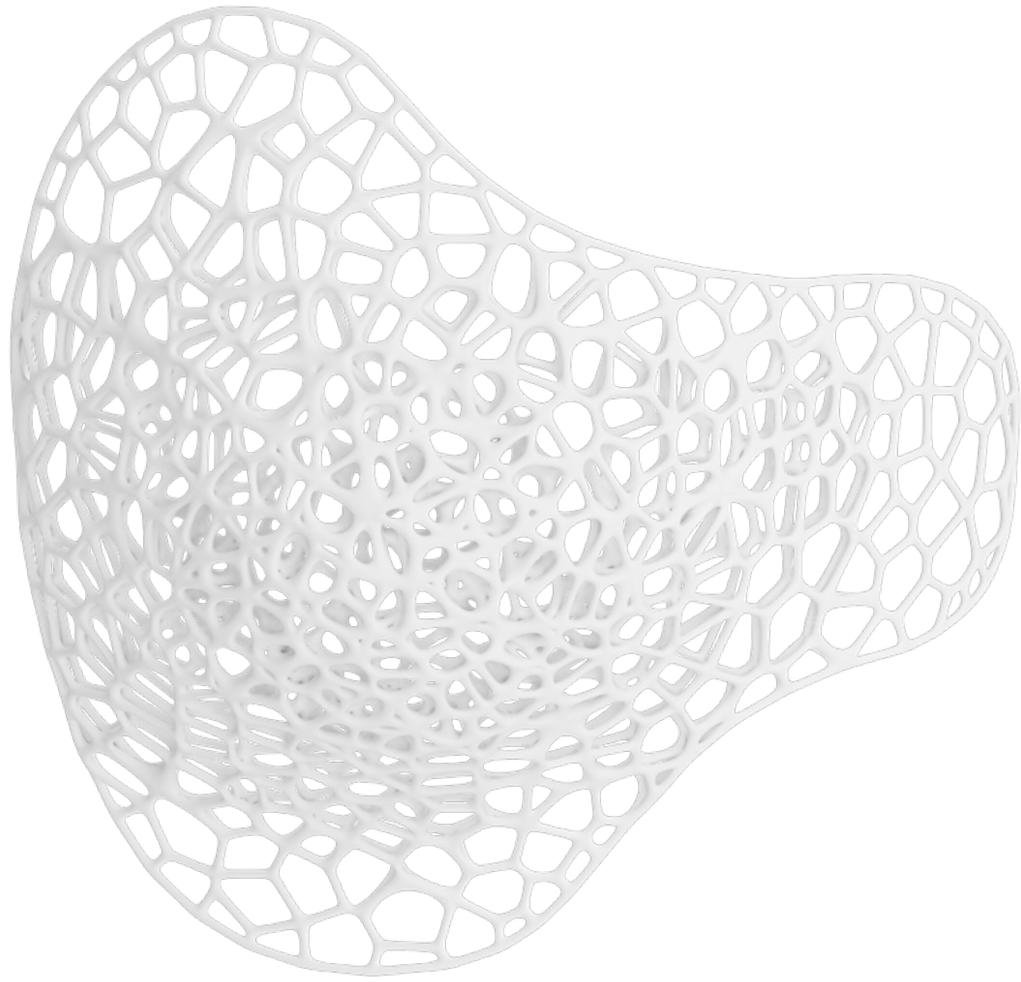
For the next iteration surface of the protector was divided into 4 areas. Where each one has an increase in radius of the circles filling the surface. This made transition of the pattern much smoother.

Together with slight adjustment of thickness, these iterations moved flexion area closer to the border and created much smoother and appealing looking distribution of the pattern.



PROTECTION DEVELOPMENT





While TPU protector version is printing - I work on CAD for protector prototype in nylon. This one will be printed in SLS printing technology.

This technology gives me possibility to explore different, more complex structure pattern, compared to one I have used for TPU version printed with FDM.

In this prototype I chose to work with so called Voronoi pattern. This pattern creates an interesting organic look and unique visual identity for the product. I have used parametric modelling with grasshopper, in a similar way with other protector, which gives me control over parameters that can be changed for later iterations.

Just like in previous CAD, protector shape was divided into three areas, creating more points in central areas, achieving significantly denser and rigid structure where protection is needed. In addition to point density, various thickness also applied to the shape, contributing to rigidness and creating a beautiful flow from single layer pattern to complex double layered structure in the centre.

Figure 3. 20 points and their Voronoi cells

The way this pattern is constructed - lines are drawn on the distance furthest from individual point, between multiple points. This way, the more points I have - more lines are created, and the denser structure is. Which is opposite to circular holes pattern used in another protector, where the more circles I create - the less density the structure has.

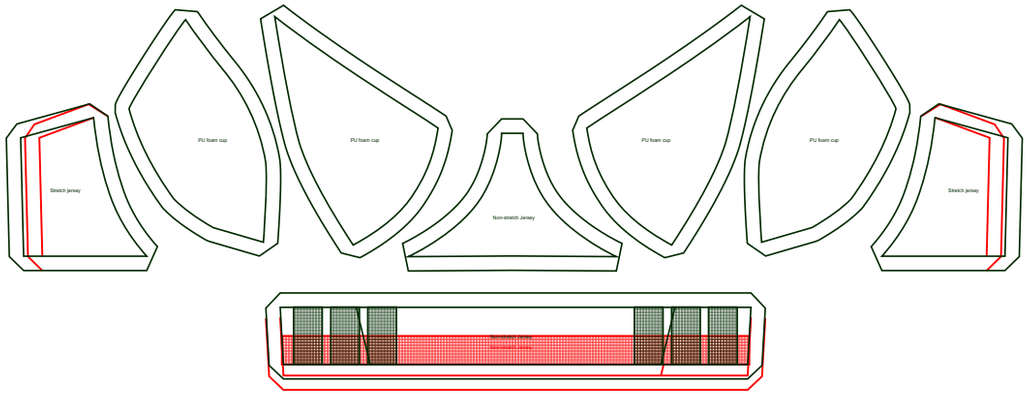
This should result in flexible structure on the periphery and safe rigid area around breast tissue. It is hard to predict the behaviour of the structure. Therefore, it has to be observed in a physical print.

Now that protectors with structures are created, I will move on to the next phase of detailing, where I need to do another session of user testing, which will include both complete parts of the product: a bra and protectors, to receive feedback on improvements I made in the product as a whole.

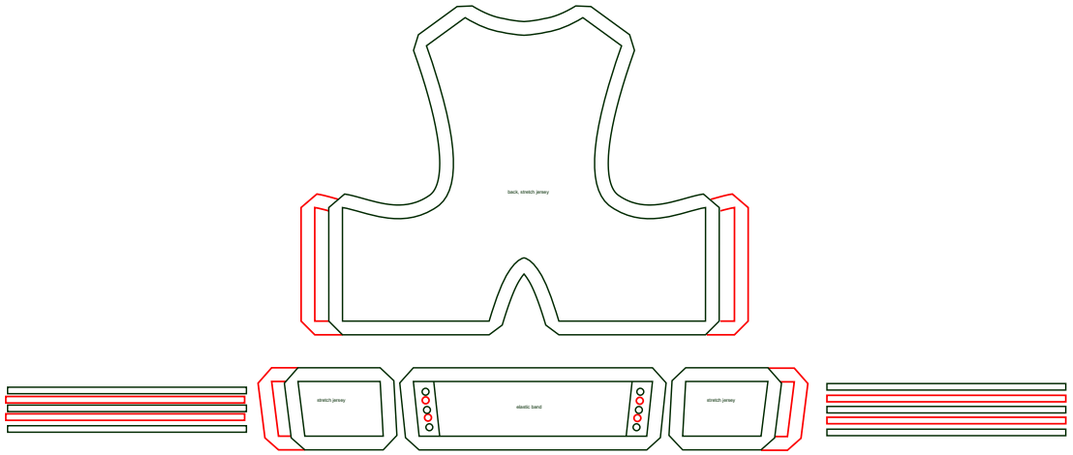
DETAILING

ITERATIONS

After processing the feedback from user testing, some iterations to the sewing pattern had to be made. This iterating and detailing included:



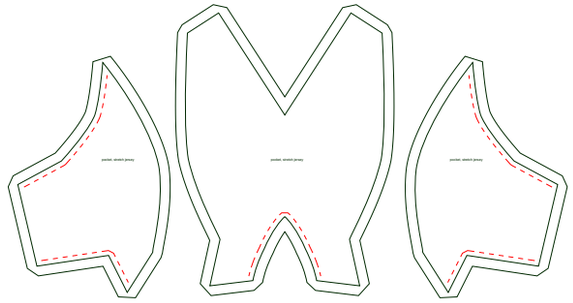
Relocation of velcro fastener surface from side to the front of the bra, where it will not interfere with elbow movements. Width of the under-breast band is limited and part of the space is taken by protector surface. For this reason width of the band was increased on 7 mm. Velcro strap width is reduced from 40 mm to 25 mm, howewer, surface and respectively strenght of the fastener is compensated by increased lenght. As a result, edges of the Velcro hook band will remain outside of elbow movements range, as a safety measure from detaching the fastener and scratching the skin.

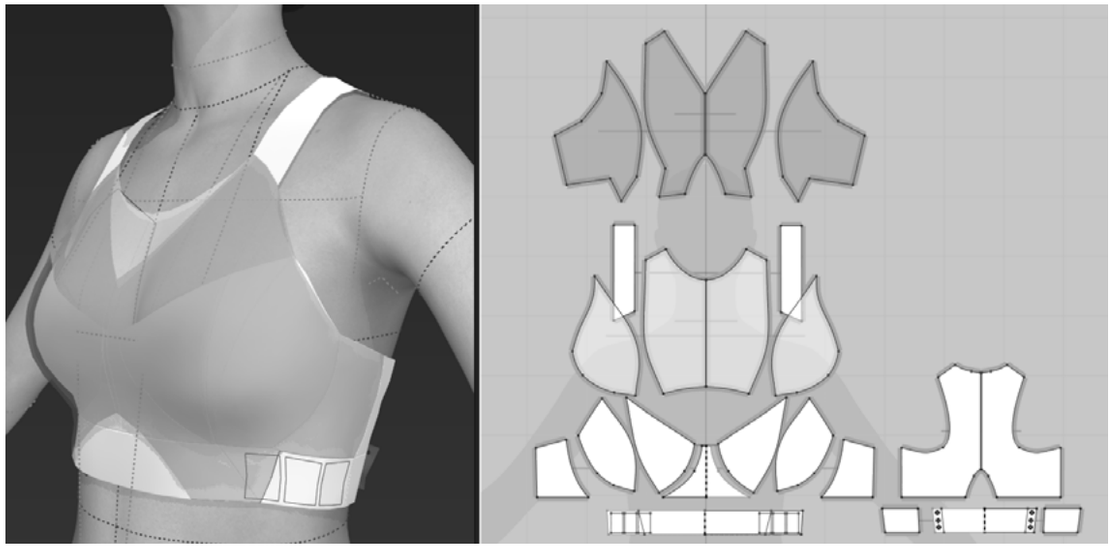


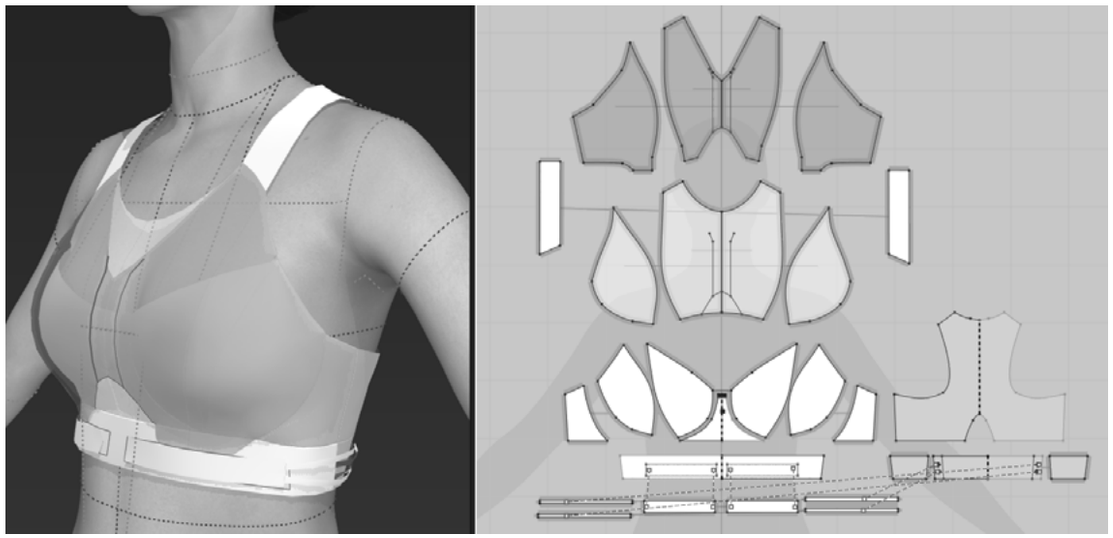
Decrease in width of the velcro fastener resulted in reducing amount of laces on each side from 3 to 2, as they now have smaller surface to be attached to.

Previous sewing pattern was quite tight in under-breast band even with given adjustments. This is due to use of non-stretch textiles in the front part of the bra. To compensate that, in the new pattern underbreast circumference was slightly increased, as well as was added more stretchy material in the proportion.

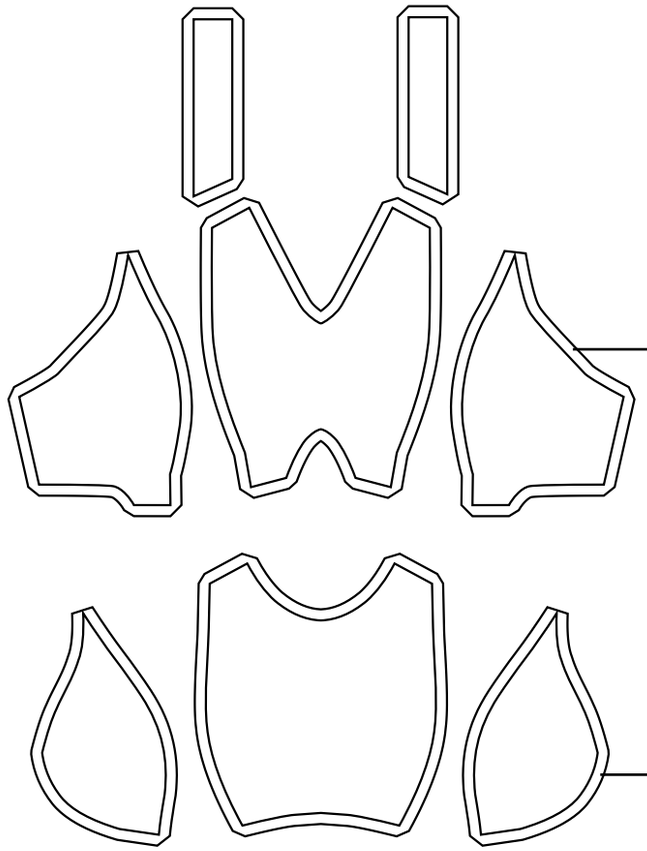
Considering that identified as the most ergonomicaly convenient way to insert the protection was through the center - in this pattern iteration all other pocket sides are securely sewn to the bra, leaving identified entrance as the only one, and ensuring that protector sits nicely in place and does not slide through any other sides.



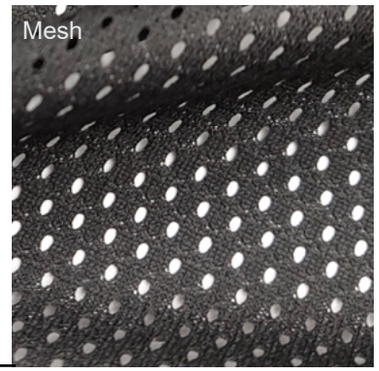


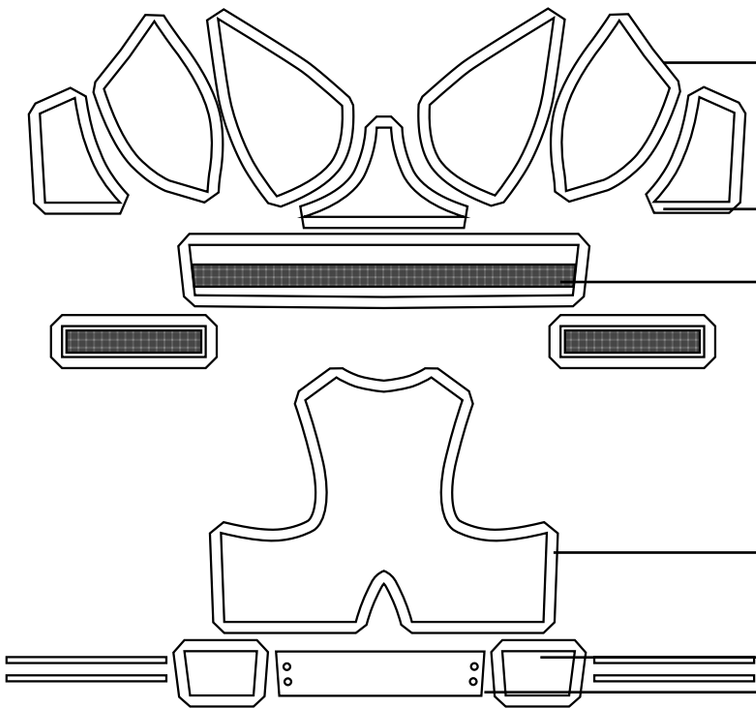


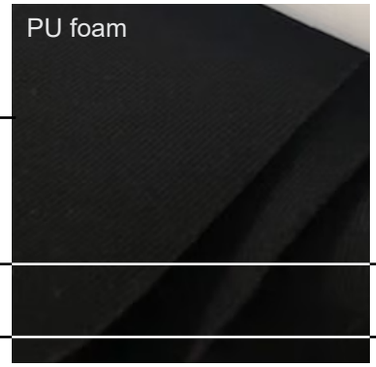
FINAL MODEL

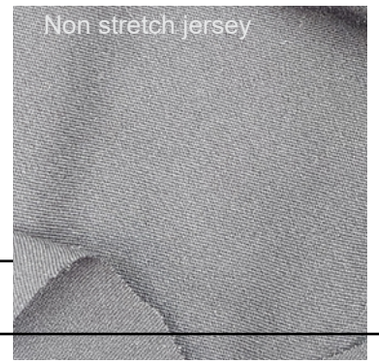



Stretch jersey

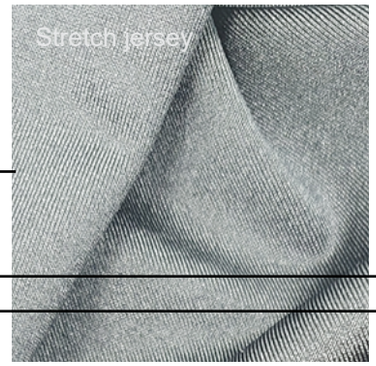

Mesh

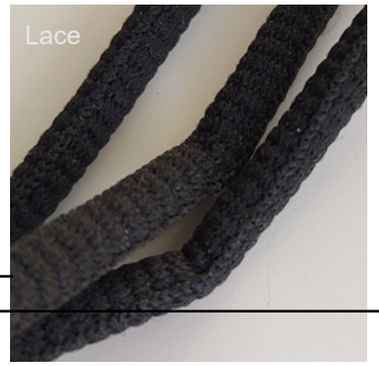


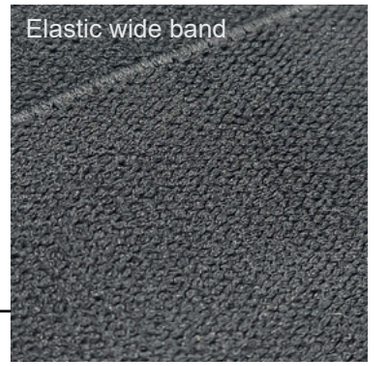

PU foam


Non stretch jersey


Velcro


Stretch jersey


Lace


Elastic wide band


JANOME
START
STOP
QUALITY SEWING
SINCE 1921
ALLVIS

FINAL MODEL

COLOUR

Physical model for the project was manufactured in total black palette, as it is a good way to source all the necessary materials.

It is also noticeable from interviews with users, that most will prefer basic and neutral colours. However, layer structure of the bra, as well as multiple elements create a good ground to introduce some vivid colours to the palette as well, to match all the preferences and elevate design features.

Therefore, colour palette includes:

Neutral white, to match the requirements for garments for such disciplines as karate or blend well under such wear as white Dobok or Gi.

And calm universal olive that matches with wide varriety of garments and white mesh layer, that will add contrast and emphasize shape lines.

Black has a good chance to be a popular choice, match easy with any other sport garment and keep its colour for longer time without stains and discoloration compared to very light colours. Vivid elements. Maintaining a good balance between neutral palette and sport colours. Highlighting design elements: colourful mesh on contrast with dark pocket indicates the entrance for protector insertion, as well as bright laces give attention to size adjustment feature.

Vivid elements may include red and blue, as part of indication of corner colour in some combat disciplines;

FINAL USER TESTING

For this user testing session I have contacted same young women, who gladly agreed to participate both times. I have also included in the testing another active young women, who does not participate in combat or contact sports. But certanly have a valid opinion on sport bra design and ergonomics. Not to mention that all the prototypes were tested and tried on by myself as well.

Results showed that: Velcro adjustments are no longer in range of elbow movement.

It also showed that adjustments are helpful for easier putting on and off, as loosening it in under breast band gives more space for taking it through head and shoulders.

Now that both TPU and nylon protectors were tried on, I have received the feedback, that nylon protector sits well, but during the movement edges feel quite hard against the skin. Even though border area of protector have certain flexibility - it is not on the desired level.

TPU protector on the other hand was perecieved as comfortable. With much softer edges and general flexibility - it did not interfere in the movements.

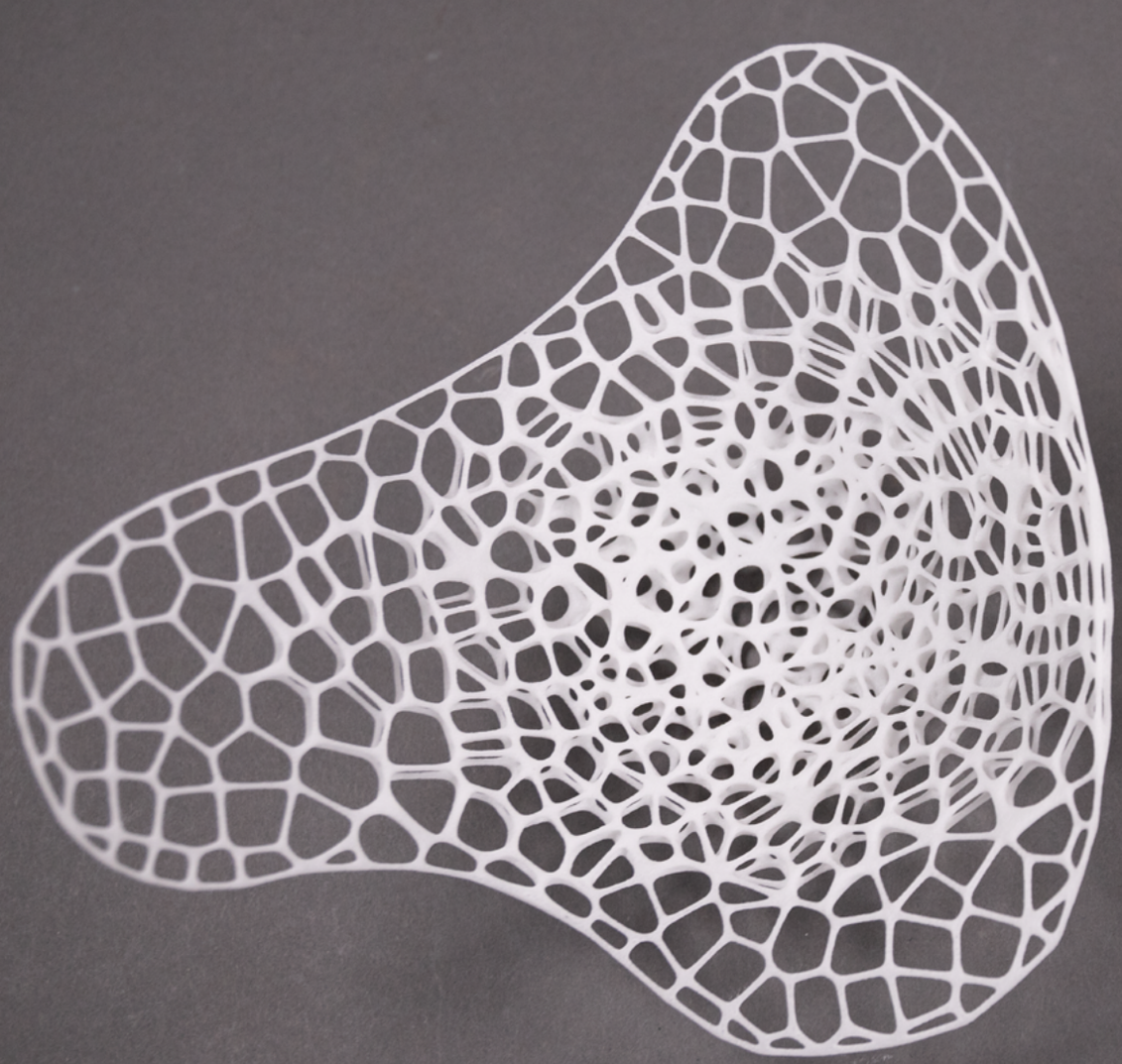
Both prototypes were percieved as giving good protection, based on personal sensations and feelings similar wearing CE approved protection cups currently used in kickboxing.

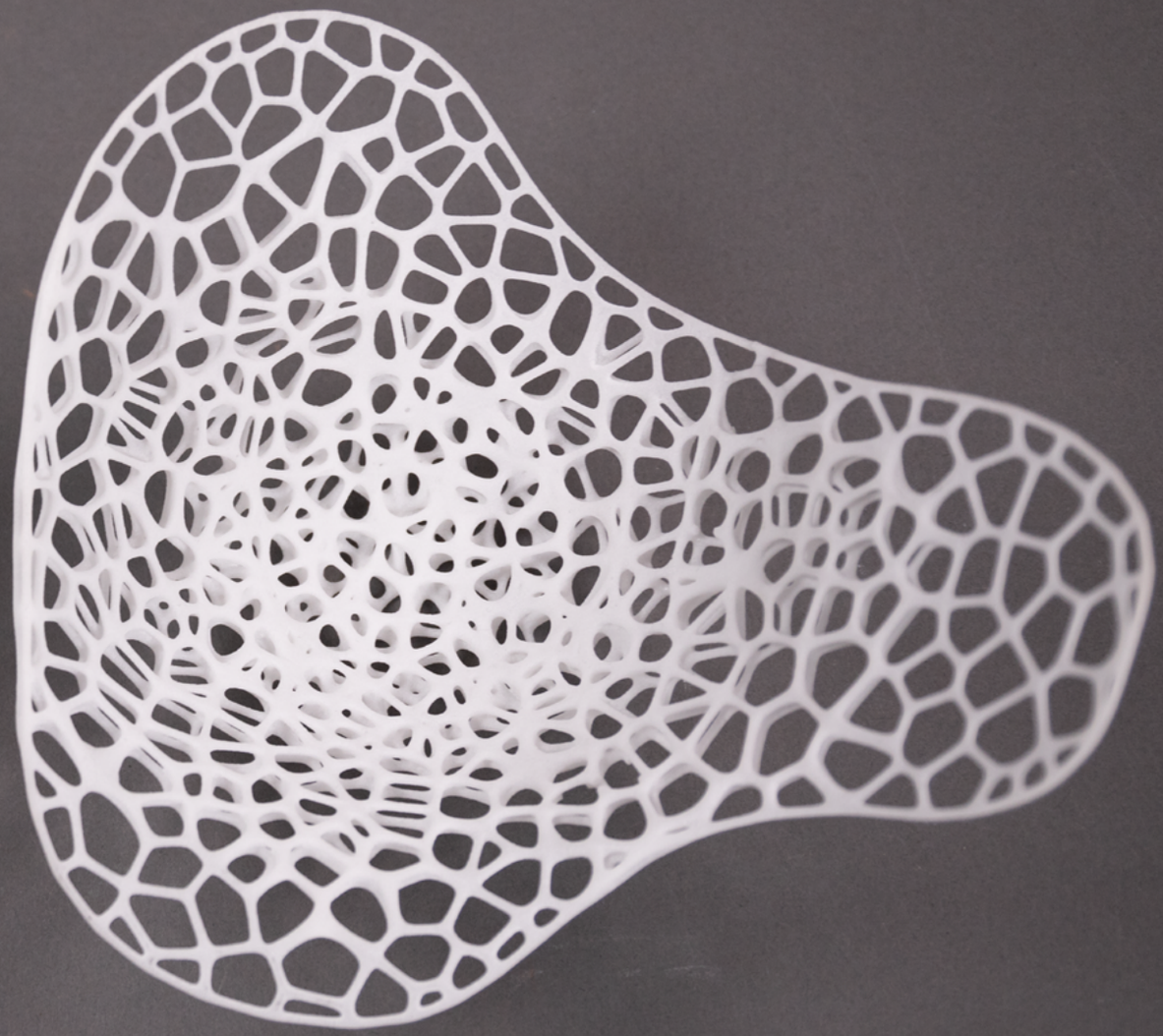
FINAL USER TESTING

LOOK WITH AND WITHOUT PROTECTION

FINAL USER TESTING

Based on feedbacks from users, I created an iteration of SLS nylon protector, where thickness of the pattern was reduced to achieve more flexibility.





WHAT IS NEXT: REFLECTIONS

Unfortunately, nylon protectors showed themselves too fragile for this purpose of use and with given thickness. Increasing thickness might make them way stronger, but too stiff as well.

Definitely, flexible materials are to go for in this case. For example, in case of overload, material like nylon will snap, when TPU will bend in the worst scenario. Therefore I consider nylon protector more of a visual model for further exploration with different materials.

Another my reflection is that even though my initial concept was to use advantages of 3D printing technology for production of protectors. I have discovered, that circular pattern created for TPU print is quite possible to readjust for injection molding.

Both of the methods will have their benefits.

For instance 3D printing will not require production of a mold, thus makes it easier to produce a wider size range to cater for different body proportions.

With wide size range and separate cup protectors in flexible material will be possible to cover needs of most user. But for few individuals who need that — 3D printing makes possible custom shaping protection.

Traditional injection molding on the other hand, should make product cheap and available, as 3D printing as a production method is only developing.

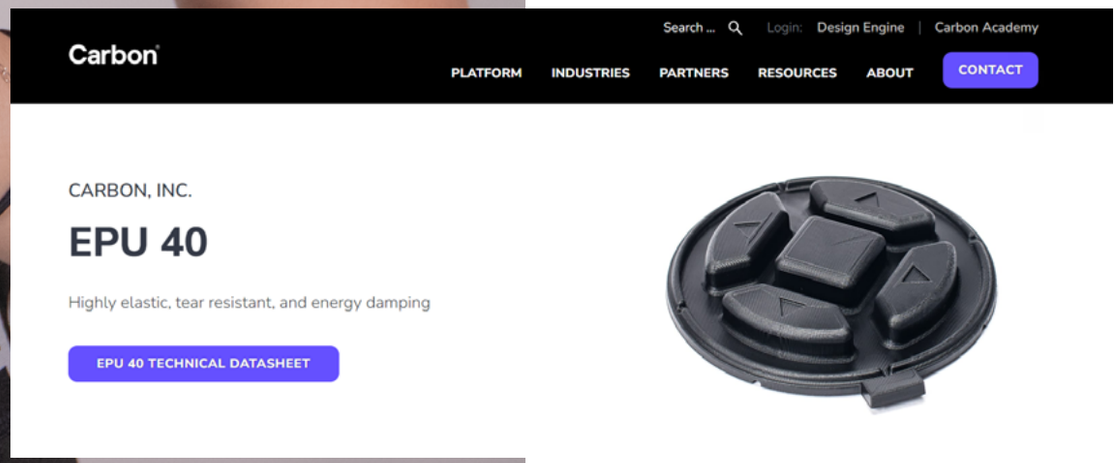


Figure 4

WHAT IS NEXT: REFLECTIONS

A potential next step in development will be impact testing. It is important to evaluate precisely in numbers, what impact protection can handle. And does it meet the requirements.

Except for the impact, the product will need to be produced and tested in different sizes, because changes in dimentions may affect characteristics, both for bra and protectors.

Potentialy, it would be a long way of testing and gaining official certification and approval of sport federations for use of new protectors.

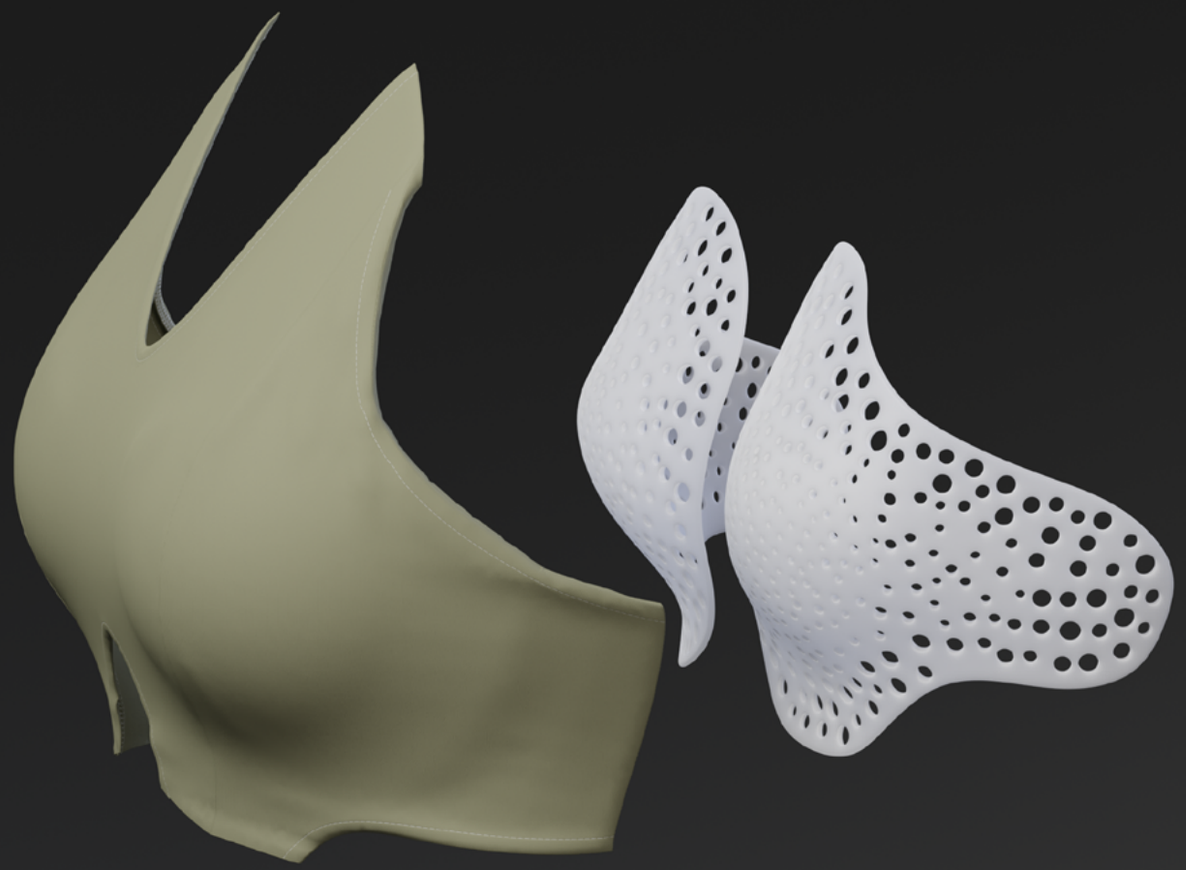
However, the bra is well compatible with separate protection cups that are currently available on the market.

VISUALISATION

VISUALISATION

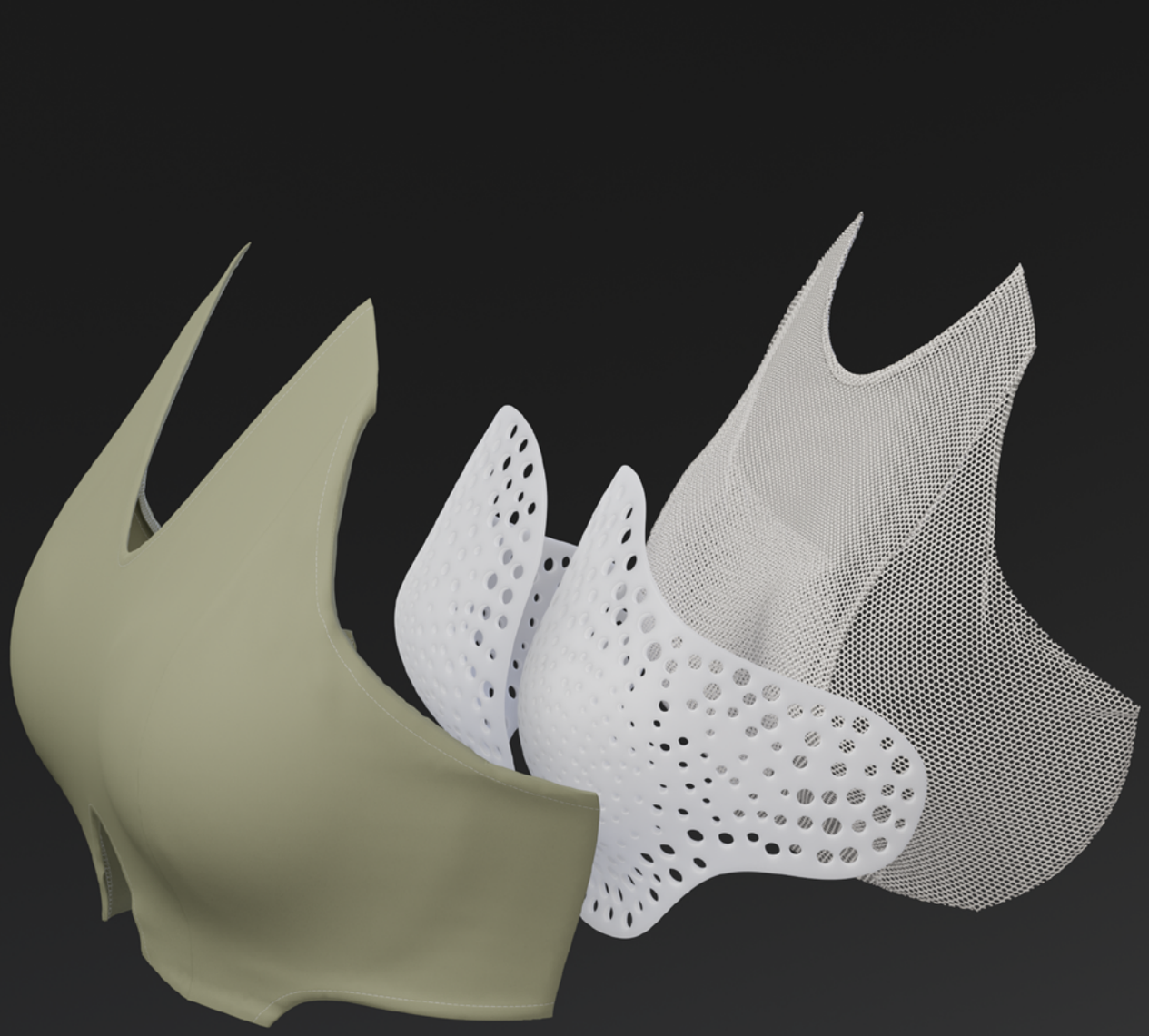
VISUALISATION

EXPLODED VIEW



VISUALISATION

EXPLODED VIEW



VISUALISATION

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