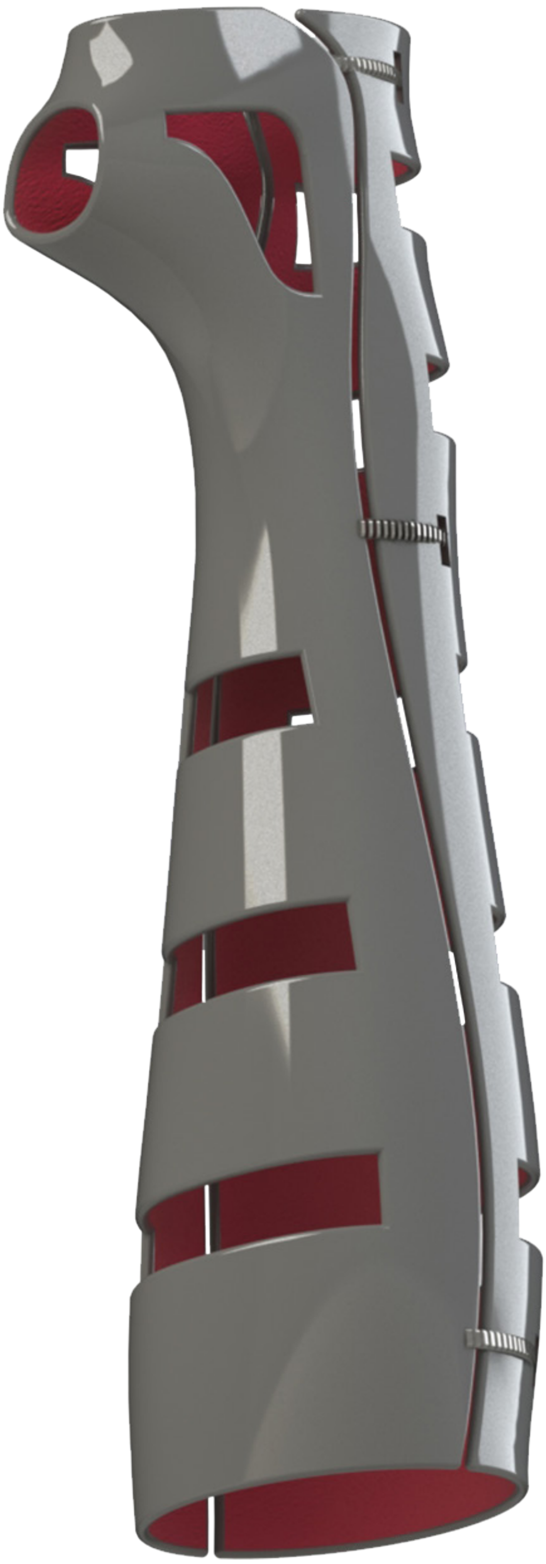
A CAST FOR THE FUTURE
DESIGN FOR BIOMEDICAL ENGINEERING



DESN 303
ASSIGNMENT 3
BY INNES GALLOWAY 9159262 & RHYS WYNNE-LEWIS 8475014

EXECUTIVE SUMMARY

Breaking a bone is a problem that many of us will have to endure at some stage through our lives. The initial break might seem like the worse part about the ordeal but having to have your arm in a cast for the next 6 weeks can prove to be very difficult and frustrating. Fibreglass and plaster casts are not very user friendly in their design and make it hard for the user to carry out basic day to day tasks such as having a shower or being able to wear a shirt. Not only do they have these problems they are also applied in a two step process first a plaster cast then a fibre glass cast.This two step process can be very problematic especially if you live out of a main city centre and you have to travel a considerable distance to get to a fracture clinic. Adults may need to take time off work and incur travel costs just so they can get one cast changed for another.

With this in mind we look to redesign the medical cast and process in which it is applied so that it is more user friendly and environmentally friendly. Our cast we have design is based on a 2 shell system with adjustable straps on either side which will enable the cast to expand or contract depending on a persons arm size and swelling amount. These straps will be able to be adjusted by a local GP using a key lock system to tighten or loosen the cast depending on what is needed. This will mean the user wont need to travel into a fracture clinic and could get it adjusted in their home town. The cast will be made out of an ABS outer shell and a neoprene inner given the cast a strong structure while enabling still enabling comfort. A big goal with our cast was to make it waterproof so that the user could easily have a shower without worrying about their cast. This neoprene layer will allow the user to do this as it will be able to dry within 30 minutes to an hour.

Our cast has been designed from a very sustainable approach. At the moment 100% of medical casts are chucked out after they have been used, no materials get re-used or recycled. Because our cast has a hard outer shell it will be re used by patients, the neoprene inner used will be able to be recycled making our product fully recyclable.

BRIEF & NEEDS

The Problem

Breaking a bone is not a very enjoyable experience and is something most of us will have to endure at some stage through our lives. However what makes the matter worse is having to put up with wearing a cast for the 4 to 6 week period whilst your bone heals. When you get given a cast one thing the nurse hands you is a ‘cast care’ booklet which informs you on things not to do such as getting your cast wet or sticking any objects down it. This can either go to ways users trust this information and have an uncomfortable 4 to 6 weeks with an itchy smelly limb or they do not follow instructions and run the risk of damaging their cast and possibly ending up with infections or pressure points.

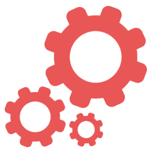
Another major problem surrounding the current process of getting a cast is that it is a two step process. First a plaster cast is used to help with swelling then a fibreglass cast for strength and durability, this is an inconvenience especially if you have to travel a considerable distance to get to the hospital.

Project Brief

Develop a medical cast which mitigates the two step process of having two casts applied as well as allowing the user to carry out daily routines that current cast options would have prevented.

User Needs

- Comfortable
- Waterproof
- Quick drying
- Lightweight
- Breathable
- Aesthetically pleasing
- Affordable



Physical Needs

- Durable
- Strong
- Easy to apply
- Reusable/ recyclable
- Easily stored
- Quality
- Basic construction
- Adjustable

RESEARCH SUMMARY

Primary Current Options

At the moment there are two main types of casts that are used to heal broken bones. Plaster of paris is the first one, it is a "heavy white powder that forms a thick paste that hardens quickly when mixed with water" (kidshealth). Swelling occurs after a bone is broken, this is due to blood leaking out and causing a fracture haematoma. This haematoma helps keep everything to stay together to help the mend. Plaster of paris casts are used at the start of the healing process as they can be cut down the sides to allow for swelling but still be kept firmly around the arm with the soft cotton material on the inside. When talking to the nurses in the Otago hospital fracture clinic they said they prefer working with plaster of paris as it can be easily moulded to get a nice firm fit. However for the patient plaster casts do have a few downsides, the plaster is heavy and quite bulky (Fig1). You also have to be very careful with a plaster cast that you keep it as dry as possible as the plaster doesn't hold up well in water.

The next type of cast that is currently being used is a fibreglass cast. Fibreglass casts are generally applied to the patient a week after the break has occurred this allows enough time for the swelling to have settled. The cast is made of "water-activated polyurethane resin combined with fibreglass bandaging materials" (wisegeek) these materials give the fibreglass a greater strength than plaster and also allows the cast to be thinner and lighter. However there are downfalls of the fibreglass cast too. The materials set a lot quicker and so it is harder to get a nice moulded fit on the patient (Fig 2). Although many are under the conception that fibreglass casts are waterproof they are not, the outer layer is however the inside is still soft cotton and does not dry out very well so can cause irritation and possible infections. You can get a waterproof liner for a fibreglass cast, but this liner as instructed by the nurses at the fracture clinic is uncomfortable, deteriorates very quickly, and still takes a while to dry it also can only be used for a few types of breaks.

Secondary Current Options

There are other methods that are being introduced privately such as 3D printed casts (Fig 3) which work by scanning the arm then making a 3D printed cast. However as good as this system and idea sounds we believe there are a few reasons of why it has not been introduced and being used in hospitals. The first one is price, compared to current methods the start up costs are considerably higher as each hospital would need a high tech scanner as well as a top of the line 3D printer which will be able to produce a cast in a short amount of time so the patient isn't hanging around the waiting room all day for the cast to print. Another major problem is due to the swelling if this method is implemented straight after the break then the 3d model will be made when the arm is swollen and when the swelling goes down the cast would be loose and not effective at all.

Plaster of Paris Cast

Fig 1

Fibreglass Cast

Fig 2

Materials

Our cast has been designed to be made out of three different materials. The first material we looked into was for the outer shell of the cast. This meant the material needed to be strong, cheap and durable. To get inspiration we looked at bike and ski helmets as these products share similar values of what they need to provide. We found that general purpose ABS would be the best material to produce the outer shell out of. “ABS (Acrylonitrile Butadiene Styrene) is a thermoplastic resin commonly used for injection molding applications” (absmaterial). ABS will provide us with a strong, rigid outer layer to our cast and will be inexpensive compared to other materials.

The second material we had to research for was a material to put on the inside of the cast where the cast meets the skin. Properties we looked for with this material was that it could be soft to touch but still firm this will allow us to give a nice comfortable fit for the user but still provide the body part with stability around the break. We were also looking for a material which could be waterproof and dry out really fast this would allow the user to not have to worry about getting there cast wet. When looking for this material we took some inspiration from a wetsuit and looked at the benefits neoprene (Fig 4) could provide. “Put simply, neoprene is a type of foamed synthetic rubber” (seventhwave) we believe it will provide our inner shell with a plushy inner that will have enough give to make our shells more customisable to each individuals limb. From researching various wetsuit sites we saw Rip Curl have introduced a product in there wetsuits called Flash lining which has a “rapid dry time and is also one of the warmest, most comfortable linings out there” (ripcurl) we would look to work with Rip curl and use this technology or create a similar material.

The final material that will be used to make up or cast will be for the clip which tightens up the cast. The strap that fits in and through the clip will be moulded out of ABS be part of the outer shell. For the clip we would need something with a high amount of tensile strength as the clip and strap will be the area were the highest amount of stress and strain will be placed on the cast. When looking for materials we thought stainless steel would be the best option. Stainless steel has a relatively high tensile ultimate and yield strengths of 505MPa and 215MPa. This will give the clip good strength and make sure it does not fracture under pressure. Stainless steel is also reasonably cheap so this will aid us in keeping our cost down for our cast.

3D Printed Cast

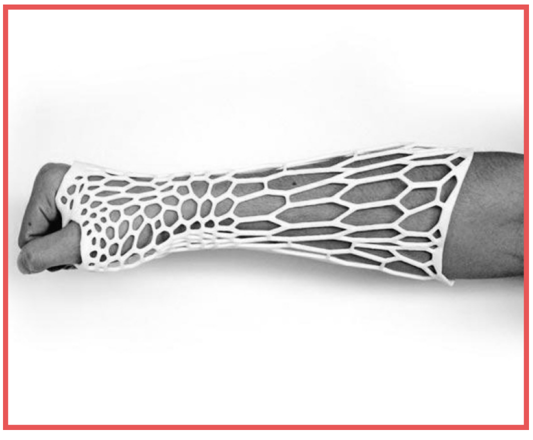


Fig 3

Neoprene Sleeve

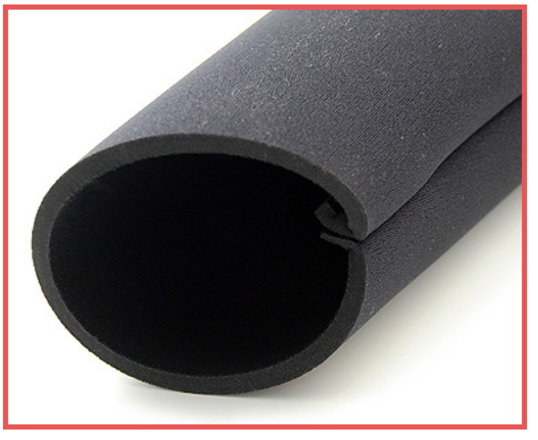


Fig 4

DESIGN STRATEGIES

Inclusivity

Our cast has been designed in a very inclusive manner. Throughout the design period we have been in contact with Doctors, Nurses and direct patients from the Dunedin Hospital as well as past and potential future patients from the University of Otago. Through doing surveys and questionnaires with our stakeholders and consumers, we were able to get a wide range of valuable information that has helped us accurately develop specifications and guidelines for this design.

Another way in which we have included inclusivity into our design strategy is talking to fellow design students and getting their thoughts on our project and gaining constructive criticism from them. This feedback that we gain from fellow students is very valuable as they also very knowledgeable of where ideas are going and will be honest in telling you if you are heading off track.

Sustainability

Sustainability has been something we have looked at throughout the design stages. Currently medical waste is a huge problem as a lot of it is non renewable. We have redesigned the cast to be fully recyclable both inside and out. With an exterior layer made of ABS this cast design will be extremely durable and can be washed and reused for up to five years. The interior layer is made of a neoprene type material that can also be melted down and recycled.

Because the casts will come in ten universal sizes they can simply be sterilized and reused by the next patient. This means the recyclable rate of the casts will far out weigh the rate of the need to produce new ones. Although the original cost of producing one of these casts is not as low as the current production cost, the affordability of these casts will come through the recyclability as well as efficiency of application. Cutting down the time that Doctors and Nurses have to spend with patients creates more time to work with the next patient meaning more patients are seen each day.

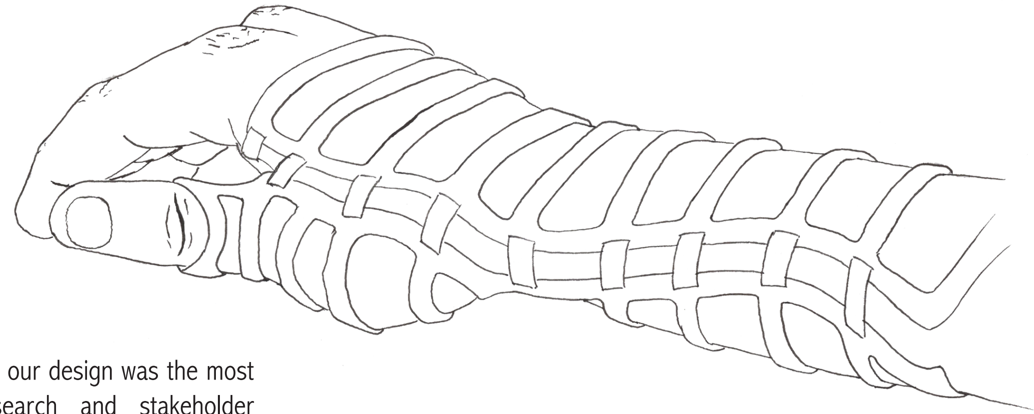
Frugal Innovation

Although we have designed a slightly more complex cast to the casts we see today there is still some frugality to our design. We believe this cast can not only save our environment from medical waste but also save a lot of time and money for hospitals around the world. Time management is extremely important in hospital work and broken bones aren't always on the top of the list. This design makes applying this cast extremely quick and easy for medical staff. Affordability is gained from quick and easy application as well as the products reusability.

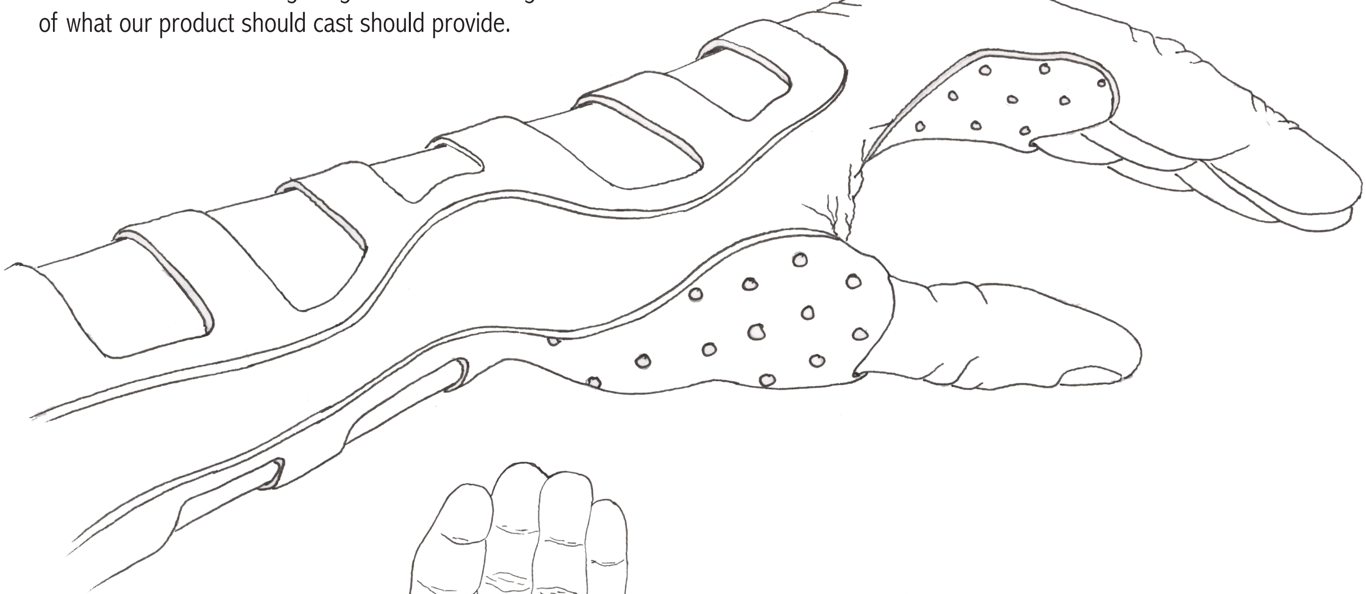
For the patient having to spend more money on a cast when it is applied might not seem like the cheapest option, however developing a cast which will cut down the time the patient needs to go to the hospital could be saving them alot of money. If a patient needs to travel a considerable distance to the hospital this could mean getting the day off work. This is a huge cost the users will have to pay to get their cast switched over, added in with costs such as petrol it makes the concept of spending more on a developed cast worth it.

We have used these design strategies to better understand exactly what we were trying to achieve and what the consumers wanted. By including multiple stakeholders into the design it made it easy to locate the most accurate and valuable information possible. Sustainable design is the way of the future and if our design were not made to be sustainable it would be no better than the casts we use currently and therefore no point of difference to create future sales. Frugal innovation has helped us to look at the design in a different perspective and realize what is actually needed from the design itself and why.

CONCEPTS & DEVELOPMENTS

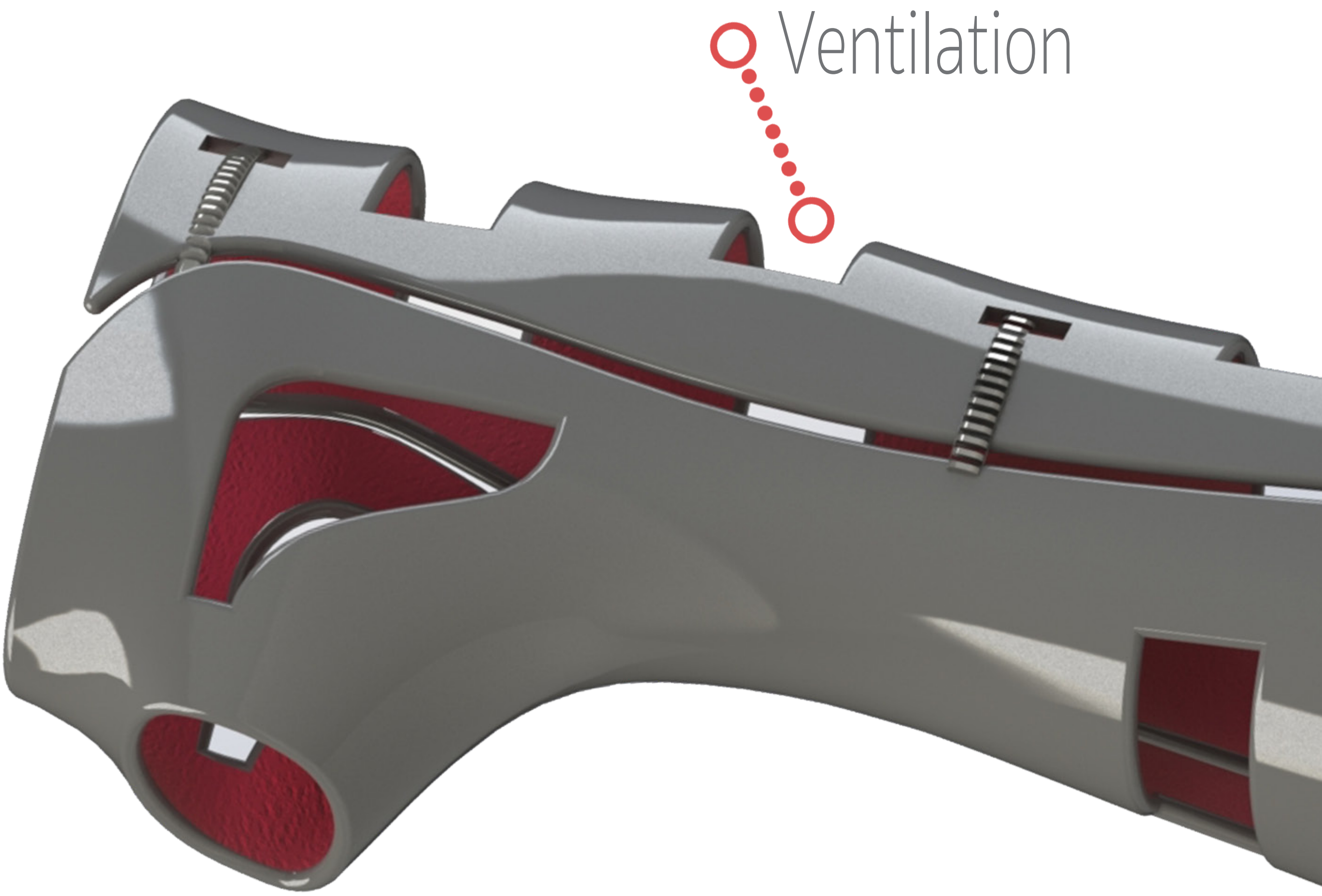


- The conceptual stage of our design was the most complex. Through research and stakeholder feedback we were able to get a good understanding of what our product should cast should provide.



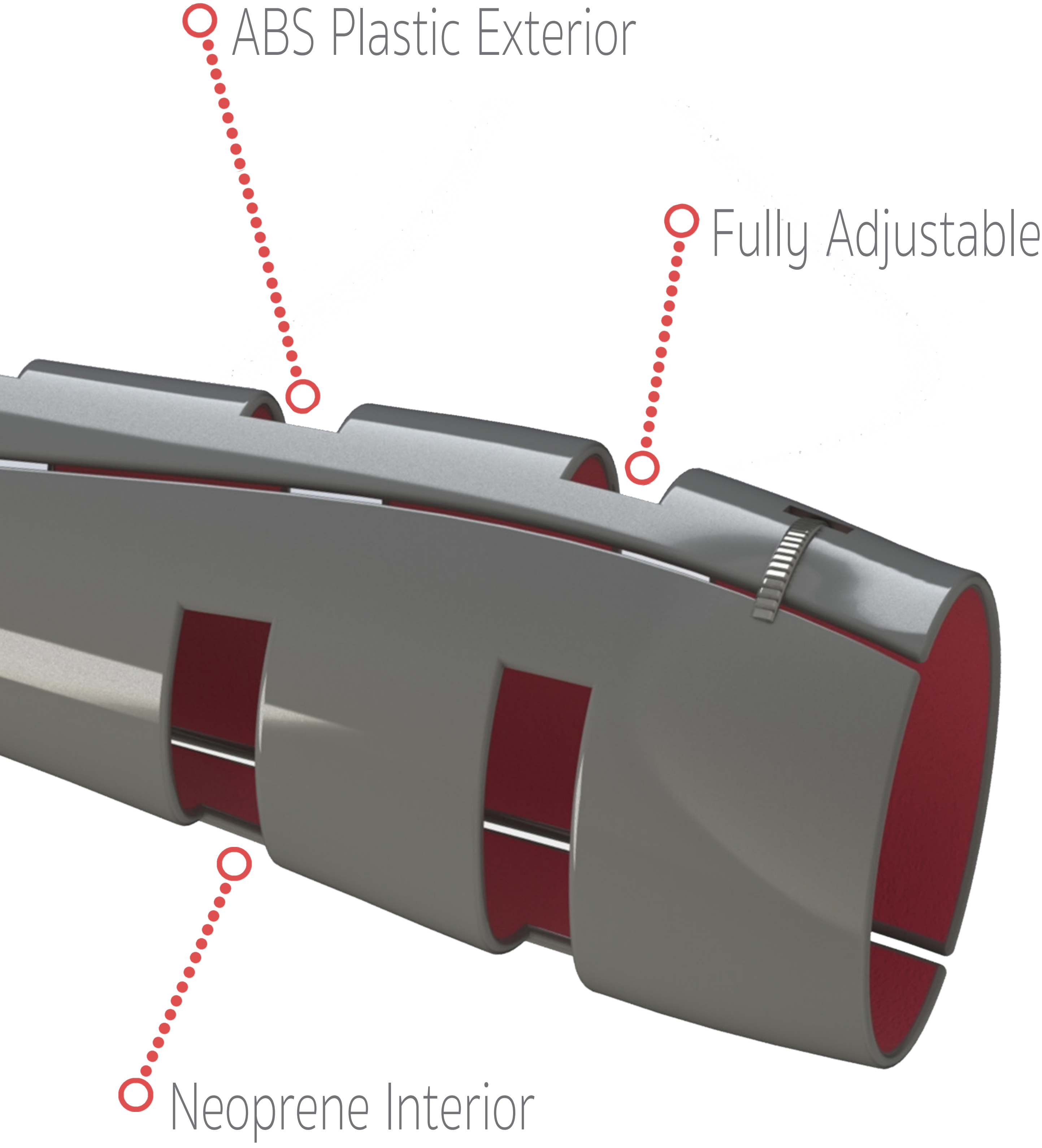
- We started with light weight, ventilated designs but found these were going to be too weak. We then moved on to look at a combination of ventialtion, comfort, ease of application and strength which gave us a general shape. Gaining feedback along with suitable material selection then gave us the inspiration to continue development and move into prototyping and computing a final prototype concept on solidworks.

FINAL OUTCOME
& DISCRIPTION



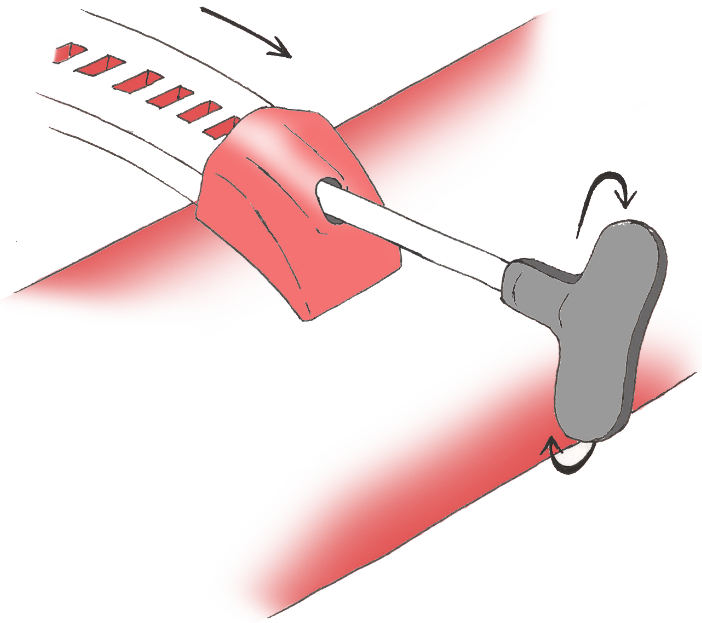
Description of Needs Met

Our final design definitely still has some room for improvement but this will take time to gather the relevant information and data that we need to proceed. With the time frame that we were given and the lack of knowledge that we originally had, this design has exceeded expectations of both our users and ourselves. Through extensive research of our problem we identified a set of user and physical needs that we thought are crucial to our design. From here we created this concept that is aimed at satisfying all those needs whilst at the same time keeping frugal innovation and the environment at the forefront of our design. Through regular communication and feedback from our user group we were able to specifically design the cast to suit exactly what the user wanted as well as what was actually needed from the functionality of the cast itself. The cast provides maximum comfort through its neoprene interior layer that is also waterproof and quick drying within 15 minutes. Ventilation holes mean that the users arm can breathe which stops irritation, itchiness and can also prevent infection to any wounds. The ABS plastic exterior layer gives the cast a rigid, durable quality, which is essential to heal a break or fracture. This material can also be easily moulded to any shape and can be washed at high temperatures for sanitation. This material is also extremely light and even if the material is not very thick it is still strong so this also covers the need for the cast to be non bulky. Our concept has been designed with storage in mind so each side of the cast can fit into each other taking up less space. The adjustable clips are made of stainless steel, which is extremely durable in any conditions. With the ability to adjust inwards or outwards this cast can be set to the perfect position of comfort by your medical practitioner. The adjustments are refined to medical staff only by including a unique screw drive that will only be made available to hospitals or medical centres. Although this cast isn't the cheapest product to produce it saves time and money through its reusability, recyclability and its ability to be applied to patients within seconds.


ABS Plastic Exterior
Fully Adjustable
Neoprene Interior

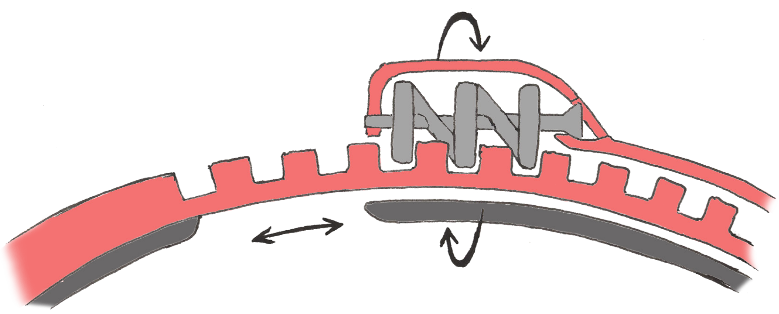
ADJUSTIBLE CLIP DEVELOPMENT

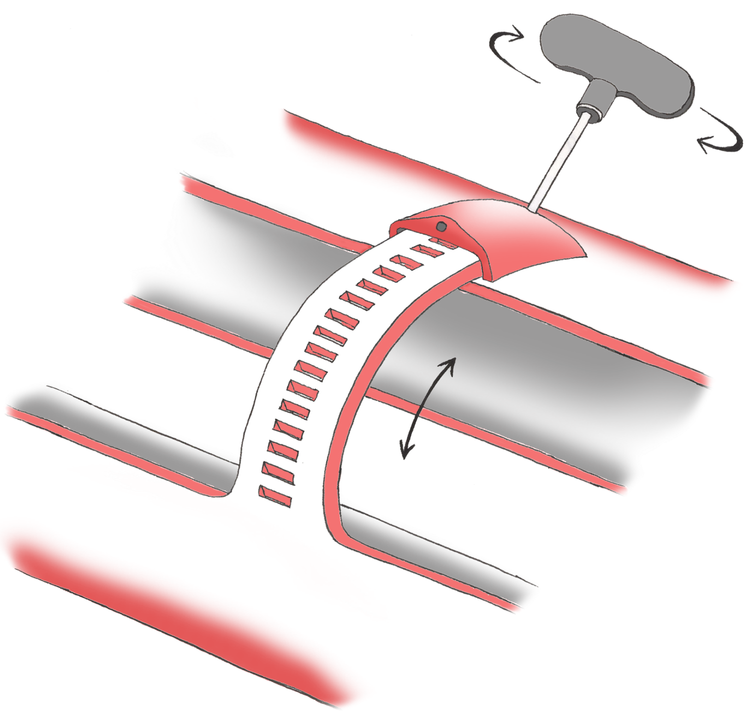
Fig 5



- As you can see from these images we had to design an adjustable clip to fit the cast and hold it firmly in place. Through research and development we came up with this idea which is based on a Jubilee Hose Clamp (Fig 5). This idea suited what we were looking to achieve as the strap and clip combination had to be adjustable but able to be fixed in place by medical staff making the cast rigid. The Jubilee Clamp alows the cast to be adjusted through a screw type mechanism which can be tightend or loosened with ease.

- From this cross section image you can see how the srew type mechanism can be turned left or right to determine how much the cast is tightened or loosened. This makes it easy for medical staff to adjust the cast size to allow for swelling. The excess strap is guided between the outer shell and the inner layer to provide a more comfortable fit.





- This image is here to give an understanding of how the key would work to tighten or loosen the cast. The nurses in the fracture clinic told us that a reason why splints are not used often is because they allow the user to take it off when they choose. To stop this from happening our lock system would use a special head on the screw. Medical staff would be the only ones with access to the unique key. The strap will be made from the same ABS material as the outer shell is made from so it is ridgid yet bendy enough to wind in with the screw mechanism.

FUTURE OF OUR DESIGN

Testing

Testing must be undertaken by our prototype to see if it is capable of serving the purpose we have designed it to do. Structural and strength testing will be computed on our solid works model prototype through the stress stimulation tool used on solid works. Testing how much stress and strain that can be put on the structure and materials we have used will be able to give us an indication of how the model will hold up in real life. With this feedback we will then be able to deliberate further on whether the materials and structure of our design are suitable or not.

Another factor of our model that we will be testing is the comfort and overall aesthetics of the cast. Comfort is a huge factor for a medical cast as it is a device you would be wearing for approximately 6 to 8 weeks. We will need to test the inside neoprene layer to make sure that having it rested against skin for a long period of time is non irritable and also that it dries out sufficiently after getting wet to prevent sores and infections from occurring. Using solid works test we will also be able to test to see how slim we can make the outside layer before it loses its strength, having the cast as slim as possible will be beneficial to the user when doing everyday activities as well as sleeping. Getting feedback through the public will help us get a good idea of what aesthetics users would prefer. Although this factor may not be as important as others from our perspective as the designers, it is a very important contributor to the users overall experience of the product.

User feedback will be essential part of testing our model, once we are happy with a working prototype we can then get users to wear the cast for a 4 to 6 week period and get real time feedback of how the cast is feeling and that it is still maintaining it's structure. This information will be valuable as it will be a real life simulation and be able to provide us with information in which CAD testing programs will not.

Feasibility

Feasibility is a very important when it comes to proving our design is viable. To prove feasibility of our design we will need to look at future costs of our development. Such things we would need to take under consideration would be cost of materials, cost of manufacturing our product, shipping costs. Making sure quality is kept in the product is still a necessity, you don't want to cut costs by getting your product by a cheap manufacturer as you will most likely be trading off product quality. Because this is a medical device and is designed to help someone recover, quality would be in the forefront of our goals.

Another contributing factor of making our project viable is that we would need to get funding from ACC and have our cast approved by New Zealands District Health Boards to be allegeable to be used on patients. Meetings and focus groups with these various organisations would help to push our design to showcase what benefits it could provide. Another factor in terms of funding could come from patients having a choice of whether they would want to have our cast and pay extra for it, similar to what they do with waterproofed lined casts now. This could provide extra money to allow our product to be feasible and allow it to be viable.

REFERENCES

Text

1. “Broken Bones.” KidsHealth - the Web’s Most Visited Site about Children’s Health. The Nemours Foundation. Web. 26 May 2016.

2. “What Is a Fiberglass Cast?” WiseGEEK. Web. 26 May 2016.

3. “ABS Materials or ABS Resin.” ABS Materials or ABS Resin. Web. 26 May 2016.

4. “Seventhwave Wetsuits Ltd.” Seventhwave Wetsuits Ltd. Web. 26 May 2016.

5. “Rip Curl Wetsuits.” Mens Wetsuits Online. Web. 26 May 2016.

Images

1. Corazon, Dulce, and Jenn Walker. WiseGeek. Conjecture. Web. 26 May 2016.

2. “Broken Bones.” KidsHealth - the Web’s Most Visited Site about Children’s Health. The Nemours Foundation. Web. 26 May 2016.

3. Reilly, Rachel. “Is This the Plaster Cast of the Future? Designer Uses 3D Printing to Create Tailor-made Exoskeleton to Help Heal Broken Bones.” Mail Online. Associated Newspapers, 2013. Web. 26 May 2016.

4. “Leerburg | Neoprene Sleeve Arm Protector.” Leerburg | Neoprene Sleeve Arm Protector. Web. 26 May 2016.