THESIS REPORT

The next generation of a Surgical Power Tool

Alexander Abele
MFA Advanced Product Design
Umeå Institute of Design
A thesis report that outlines key problems and design opportunities for the next generation of a surgical power tool which was examined during spring term 2019.

In collaboration with
B.Braun AG
Aesculap
Werk_39
As a product designer, I would like to use my passion and ability to create products and services which help people and add value. Therefore, I have a strong interest in the healthcare sector which is also related to my family’s background. My mother has always worked as a nurse and my cousin is on the way to become a doctor. In previous years I supported elderly people in my neighborhood to manage their household between school breaks as a side job. During my education as a product designer I have done some projects related to the medical sector which I found interesting and informative.

In addition, I have been working in medical projects when I was interning at designaffairs in Germany and Veryday in Sweden. Now, I want to use the possibility for my Master Thesis to work with a professional medical company to get a deeper insight into this sector. I also want to explore if this would be the right area to start as a designer after I have finished my education. The opportunity to work together with different stakeholders during my thesis will also train and enhance my ability to lead and manage a project in a professional setup.

RESPONSIBILITY OF TODAY’S DESIGNER

I believe that good product solutions are not driven by the market economy where cost pressure leads to rapid decisions. Instead, new product innovations require a long user study including their surroundings and work-life. In a fast moving world where automatization has often been seen as the solution, I want to challenge the industry by humanizing the work through enhanced systems which will be more valuable for the society in the future.
01 | INTRODUCTION

Abstract
Background
Collaboration partners
Historical review
In collaboration with Aesculap and Werk_39, which belongs to B.Braun Medical in Germany, a new generation of a surgical power tool was examined and designed for this master thesis. Aesculap is a quality provider of products and services around surgery processes and Werk_39 is a new startup that focuses beyond the product which includes the exploration of new services, systems and the upcoming UI/UX challenges.

The Healthcare sector worldwide is under pressure with an aging society and the increasing number of patients, with many healthcare providers now recognizing the urgent need for an enhanced system transformation. Digitalization and connected health can be the key to make procedures more efficient, starting from planning, executing and monitoring treatments and instruments.

Hospitals are experiencing an increasing amount of canceled surgeries which leads to a higher time and cost pressure. As surgical instruments have the highest expenses in the hospital inventory, better and accurate processing of the tools are key and should be considered early on in the planning phase of a new surgical power tool. Problems with lost parts, dysfunctioning tools, wrong scheduled or unavailable instrument sets are amongst the ten most frequent causes of surgery delays. Surgical instruments go through a specialized cleaning and sterilization process hundreds of times each year and unaware or not correct treatments lead to an earlier wear out or to dysfunctioning parts. In the best case, each tool and device which will be used during surgery should be checked and tagged to the appropriate surgery to enhance the planning and reduce failures in the future, so each tool has a specific history and can be viewed digitally. A better connection between Aesculap and the hospital could improve the regular maintenance and service. But this procedure is not fully implemented today and it still happens that tools and adapters were used more often than they should be or were not maintained regularly.

Surgical power tools from Aesculap have been the key for many surgeries ranging from orthopedics, traumatology, cardiothoracic surgery and dermatology. Especially orthopedic surgery is today still one of the most dangerous work environments for surgeons and often lead to physical pains. The need for safer and more ergonomic instruments and procedures are getting in focus. In addition, planning, maintaining and storing instruments have not changed for a long time. An enhanced digitally system for tagging and storing tools can simplify this workflow even more.

My thesis goal was to examine the changing routines around the surgery room of the future and how this tool can be adapted to upcoming challenges like robotics and improved ergonomics. The next generation of this surgical power tool can include a system which enhances the overall process and provides a better service between end-user and provider.
BACKGROUND

HEALTHCARE SECTOR

THE FUTURE OF HEALTHCARE
Several challenges are facing the healthcare sector in the future ranging from an aging society, an increasing population with higher expectations and the consequential cost pressure.

In the last years’ companies in this sector focused mostly on increasing product quality and performance. While the tech-industry is changing quickly and is today a leading force of new digital and connective approaches, the healthcare sector is lagging.

Patients as well as the health workers are not always satisfied with the current medical procedures and ask for a similar level of innovation like the tech-industry is offering. New medical startups are focusing more and more on patient or customer experiences rather than product innovations.

Well-known medical companies are challenged to adapt their existing products and systems to the upcoming changes. Aesculap is a leading provider of surgical instruments and has seen the opportunity and need for adapted surgical tools are getting more already in the planning phase of a new generation.

The surgery room is the heart of every hospital where efficiency and accuracy are the core values to save lives and treat patients. To offer an enhanced system where manual steps of planning and organizing are improved could be beneficial for Aesculap future goals.

This could strengthen the relationship with their customers and build a good foundation to handle the upcoming problems together.

When companies start to place users’ needs first which are in this project scope the surgery personnel, new tailored solutions can be offered. It is beneficial for increased revenue performance and creates more job possibilities for Aesculap’s personnel, new tailored solutions can be offered. It is beneficial for increased revenue performance and creates more job possibilities for Aesculap’s personnel.

In addition to the gender equality goal, the instruments for the surgeons were mainly designed for males in the past. But this sector is evolving and women are not only surgery assistants anymore. They are well-qualified in the field and are well-known surgical power tools exist of many single parts which can be attached or changed to customize it for every specific need. To keep track of every single part from planning, maintaining and storing, could be further improved than just labeling each piece for traceability.

After the surgery was successfully prepared, the instruments were used in the way they are mainly designed for. Back in the days till today, the surgeons are still exposed to physical strain which can lead to workplace injuries. To design for the future, it will be necessary to learn from the history till today, to foresee the upcoming challenges where the sector is heading. Automation and robotics are topics which are getting more and more in focus.

While a robotic supported surgery like the Davinci Surgical System is mainly used for laparoscopic surgeries which means minimal-invasive procedures inside the body, Aesculap surgical power tools are mainly used for non-invasive procedures and designed as a handheld device. Robotics offers a high-precision which can’t be done with human handling. But in the future robotics will eventually be used for non-invasive procedures as well and this requires an adaption of these power tools. Could there be a new product generation or system which is designed or adaptable to new routines like robotics or semi-automated procedures?
B. Braun AG was founded in 1839 and is one of Germany’s biggest medical and pharmaceutical device providers. The company provides an immense contribution to protect and improve people’s health in everyone’s and everyday life. The company is split up into four main departments which focuses on its specific areas around effective medical care solutions. Hospital Care handles products related to infusion and injection and other disposable hospital supplies. Out Patient Market includes all products for households and home healthcare services. B. Braun Avitum handles products and services related to extracorporeal blood treatments.

I collaborated with Aesculap the fourth department whose portfolio includes products and services for core processes around surgery. It ranges from surgical instruments for open or minimally invasive treatments, implants, surgical sutures, sterile container, storage, navigation systems and motor systems like the Acculan I focused on during this thesis project.

A new department from Aesculap is the innovation hub Werk_39 which focuses beyond the product. With the start-up like infrastructure, they are specialized in services, solutions, business models etc. Located in the heart of the medical valley in Germany, flat hierarchies, a high degree of autonomy and an engaging workplace makes it easier to ideate, test and run projects faster before applying them in the big infrastructure of the B. Braun company. For the digital/service component which was a smaller part of the thesis outcome, they supported me with their experience and knowledge. It is also the office I started the project and worked remotely on at the beginning of the project.
Surgical power tools are universal devices for many applications from Orthopaedics to Traumatology. Is it an emergency surgery, a broken leg or the installing of prostheses, surgeons are working highly concentrated to tend the patient in the best and fastest way. Fractures need to be stabilized with plates or implants and a handheld power tool is necessary for many of these procedures. These are daily scenarios around the world and specialized tools make the surgeons work quick and efficient. The devices rely on high-performance mini motors for optimal surgical outcomes. Technological improvements make operations less invasive and decrease the time of tissue recoveries.  

Aesculap has been a quality provider of surgical power tools for ages. It goes back to 1904 when they introduced its first electric powered tool which was a huge step from hand-powered drills. Around 50 years later in the 1960s a compressed-air system was added to their portfolio. In the following years, the focus was around increasing the motor speed and power as well as improving the cable flexibility. Due to the broad usage, a major challenge was always the low flexibility of the cable power source. It reduces the distance range and complicates the handling of the tool between the surgeon and the scrub nurse. In addition, the cleaning and sterilization after usage were difficult. Therefore, in the 1980s the first battery driven tools were introduced. The free handling tool enabled better procedures and flexibility. The operation workflow was increased and it was possible to reach the patient easily in many positions. But not everything was better at the beginning and isn’t today. Back in the days, the batteries were heavy and big. The bulky battery prevented the surgeon to reach narrow spots around the patient and the unergonomic grip and weight led to wrist pains. The main focus in the last years was to reduce the weight, increase the power and durability as well as fulfill the sterilization regulations.  

The instruments have always looked like craftsman tools and the requirement for precision, heat and vibration is high. Therefore, many of them are still heavy and bulky due to the extreme environment and regulations. But they are also used for high precision jobs where the surgeon has to hold and aim the device for several minutes without shaking and moving. So far the tools have met the technical requirements but do they really meet all user requirements including ergonomics and handling? Is the point-of-view behind the tool optimal to see and aim accurately even if the body of the device is in the field of vision?

---

**HISTORICAL REVIEW**

**SURGICAL POWER TOOL**

---

Aesculap 1/2
Release date ~ before 2000

Aesculap 3ti
Release date ~ 2015

Aesculap 4
Release date ~ 2018

---


15. Aesculap Power Systems...get the speed you need | Catalogue 2009 | p.2

---

Acculan 3ti
Release date ~ 2013

---

Acculan 1/2
Release date ~ before 2000

---

Acculan 4
Release date ~ 2018
THE SURGICAL POWER TOOL MARKET TODAY.

The market is continuously growing (growth rate of 7.72%) due to the aging population and the increasing need for orthopedic surgeries. Especially the Asian market will drastically expand in the following years through increased accessibility to healthcare, medical tourism and newly affluent society. There are several key players who shape the surgical instrument market today. Aesculap, Stryker, DePuy Synthes and De Soutter are all quality providers and widespread in the sector. There is a distinction to be made between hospitals which are equipped with one brand and the ones which are using different kind of brands for each field. One key driver is the personal preference of the user as well as the service and benefits each brand provides. As Stryker offers cheaper acquisition costs with higher maintenance expenses, other brands like DePuy Synthes have special offers in combination with implants and other types of equipment. From the usability perspective, one of the main differentials is the placement of the battery. Aesculap is a pioneer in the introduction of non-sterile batteries inside the handle of the tool. This allows a longer battery life and removes the bulky battery on the bottom handle as everybody knows from a drill. Due to the cost pressure, the hospitals are facing, the overall asset costs are not so far apart from each other and range from 3000-5000€ depending on the accessories. This leads to a competitive market and the service and customer experience is getting more and more in focus. There are still improvements to be done around the tool’s architecture and ergonomics. Surgeons are exposed to risks related to the working postures and vibrating and loud tools which result in wrist and neck pain. Furthermore, inadequate quality assurance, lack of proper sterilization practices and maintenance related communication offer new possibilities to distinguish themselves from the market and improve the customer experience.

1. DePuy Synthes
2. Arthrex GmbH
3. CONMED Medical
4. Stryker
5. Auxein
6. Aesculap
IT IS IMPORTANT TO GET A HOLISTIC OVERVIEW OF THE CURRENT SITUATION

STRATEGY FOR THIS PROJECT

My thesis project included different stakeholders from Aesculap, Werk_39, surgery personnel and Uid responsible. It was necessary to understand first the company’s interests including their philosophy and future goals to examine and design in the specific application area together with them. The main focus was around the user who is involved in the surgery process. Therefore, I started with a broad research phase first at the headquarter of Aesculap. Afterwards, I visited two hospitals in Moers and Cologne to follow the whole process chain of a surgical power tool and interviewed the relevant users. I also accompanied four surgeries where the device was used in different scenarios.

The goal was to find common needs and problems which I defined later on during the project.

PROJECT OBJECTIVE

The healthcare system is a complex industry and the hospital is the core where a multitude of professional disciplines come together to efficiently perform an immense amount of work. There are many regulations and requirements to standardize medical procedures and instruments to overcome the challenges. It is one of the reasons why this area has a hard time to adapt to new technologies and systems. Each hospital is fighting to improve its cost efficiency and there is only a short percentage left to invest in new systems and devices. It is no surprise that every institution is on another level of innovation. Medical providers try to optimize their instruments to constantly match the application requirements. But at the same time, they struggle to sell their latest innovations to the customers due to the investment shortage. Is it not time to review the problems on a bigger scale? Can medical providers not be supportive with enhanced services to ease the complex infrastructure hospital personnel is exposed to daily?

To find solutions and to overcome some of these issues it is important to get a holistic overview. On the basis of a new generation of a surgical power tool, enhanced communication and usability can be one key to increase efficiency and to reduce failures. A small improvement can already have a valuable impact and be adapted in a bigger scale later on.

In the following pages, I explained the relationships between the various users, application areas and summarized the research outcome including valuable insights and opportunity areas.

20 Interviews | 4 Accompanied surgeries | 2 product cycles
Surgery Insights

During the field research, I accompanied four surgeries to review daily usage scenarios and to learn about each requirement the tool needs to be suited. Overall, the main application areas are routine interventions which are done several times every day and can take from less than one hour to several hours. On each operation, the surgical power tool has vital tasks and the overall usage can take from a few seconds to several minutes. It is used multiple times during procedures to fulfill various tasks which require several tools and many handovers between the surgeon and scrub nurse.

My impression after observing operations was that the tool gets pretty slippery due to the body fluids on the smooth metal surface and this leads to unsecured handling. The device is designed to be held in one hand and as compact as possible. But a lack of guidance and control requires the second hand to support the performance. The result is a hand position which is placed right on the action area and can cause injuries for the surgeon or scrub nurse. In addition, a lack of reachability of body areas leads to an unergonomic and uncontrolled tool grip. If a tool gets caught in a bone, all the power and vibration go to the wrist and surgeons can suffer from joint pains over time.

Application Scenarios

Surgical power tools are a universal device to assist and perform in various surgeries from Orthopaedics to Traumatology. There are different tools available for a specialized usage like cutting, drilling, milling and sawing. The system is often used in combination with supportive instruments and templates, to perform high-precision operations. The Orthopilot Navigation System is designed for precise surgical interventions. It is mainly used in combination with a surgical power tool in artificial knee replacements to prepare accurate bone cuts and align implants. It minimizes the operation time and eliminates preoperative examinations or radiation-intensive methods like CT or MRI.

Spine surgery or spinal fusion is a neurosurgical or orthopedic surgical operation where two or more vertebrae are merged together through screws and wires to reduce tension and pain or to straighten the spine. Surgical power tools are mainly used to drill holes and to place screws in this scenario. Templates and supportive imaging is necessary to perform this intervention around the high sensible area. Therefore, it is most likely that supportive robotics or enhanced computer-assisted devices (AR/VR) could place an important role in the future for any high precise orthopedic operation. Bone fractures or hip replacements are routine scenarios and the surgeon can use the device without any support to cut bones and place implants and screws. It is essential for the following design phase to review the different application areas and how the tools are used in the specific set up to oversee future changes and requirements of the device.

Notes:
2. https://www.webmd.com/back-pain/spinal-fusion-facts#1
3. https://www.webmd.com/back-pain/spinal-fusion-facts#1
4. https://www.webmd.com/back-pain/spinal-fusion-facts#1
5. https://www.webmd.com/back-pain/spinal-fusion-facts#1
6. https://www.webmd.com/back-pain/spinal-fusion-facts#1
7. https://www.webmd.com/back-pain/spinal-fusion-facts#1
I started my thesis project at the headquarters of Aesculap in Tuttlingen (Germany) to get a deeper understanding of their power tools and initial goals for future generations. Introductions from the Director of the R&D Power Systems and Devices as well as the Project Manager F&E Power Systems, engineers and marketing personnel were pointing out the current situation of the instruments and the challenges and opportunities they are facing in the following years. Due to the confidentiality agreement that was signed in connection with the setup of the collaboration, I can not go into detail of their initial goals and wishes for the future. But I realized that my first insights and thoughts

through my desktop research contained relevant areas where I will further focus on during the project. In summary, the hardware ranging from the power tool, battery charger as well as the sterile container offer space for improvements. But considered on a bigger scale, it is even more interesting to zoom out and examine the interaction with the system through the different stakeholders and the associated communication. During the stay, I got further introductions to their product portfolio at the Aesculap museum and explanations of the various usage possibilities in comparison to the market status quo of their competitors.

THE ACCULAN SYSTEM

Acculap 4 is the latest version of Aesculaps battery-operated power system for orthopedics, traumatology, cardiothoracic surgery and dermatology. The system exists of a small drill (GA344), a bigger drill and reamer (GA330), an oscillating saw (GA331), reciprocating saw (GA334), oscillating saw straight (GA336) and dermatome (GA340). In addition, a wide range of attachments offers flexible use of a different drill, reaming and saw blades sizes. The latest charger for the batteries include indicators of the charge progress and battery status. An indication warns the operator if the battery needs to be replaced or an error occurs during the charging mode. Aesculap offers a wide spectrum of implants and gears which is needed in combination with the Acculan system. As a customer, it is possible to get fully equipped with B.Braun/Aesculap devices to fulfill many daily operations around the surgery process including instruments and sterile containers.

The next important step was to test the tools by myself to get a feeling and understanding of the usability, ergonomics and limitations before reviewing the system in life scenarios at the following hospital visits and interviews I had with the relevant user groups.
At the test lap, I got introductions in the usage and handling of the power tool which started from placing the non-sterile battery inside the tool before an operation can actually start. Therefore, it is important that a non-sterile person is placing the battery from the charger inside the tool through a sterile funnel which is placed by the sterile scrub nurse. This procedure is very sensitive because every contact with the non-sterile person would make the tool unusable for the procedure. Problems with placing the battery can appear through inserting it in the wrong direction or it gets stuck inside an old funnel which has worn out during many cleaning processes. The most strain on the user and the device appear while working with a reamer or oscillating saw. It was tricky to keep the device still. So a lot of force is needed to hold and aim the device. Even though the saw blade got stuck and the tool broke out several times, I could feel the strain afterward in my wrist and this was an optimal holding position. Imagine a surgeon wearing sterile gloves with wet and dirty fingers and the procedure position requires an ergonomic work posture. The handle size is quite big due to the battery architecture beneath. A small female hand gets trouble to grab the tool safely and the trigger position is hard to reach with the index finger. Not to mention controlling the trigger sensitive in delicate operations when no optimal grip is guaranteed. In addition, the index finger needs to angle downwards to reach the trigger which applies more pressure on the upper edge of the finger and feels unnatural. After usage, the battery needs to be removed from the device before packing the set for the postprocessing. But it can happen that the battery stays inside and the user later on cleans and sterilizes the battery as well. The outcome is a dramatic loss in power and lifetime of the battery which can be a problem during the following surgeries.

For every surgery and cleaning process, the tool gets placed back on a specific tray of the sterile container. It took me over four tries to place the tool in the right position on top of the metal grid. It is planned as a modular “LEGO” system but it is not that intuitive. For the cleaning procedure, the devices need to get flushed from the inside and outside. Therefore, rubber tubes need to be installed with a special adapter. This requires several manual steps and if not placed right the hose gets lose and worsen the cleaning outcome. In addition, due to the sterilized cleaning procedure, all the oil which is needed for the ball bearings and the moving parts is lost. Afterward, it needs to be oiled with a special spray can and defined steps. Nonetheless, this step has often been forgotten or has not been done right. The tools are manufactured and designed for a long life-time but through human mistakes, damages occur that shouldn’t. Every tool needs to be serviced and maintained regularly by the provider. Therefore, tools need to get sent in once a year for maintenance. But only a small percentage is serviced regularly. Most instruments arrive as soon as a damage or dysfunction occurs. This is not ideal but the reality. Can an inconspicuous merge of a physical and digital system be the key to ease the process?
After I tested the Acculan devices in their lab I went to the next tools trade to review different handheld devices with a similar background usage. Overall the old compressed air and the latest electrical powered tool shown above have a familiar handle size and shape as we know it from commercial power tools. But the biggest issue I experienced was the forced placement of the fingertip on the trigger. The back body is probably placed too high or the trigger caused by the technical components too low. The result is a less sensitive control and a pressure point on the edge of the upper part of the trigger. The same problem appeared on the battery-powered Acculan machine which was even worse through the big handle diameter caused by the placed batteries beneath. But battery powered tools are the future and the area the surgical sector is heading. On the right side, I experienced the same issue on some commercial power tools as well. Few brands have it right and got a straight placement from the back body to the triggers.
During my field research, I visited two hospitals in Germany where I had the chance to follow two complete process chains of a surgical power tool and to talk with the relevant users. The journey started with the preparation of the surgery room. The surgery assistants (scrub nurse, circulation nurse) collect the needed instrument sets in the storage which are listed on the surgery instructions. There is a differentiation between sterile and non-sterile assistant. The sterile assistant opens the sterile containers and prepares the surgery tables. The battery charger for the tool is placed in the storage facility or operating room. The non-sterile person collects a battery and places it inside the tool container. Afterwards, the clean side receives the instruments to perform a visual quality check and to pack the set orderly. The last step is to sterilize the packed and closed machine. It requires many manual steps to wash and pack properly the sets, including attaching the rinsing tubes on the power tools to flush and clean even the inside housing. Afterwards, the clean side replaces the instruments to perform a visual quality check and to pack the set orderly. If a battery is available (not always the case) they need to get oiled after the quality check. Due to the immense amount of instruments it happens that parts get switched between sets to complete the ones which are most important. Many instruments also need to get oiled after the quality check. Due to the immense amount of instruments it happens that tools are forgotten or not oiled right or enough. It leads to an earlier wear out and loss of power (surgical power tool). The employee also doesn’t get any notifications if the tool needs to get maintained or not.

If all instruments are alright the employee scans the set (not every single instrument) and the software (for example Instacount) provides the packing instructions. Missing tools or wrong placed tools should be discovered here and marked inside the software. It happens that parts get switched between sets to complete the ones which are most important. Many instruments also need to get oiled after the quality check. Due to the immense amount of instruments it happens that tools are forgotten or not oiled right or enough. It leads to an earlier wear out and loss of power (surgical power tool). The employee also doesn’t get any notifications if the tool needs to get maintained or not.

The last step is to sterilize the packed and closed instrument sets inside the autoclave before they are transported back to the hospitals and their storage facilities. They scan again the set and place markings on the outside of the containers which describe the destination and lists any missing parts. The operation management has access to the information when a set is processed and back inside the storage facility. But if a problem occurs and the set isn’t ready, there is a lack of communication where the set is right now (repair/maintenance) and when it will be back.
The surgical power tool passes through many hands and departments every day for usage and processing. A working communication and information exchange is therefore key to plan efficient surgeries without interruptions. This spectrum gets even bigger if the tool is not processed properly or maintained regularly and a dysfunctions tool needs to get repaired more often. In this case, a contractor or Aesculap takes over to eliminate the problems which include more people and communication into the cycle. It is necessary to understand the users’ needs and wishes to find the main pain points around the tool and the system.

**SURGEON**

Surgeons are surely the key user of a surgical power tool. Their goal is to perform many surgeries in a reasonable timeframe. They need to work with an ergonomically and sustainably developed tool which makes it easy and safe to work with. Therefore, reliable and durable systems are preferred so the hospital can plan and invest more accurate in the future. Each delayed or canceled surgery means lost money which is urgently needed to expand or upgrade their facilities. They need a tool which fits to their tasks.

**INSTRUMENT MANAGEMENT**

Instrument management Gabriele K. 2019

It is hard to keep track of each tool through processing, parts get lost or switched between instrument sets or are not prepared right.

**USER INTERVIEWS**

**SCRUB NURSE / CIRCULATION NURSE**

Their goal is to serve surgeons in the best way so they can fulfill their tasks easily without interruptions. They need to know every step of each surgery to hand over the right tools to the right time. Broad knowledge about surgical procedures and instrument requirements are necessary. Therefore, complex or uninviting instruments or gadgets disturb their workflow. It is hard to handle all the tools with two hands in a short time during procedures. When tools get slippery or are unergonomic it hinders their tasks. Due to time pressure and bad visibility of the lock mechanism, adapters of the surgical power tools are changed by pressing it against their body to prevent it from falling and to increase the grip without using the lock mechanism which could lead to injuries. If the tool is used for a long time the housing can get hot which makes it difficult to handle. If a device is not functioning properly they have to check quickly if another system is available in the storage. This can lead to an extreme interruption for the current and the upcoming surgeries.

**Everything should be as simple as possible to prepare and assemble and nothing can go wrong.**

**CSSD EMPLOYEE**

They need to process the incoming instruments as quickly as possible to ensure a smooth workflow for the next surgeries. Their goal is to work efficiently but the immense amount of instruments and the different requirements makes it hard to keep an overview. Sometimes they are annoyed about the condition tools or instrument sets are coming back or are placed inside the containers. Many manual steps are required to wash and prepare the washing machines and the modular instrument sets are not intuitive enough to work fast and always correct. They are not every time guilty of missing or misplaced tools. Often tools are already misplaced or forgotten in the surgery room. A better control about the tools is always good but they have a specific timeframe to do the job and there is not much space left to check the devices properly or review the maintenance date on the device.

**A better communication and information exchange including simplified procedures have always been a need.**

**TECHNICAL SERVICE**

Service and maintenance are expensive for customers in comparison to the repair costs. Therefore, just a few percentages of the tools are sent in regularly which is a problem. So customers are mostly responsible to keep track of their tools when they do not take the provided service plan from Aesculap. Their goal is to maintain tools before it comes to damages or malfunctioning parts but it is often not possible today. So the tools are sent in when it is already too late and need to be repaired as quick as possible. Aesculap provides rental service for their customers to avoid interruptions during procedures but an enhanced system would ease the process. Another problem is that tools are often sent in without any descriptions so they need to test the tool and search for the problem before eliminating the issue. Better knowledge about the usage and treatment of the device could help Aesculap to work more efficient and customized to their needs. This would reduce time and cost which is valuable for the hospital.

A better communication and information exchange between the hospitals and technical service could be beneficial but it would require an enhanced system which keeps track of their tools so the technical service can support or prevent them earlier for problems.

**More knowledge about customers including the amount of usage and treatment is helpful to plan in advance and support them more individual.**

**SALES PERSON**

The customer “never” comes to them willing to buy a system. They come with a problem they try to solve together with them. Aesculap shows how to optimize procedures through changing or updating their product portfolio. But hospitals can’t invest in a whole system change or update so they provide the customer a plan on how to purchase the products in steps year for year. Old and cheaper systems are often more attractive due to quantity vs. quality. Aesculap machines are more expensive and so fewer tools need to do more work. Where is the added value to invest in a high-quality product if more cheap tools ease the planning phase and more surgeries can be done? But ergonomics, usability and outcome are important as well and a sick surgeon or a bad surgery outcome is worse for the hospital. Therefore, a high-quality product needs to ensure a long life-time without losing precision and power. To achieve this goal good maintenance is the key and hospitals need to be more aware of their tools’ condition. The sales persons stay in close communication with the hospital so if problems occur they often call them to get quick support and help.

The more information Aesculap gains over a hospital and the application frequency of their tools a better-suit plan including repair and maintenance costs can be provided.

**A Centralized digital database of their customers and tools can improve their job and allows them to provide customized solutions.**

*“The motors can not talk to us so I don’t know how it was treated or used...I would be great if tools can be read out like car repair shop do with care”*

*“Some customers do not have their instruments under control so I try to help and support them if problems occur with our sold tools”*

*“It is hard to keep track of each tool through processing, parts get lost or switched between instrument sets or are not prepared right”*
After I reviewed the current situation there was still the open question how the future of surgeries will be challenged through new technologies and enhanced systems? Since the beginning of surgeries, there has been a wish to ease their work, improve safety and outcome through supportive technologies and devices. But there is a decisive change happening in the future. So far the surgeon has always been the operator as well as the central part of the procedures. But robotics, AI and new innovations can take over their job and replace the surgeon as the main operator. We are still quite far away from advanced robotics which can be used in a wide spectrum. Even though “The global market for surgical robots will experience a combined annual growth rate of 10.4%, from $3.9 billion in 2018 to $6.5 billion by 2023”

Today assistant technologies like enhanced imaging (AR, VR) and supportive robotics will be more and more valuable in the following years. It is like the beginning of the mobile phone market. The phones were too expensive, big and the battery didn’t last long. Today surgery robots are on the same starting stage and as soon as the costs, size and complexity go down it can offer more features than we can imagine today. Writing messages and calling people were just the starting point but today's smartphones deliver more services and support in our daily life. The main objectives for a successful integration are that it must be a common procedure, the result can only be achieved with this technology and it must fasten the workflow to be economical.

How can it affect the surgical power tool market and its application scenarios? Today’s procedures around orthopedic surgeries can be done with the current set up. But the precision and outcome can be valuable for sensitive interventions like artificial knee surgery or spine surgery. Some providers have already introduced new supportive inventions. But why is it not used in a broader spectrum today? The disadvantages are the preparation and after work time which can be as long as the procedure itself. The cleanliness hasn’t met the standards yet or is too complex. Investment and increased running costs are not economical. As well as the surgeon is highly educated and succeeds in many operations every day (orthopaedic) which doesn’t show a big need for a change. In addition, if the system fails, is the future surgeon still able to perform a standard operation without the added technology? The main driver today is the marketing and advertisement aspect. If many hospitals update their portfolio, the leftovers need to follow to be competitive. Because the patient is the key person and decides often for the hospital with the latest equipment and a good evaluation even though the outcome is not better and the procedure is not cost effective today. This can add pressure to the already overstrained hospitals because they often cannot charge all of the increased operation costs.

Therefore, I believe before adding more complexity to the surgery environment it is important to build a solid foundation before jumping into the future of surgery. Through this project, I wanted to address the issues which should be considered first and will be valuable in the near future. Because a handheld surgical power tool will always be needed besides robotics. In many application scenarios like emergencies, simple standard operations robotics will only be a side technology for a long time.
CURRENT SITUATION

WORKPLACE ERGONOMY

As I thought the first time about surgery I had the impression that it must be a perfect and modern environment. It has to be on the latest innovation level and the work conditions should be optimized. If we can travel to the moon and manage all kind of challenges then the environment to treat us humans must be on an even better level. And truly it is! For example, laparoscopy and neurosurgery are developing quickly and modern assistant robotics and new technologies support the surgeon to perform minimally invasive procedures with incredible outcomes. But it is also true that the healthcare sector is today under enormous cost pressure which is noticeable in other areas. While money is saved for elderly care, staff shortage at many wards and as well for some surgical interventions. Orthopaedic surgery and traumatology interventions are accounted for one of the first successful surgery performances. Today especially the orthopaedic surgery are standard procedures. Every hip and artificial knee surgery has fixed list prices which should be kept as low as possible and are under pressure from the health insurance. Therefore, these surgeries are operated comparable to an "assembly line". In my opinion, this led sadly to investment shortages in the past. It is also the reason why this area lacks behind in improving the work environment and innovation level of instruments. Surgeons need to perform many surgeries a day in the prescribed time frame to be economical at the end. The outcome I experienced is that surgeries had from operation room to operation room and ignore important breaks in between if a surgery took longer than expected, to perform all scheduled interventions in a day. That’s why a specialized instrument for this sector must be worth the extra costs in the way of increasing speed or outcome. In comparison to laparoscopy, orthopaedic interventions can be done successfully without robotics. If someone wants to apply supportive robotics in this sector it must increase the speed significantly to be economical because the procedures can be done without as well. My first conclusion is by adding more cost pressure including robotics which takes almost the same time for preparation as the procedure itself. It is more important to fix the current and most obvious issues about workplace ergonomy. The surgical power tool is just a small part of the bigger issue which is shown in the article to the right. The first step is to reduce manual work by increasing the usage of power tools and at the same time making them as ergonomic, light and safe as possible.


Orthopedic Surgery is Dangerous...for the Surgeon! | Orthopedics This Week

Spine Feature

Orthopedic Surgery is Dangerous...for the Surgeon!

Bill Donovan • Fri, March 29th, 2019

In a recent survey of the current and 12 former presidents of the Scoliosis Research Society (SRS),

- seven of the 13 had rotator cuff pathologies (one bilateral),
- five had lumbar pathologies, including three cases of herniated nucleus pulposus, which were treated surgically,
- three reported having had endoscopic joint arthroscopic, one resulting in retromuscular,
- one reported an arthroplasty,
- a case of carpal tunnel syndrome required bilateral surgery, and
- one suffered an acute distal phalaxx fracture during surgery.

That’s a lot of workplace injuries. Is this small sample an anomaly?

Baron Lomner, M.D., Professor of Orthopedic Surgery at Mount Sinai Medical Center, New York City, said harsh stats in March during the annual meeting of the American Orthopaedic Surgeons (AOS)

Dr. Lommer was also one of the researchers in a larger survey, Disorders Among Spine Surgeons, Results of a Survey of the Society Membership led by Joshua D. Auerbach, M.D., in 2009.

Orthopedic Surgery is Dangerous...for the Surgeon! Or

It's a worldwide surgeon injury epidemic.

A search of Google Scholar with these keywords, "prevalence of musculoskeletal injuries in orthopedic surgeons," reveals several more U.S. studies published in 2018—and reveals that it's not just happening here. That one search of a few Scholar pages turns up similarly dire surgeon injury reports from Canada, India, Italy, Korea, Kuwait, Norway, Poland, and Saudi Arabia in 2018, Iran in 2017, and the United Kingdom in 2014.

Nir orthopedic surgeons the only victims: recent studies say dentists, bariatric, heart, and plastic and reconstructive surgeons are vulnerable as well. Two 2010 studies added laparoscopic surgeons to this list.

Another study, "Work-Related Musculoskeletal Discomfort and Injury in Microsurgeons," notes that microsurgeons who use lenses and microscopes to see...
PAIN POINTS

PRODUCT AND ACCESSORIES

The product system exists of the surgical power tool including accessories and adapters. The battery charger and the sterile container with the grid system. During the four accompanied surgeries, I reviewed the current usage scenarios to get an understanding if there are major issues or problems. On the right side you can review similar usage applications I found online during the desktop research on Youtube and articles. It was not possible to do images during my visits inside a surgery room but they visualize the same impressions I gained in the field research.

The surgical power tool is used in many different grip positions to reach relevant areas,
- Bad working postures lead to wrist, neck and body pain over time
- Even in an optimal position, the oscillating saw is hard to hold and control but the surgeon needs to change the firm grip to rotate the tool and reach relevant areas which reduce a safe performance.
- The tool actually allows a flexible use but could it be further optimized to improve the ergonomics, usability in more than one position?
- The reasons for different grip position is often visibility and accessibility
- Can the visibility and accessibility be improved without changing the grip position?
- Can the tool be more modular or modified for an extra grip?
The tools are designed to be held in one hand.
- This is good and bad - it offers flexibility and the decision is left by the user where to place the second hand. But the hand is often placed near the danger zone to achieve a safer operation for the patient.
- Due to a lack of guidance and control, the second hand is urgently needed
- During a hip surgery, the reamer can get stuck mostly at the end of the procedure.
- This can lead to major injuries for the surgeon (the tool breaks out and can injure the wrist)
- Therefore, a second person is sometimes used to support the surgeon with a third hand on the tool.
- The wide handle diameter of the Acculan system and the tools’ weight makes it especially difficult to operate with dirty gloves. The shiny metal surface just gets to slippery.
- This is also a major problem when the scrub nurse needs to change adapters and press the tool against the body to increase friction.
- The lock mechanism should ensure a safe tool handle but if it is not used correctly due to reachability and visibility it is useless.
- The tool needs to get oiled after processing to ensure a long-life (gears, ball bearings). Wrong treatments happen here and there and can have a dramatic impact.
- The grid system for the machines is not intuitive enough to use slots correctly under time pressure or unawareness.
- The battery charger measures the battery condition and informs the user as soon as the battery should be changed. But the user often does not notice it or ignore the light indication. Is there a better way to ensure that an insufficient battery gets out of the usage cycle?
- Additional grip - middle & back
  Is the grip area supportive enough?
  >>Guidance and power<<
- One-handed grip
  Product was mainly designed for this
"AT LEAST AT EACH 10TH SURGERY I NEED TO CHANGE GLOVES DURING THE PROCEDURE!"

Dr. Guschelbauer 2019

This could happen up to 2-3 times a week.

The need to change gloves can be caused by several reasons. First, the surgeon always wears at least two pairs of gloves for safety reasons. If the patient has contagious diseases it could be even three. From a material perspective, the gloves sadly let through liquids in a molecular size level caused through the intense stretching after a longer time. Therefore, after a specific time over a longer surgery which can be range over 6-10 hours the surgeon is supposed to change gloves. But in the orthopaedic field, it is caused by other problems. First cut or fractured bones can easily perforate the gloves. Even more problematic scenario is shown above. The surgeon grabs the tool around a moving saw blade. The side edges are not for cutting in this scenario but still dangerous enough to destroy a glove. In the worst case, the surgeon comes by mistake close to the front blade and cuts into his own skin. To bleed into a patient would be a tremendous issue. It didn’t happen to the surgeon I interviewed but they ensured it could happen or even worse have already happened. This is truly a disturbing thought and needs to be further examined during my thesis.
CHAPTER 03
CONTENT SYSTEM EXAMINATION

PAIN POINTS BEYOND THE PRODUCT

A surgical power tool passes through many departments over the lifetime. The infographic on the right site describes simplified the involved personnel starting from purchasing a new tool, the tool cycle inside the hospital and the related steps which are necessary for repair and maintenance. It is obvious that traceability and communication are key to share information successfully between the users.

- Cost pressure makes it hard to invest in a whole new system set up (interval purchases)
  - Therefore, each tool needs to get maintained differently over time.
  - Old and cheaper systems are often more attractive due to quantity vs. quality. More cheap tools ease the planning phase and more surgeries can be done. Cheap systems are often used till they are dysfunctional and it comes to a new purchase.
  - A high-quality tool needs to be worth the cost. Only maintenance and the right treatment offer the value over a long time if the service/maintenance procedure is guaranteed and done right over a long time.
  - Not every hospital has a maintenance contract which is a reason why just a few tools get sent in every year (they forget about the date, they don’t care, maintenance is too expensive and they don’t have (want to spend) the money.
  - Is the need not big enough (level of suffering)?
  - Hospitals run down their instruments because of several reasons (cost pressure, save money for new investments)
    - Investment costs come from a different pot than repair and maintenance.
    - The overall tool cycle is “working” but the communication between surgery management and CSSD management lacks behind. (Surgery integration). It complicates surgery planning if the management is not always up to date.
    - If it comes to dysfunctional tools more departments get integrated and a lack of communication and information exchange hinders a smooth flow.
    - Is it not already too late if a tool fails during surgery? Can this be prevented ahead?
    - A lack of knowledge and control is a reason why tools are not processed correctly after usage and wear down earlier.
    - There is a service to get rental equipment to ease the maintenance phase, so is cost pressure the only reason which hinders this procedure or is there also a lack of communication? Can Aesculap be more supportive by doing the first step as a reminder and handle the procedures?
- Because hospitals are already overburdened?

To examine the relationship between the departments it will be valuable to further examine the interfaces between the departments. Also, oversee the set up from distance. Which personality describes the customer and which role should the provider play. Do we deal with a passive, active, customer or a lazy, unaware, overstrained, poor customer? Should the provider be an active, passive player or a caring, benevolent, precautionary player?

LACK OF COMMUNICATION, DATA AND INFORMATION EXCHANGE!
CONCLUSION

DEFINED PROJECT SCOPE

The starting point was to get a holistic overview of the current situation around the usage and processing of a surgical power tool. As a result, I got to see the complexity each hospital needs to deal with. In addition, every hospital is at a different level of innovation and can differ in the company structure. Overall, the system is working today and they fulfill an immense amount of work. But if it comes to troubles or unforeseen events, hospitals struggle to adapt because of the complexity and the many stakeholders and interfaces. When it comes to a high-quality surgical power tool maintenance and control of the tool's condition is essential to prognosis problems before they occur which can reduce errors and relieve the organizational structure. Furthermore, surgeons and patients are key players and to enhance ergonomy, usability around the tool which can result in a better outcome for the hospital as well as the provider within the existing infrastructure.

Better usability and ergonomy is one of the main objectives around medical devices and there is still room for improvements when it comes to better control, guidance as well as safety.

A modular system should convince through simplicity and intuitively. This includes adapters, accessories as well as the sterile container. Colors, similar shapes or icons can be supportive.

The preprocessing of tools inside the CSSD department require many manual steps and the correct treatment of each specialty requires broad knowledge and education of the employees. But it could be simplified and better controlled.

More knowledge about the tools' condition and treatment is the key to prognosis problems before they occur. The gained information can result in more control and simplifies the future planning of new investments.

The communication between the interfaces inside and outside the hospital is essential to eliminate process complications and delays. A better information exchange makes complex constructs easier to handle and oversee.

Customers should be more conscious of the importance of maintaining their tools regularly. Therefore, the system needs to be adapted to their needs and problems and to deliver an early prognosis.

An easier and more controlled way of charging and battery exchange can be valuable. This can also include a self-reliant maintenance procedure for the battery lifetime.

Customer satisfaction can be enhanced through an individualized service supported by valuable data about their tools and usage. This can result in a customized program which eases the communication between departments without a lack of knowledge. An accurate calculation of their running expenses around the Acculan system could be offered.
GOALS & WISHES

DEFINED PROJECT SCOPE

GOALS

- Review the ergonomy and usability and create various concept directions which should improve the overall handling in various application scenarios
- Build early mock-ups and validate the ergonomy & usability with the user/company
- Update the overall product language (create a common core language)
- (Keep cleanliness in mind for the new device architecture)
- Create a vision for an enhanced maintenance procedure and system around the tool
- Map out the enhanced system and service
- Talk to the company and users to discuss the feasibility
- Visualize a final holistic vision and describe how it can be adapted in the future and how it will affect the current situation
- Build a presentation model of the final outcome (surgical power tool)

WISHES

- Create a short movie of the final outcome to describe the enhanced ergonomy and usability and how the new maintenance system affects the tool cycle
- Update the sterile container set of the Acculan machine with a simplified usage
- Visualize the updated product language to the different Acculan machines

CAN NOT BE FURTHER CONSIDERED

- Research online for new innovations regarding battery technology
- Focus especially on the cleaning and sterilization procedures
- Create an enhanced system to improve planning and traceability for instruments
- Create a business model depending on the new vision
- Examine and improve a specific surgical procedure and create a specialized device/accessory
- Focus on a future concept regarding assistant surgery (VR, AR, robotics)
04 | IDEATION

Summary
From questions to sketches
Workshop, role plays
Three concept directions
Smart tool
Instrument management
In the following pages, I summarized a condensed scope of the main objectives I tried to ideated on at the beginning of the process.

In comparison to commercial power tools for construction work, the surgical tools are years behind when it comes to ergonomics and usability. A reason is the complex application scenario and the various users who come in touch with the system. Each has their own requirements and needs which must be considered. In addition, the hospital environment is much harder to withstand than a workshop. The used chemicals and heat to clean and sterilize the tools would burst almost all plastics as carrying capacity over the years. The result is the preferred use of metals which offers cleanability and stability advantages. But at the same time, they add lots of weight and a hard and slippery surface for the hand which makes obvious pressure points even more painful. As a result, a surgeon mentioned during an interview “He would prefer to use his own private power tools and just wrap it into sterile foil!” (Dr. Guschelbauer 2019)

Even a surgical power tool is much more expensive than a commercial one (several hundred € till several thousand € in comparison to a 10th of the cost for commercial equipment), they don’t have better safety, usability or ergonomy features. Which comes down to the question, why is it even worth to invest into an expensive quality surgical power tool, if it doesn’t add any more value than a bit of longer lifetime, power and fewer vibrations? For the same money, it would be possible to buy each year a new tool which would remove all maintenance and repair issues at once. Additional if a hospital plans to invest in a cheap-system, they are able to purchase more tools. To zoom out and review the current stage on a broader view it results in one open question.

Should a hospital invest in quantity or quality?

With more tools available the surgery management can plan and schedule procedures easier in advance. Fewer quality tools are used more frequently and efficient planning is required. But at the same time does a dysfunctioning tool, a handicapped surgeon or a surgery delay justify to invest into quantity? From my perspective I gained over the research phase this can not be the goal. When you deal with humans, safety, ergonomy and usability are key for a successful future. Therefore, a high-quality tool should clearly offer better specifications than a cheaper one within the same application scenario. The next generation of a surgical power tool needs to clearly stand out from the competitors in terms of quality and cost-effectiveness. It can not be the result that commercial equipment offers better ergonomy and safety features. Therefore, I believe to build a solid foundation in close relation with the users is the next important step for Aesculap and the overall healthcare sector. In combination with enhanced customer service, the required maintenance and the needed flexibility of usage must be increased. So customers can clearly invest in quality which will be on the one hand more expensive at the beginning but on the other hand, add more value in a longer run. To achieve this goal, the repair and maintenance procedure must be improved as well. Quality tools which can be used over a longer period of time are also an aspect of good sustainability.

In the following pages, I summarized a condensed scope of the main objectives I tried to ideated on at the beginning of the process.

In comparison to commercial power tools for construction work, the surgical tools are years behind when it comes to ergonomics and usability. A reason is the complex application scenario and the various users who come in touch with the system. Each has their own requirements and needs which must be considered. In addition, the hospital environment is much harder to withstand than a workshop. The used chemicals and heat to clean and sterilize the tools would burst almost all plastics as carrying capacity over the years. The result is the preferred use of metals which offers cleanability and stability advantages. But at the same time, they add lots of weight and a hard and slippery surface for the hand which makes obvious pressure points even more painful. As a result, a surgeon mentioned during an interview “He would prefer to use his own private power tools and just wrap it into sterile foil!” (Dr. Guschelbauer 2019)

Even a surgical power tool is much more expensive than a commercial one (several hundred € till several thousand € in comparison to a 10th of the cost for commercial equipment), they don’t have better safety, usability or ergonomy features. Which comes down to the question, why is it even worth to invest into an expensive quality surgical power tool, if it doesn’t add any more value than a bit of longer lifetime, power and fewer vibrations? For the same money, it would be possible to buy each year a new tool which would remove all maintenance and repair issues at once. Additional if a hospital plans to invest in a cheap-system, they are able to purchase more tools. To zoom out and review the current stage on a broader view it results in one open question.

Should a hospital invest in quantity or quality?

With more tools available the surgery management can plan and schedule procedures easier in advance. Fewer quality tools are used more frequently and efficient planning is required. But at the same time does a dysfunctioning tool, a handicapped surgeon or a surgery delay justify to invest into quantity? From my perspective I gained over the research phase this can not be the goal. When you deal with humans, safety, ergonomy and usability are key for a successful future. Therefore, a high-quality tool should clearly offer better specifications than a cheaper one within the same application scenario. The next generation of a surgical power tool needs to clearly stand out from the competitors in terms of quality and cost-effectiveness. It can not be the result that commercial equipment offers better ergonomy and safety features. Therefore, I believe to build a solid foundation in close relation with the users is the next important step for Aesculap and the overall healthcare sector. In combination with enhanced customer service, the required maintenance and the needed flexibility of usage must be increased. So customers can clearly invest in quality which will be on the one hand more expensive at the beginning but on the other hand, add more value in a longer run. To achieve this goal, the repair and maintenance procedure must be improved as well. Quality tools which can be used over a longer period of time are also an aspect of good sustainability.
WHEN YOU DEAL WITH HUMANS AND **MONEY** IS THE BIGGEST FACTOR, **RELIABILITY, SAFETY, CONTROL AND EFFICIENCY** CAN NEVER BE GOOD ENOUGH!

**IDEAL CASE**
From a customer point of view

**PRODUCT**
- The product gives me always enough control and safety
- It is clear, easy and comfortable to work with
- I can plan and work most efficiently with the tools I have
- I can invest in steps into the system
- The product can be widely used in different scenarios

**Safety | Guidance | Control | Flexibility**

**SERVICE / MAINTENANCE**
- As soon as I have the system I don’t want to care or think about maintenance etc.
- The company and I know exactly the tools condition
- The running costs are predictable in the future
- I can fully focus on my main tasks without interruptions

**Supportive | Inconspicuous | Reliable | Manageable**

My project goal: It is important to create future visions to show how reality could be changed or even improved. But it is even more important to design the way to get to that point. In this project, I wanted to design for the next following step which will create a path to the overall goal. I aimed to be disruptive and push the borders which hinder today’s progress for a bigger change but still stay true to the current issues and regulations.
I started to ideate in a broad spectrum around my defined scope. The focus was here on the physical tool and the different usage scenarios. I tried to understand the general architecture of a surgical power tool and why they are all built similarly. What are the reasons for the current shapes and features? Can a new design especially for sawing be more supportive and safer for the user? Can the commercial power tools be an inspiration for a merge to the medical world? How far can I disrupt the current stage without missing the target group? Can I integrate the usage of a needed second hand without adding a clumsy handle add-on? Is it possible to increase the safety of the tool without reducing the flexibility and usage of the current situation? Can the workflow be simplified through an easier and faster assembly of the battery? Could the solution be an additional instrument, gear without touching the actual power tool? Is it a modular or flexible tool which can change the shape or handle be supportive and does not complicate the usage? How do different handles or hand positions affect or even enhance the procedure? Can ergonomics be fulfilled through new adapter architectures? Can the trigger be changed to achieve more control and a better grip?

All ideas should improve the safety, usage, ergonomics and workflow. Asking myself all these questions I tried to sketch out all upcoming ideas to get an overview of directions I could create different concepts. I aimed to produce later on initial mock-ups to test ideas and evaluate them together with the users who have the knowledge and understanding of the current situation.
It was important to test and play early on with physical mockups to run through real application scenarios. Therefore, I built the current surgical power tool “Acculan 4” from Aesculap (CAD data was provided from the company) and two initial mock-ups from my sketches. During an ideation session including several classmates, we used the physical products to talk about the current problems and to define solutions and discuss ideas. Furthermore, I reviewed surgical procedures online to learn about their working habits and to understand the various application areas. On the basis of the models, I could reenact the grip positions and compare my impressions with the gained knowledge during my field research and the observed surgeries.

The conclusion from the workshop and my following tests were on the one hand that the current tool doesn’t offer enough grip possibilities for the needed second hand. The upper body diameter is too small to get a firm grip around the cylinder. The general handle diameter is too big to reach the trigger comfortable as well as gain enough sensitivity to adjust the speed and power in particular if the firm grip around the tool feels forced. A specific focus was on the female participants during the workshop to consider their feedback around the current tool’s architecture which was from my perspective mostly focused on the traditional handicraftsmen surgeon. For a gender neutral design regarding ergonomics and usability, it was important during the process to test regular mockups with both male and female hand sizes. Also, an interesting outcome was that most participants would use a second grip for guidance and support on the front around the saw blade which could damage the gloves and transfers the vibrations into the wrist. I got the same impression from the videos I reviewed online. In addition, surgeons rotate the device for a better reachability which worsen the control of the device. But the fixed trigger placement restricts the user to just a few handleings.

During an artificial knee surgery the tool needs to be held fairly high even if the table is lowered. A straight oscillating tool we know from the consumer products offers in some scenarios a better working posture but for the knee surgery, it leads to a raised up elbow height which worsen the ergonomics. A pistol grip is universal and leads to a lower elbow height but worsen the usability in an upside down position.
For a better overview, I created three early concept directions to combine and structure the gained knowledge in reasonable concept packages. These directions served as a starting point for further ideation and deeper examination.

1. CONCEPT DIRECTION
The surgical power tool is a universal device for many application scenarios. The main idea was to create a specific tool which is adapted to the sawing requirements or even for a specific surgery operation. So far, the market has used the drill archetype and just placed a saw attachment on the front. Can an updated tool or even a new rethinked and improved shape positively affect the current status quo? Where can a second-hand position be visually and haptically integrated? Is a protective cover needed for the saw blade? How does it affect the usage scenario if the tool is specialized to only one feature? Could this device be worth enough for the hospital to invest in more different tools or does it negatively affect the investment shortage and flexibility?

2. CONCEPT DIRECTION
How could a high-quality tool also increase the ergonomics, usability and in the same time improve the flexibility in planning and usage? So far it is possible with some brands to attach several adapters on a device. But these adapters differentiate only in various drill attachments for specific application scenarios. What if you could attach all needed adapters from drilling, sawing, reaming, etc. on one device? What if ergonomics and safety could be integrated mostly on the adapter or as a second handle add-on? Could this scenario combine the positive effects of a quality tool with the specifications of investing in quantity? If we go even further and separate the main device from the needed adapters and instruments which are used for each specific operation. The main device could be used most flexible and equal for all scenarios. If a machine breaks, it won’t block a whole set, instead, they could use and plan with any other leftover machines.

2. CONCEPT DIRECTION
Optimized handle
Add-on > additional grip
Optimized ergonomics at the adapter
Set for drilling + screwing (Implants, bone fracture, Spine surgery...)
Set for sawing / cutting (Knee surgery, hip sur-
3. Concept Direction

The third concept direction was an extension of concept two with the specifications of concept one. Different kinds of procedures require specific hand positions and firm grips to optimize ergonomics, handling, and control. On the same time, the customer would like to make the best usage of the few high-quality tools available. How would a tool affect today’s hospital routine and habits, if we consider the motor and gears which are the most expensive and maintenance relevant components as an extra component? What if they could customize this component with 2-3 different handles and adapters for the various application scenarios? It would be possible to improve specific needs in different operations without the need to buy several whole product systems. It could reduce the production costs of the expensive motor and gear component if this component is identical. In the same time, the hospital could receive and extra motor next to the 20-30 machines (for a middle size hospital). If tools break or are dysfunctional they could use the leftover motor without having an interruption in the surgical plan. They could send in the broken part to Aesculap and receive a repaired or maintained one. The additional costs for this extra motor could be saved through the ceasing costs of a rental device.

In addition, the motor component is together with the handles in a separate sterile container like concept two. Each motor set can be used for every scenario which allows an equal usage of the machines and increases the flexibility in planning and managing. This gained freedom adds probably additional asset costs but if the frequency of canceled or delayed surgeries could be reduced the added value is reasonable. Furthermore, the motor could also be used in the future for an assistant robotic arm, which could and should be the next step for Aesculap.
In today’s world, sensors and computers are getting smaller, cheaper, and more accessible than ever before. Instead of only improving the physical components regarding ergonomics and usability, could there be a reasonable way to support the surgeon during procedures or during the tool cycle? An important quote during the field research was: “I want a Range Rover as a tool; robust, durable, reliable... can the tool be designed to be failure proof during processing so I don’t have issues in surgeries?”

The main objective is “It just has to work” which requires the machine to be as simple, mechanical, and “stupid” as possible. Today, the motor control unit is already integrated inside the battery. It could be possible to apply smartness inside the battery without increasing fragility of the machine itself. Also, to enhance the processing of cleaning and sterilization and to gain more knowledge about the tool condition. It could be a solution to integrate components, which are not affecting the tools functions but allows to collect useful data.

The problem from a competitor (De Soutter medical) who allows more adapter to be changed than Aesculap is doing today, is that the machine settings need to be changed over a specific trigger combination. This is confusing and often done wrong from the users’. If the future tool and all adapters would have an RFID chip, the machine could adjust the needed settings on its own inside the battery CPU. It would strengthen the concept and allows a “smart product” without adding fragile technology. In addition, the battery would be able to recognize each tool number, usage time, and frequency and could store the data for later usage. It could also allow overviewing the current flow average to identify obvious changes which could be a sign for worn out gears, lack of oiling after cleaning or a dysfuntioning motor. Another option would be to integrate a small data chip inside the machine which will be filled with data from the battery CPU. This data could be reviewed from the CSSD personnel or the repair and maintenance department to allow a more efficient and timesaving procedure. This would reduce the upcoming costs and allows a customized service. The chip must be molded inside a ~2-3 mm plastic cover to overcome the 140-160°C during cleaning and sterilization.

1. Dr. med. Thomas P. 2019

SMART TOOL BEYOND THE COMMON USAGE

If the motor control could recognize each adapter it would be possible to customize specific functions to each adapter. For example, a way to not overtight the screw head which happens regularly if a previous implant needs to be replaced. It is hard to sensitively control the trigger with up to three gloves. The motor could adjust the force from starting low or just allow a half rotation with each activation.

Or a smart add on could recognize with the feedback sound or vibration if the surgeon reaches the backside of the bone to warn or stop the machine before the drill pierces the whole bone which should be prevented for a better healing outcome.
Each hospital has to manage over thousand of different surgical instruments from pincers to surgical needles, implants, power tools and much more. All these components are bought to different times and from various providers. A result is “Our customers don’t have enough control about their own instruments!” But an overview is especially important to keep track of the condition of the tools for maintenance and repair. The result shows that only a few percentages of instruments in general arrive back to the companies for maintenance. The reason is an overtrained customer who is overwhelmed by the quantity and the existing investment shortage exacerbate the situation. Hospitals as well as providers are aware of this problem and are constantly trying to update and ease their instrument management software. But the integration lacks behind and each hospital is on a different level of innovation and owns various software. A qualitative surgical power tool is key for their daily work and requires regular maintenance for a well-functioning process. Today it is possible to review how often a sterile set was scheduled for surgery but doesn’t give information which tool was actually used on this set. Also, the information is often not combined or even virtually structured and listed to use it time efficiently. The system also doesn’t highlight yet if a tool needs to get maintained over time. If a future tool system can provide more information than today (usage time, abrasion, problems etc.) and this information could be well integrated into the software, frequent problems could be prevented which is cost effective over time. But the full integration will take time and it is important to build a foundation step by step to reach the optimal solution. Therefore, it was important for this project to close the circle for a solid vision by proposing ideas how this created data of each power tool can get into the information cycle and to achieve a software integration over the different tool cycle interfaces.

The cloud could allow a better spread of the gained power tool information for an enhanced workflow.

There are various options to transfer the gained data into the system. The best placement inside the tool cycle would be an early operation room integration through the battery charger. The second option is the integration of the clean side of the CSSD department. There could be a test station which checks the condition of the tool or just a NFC reader to transfer the saved data from the memory chip inside the cloud. But the CSSD integration would require the usage of many devices at every work place.
05 | CONCEPTION

Second field research
Mock-up tests
Brand language
Customer service
Reflections
CSSD EVALUATION
To get a reality check and to gain deeper insights about the current issues. In Moers at the Bethanien Hospital, I had a long discussion with Petra Rosendahl from the CSSD Instrument management department. I explained to her my initial ideas (Concept 2-3) about increasing the application flexibility and enhance an equal usage of tools. During the interview, we went step by step through the tool cycle and checked where this approach could have a positive impact on their daily life or not. The first conclusion was that the second concept would be most feasible as well as still allow a good cleanability. In the same time, we compared the current usage amount of their existing power tools from Aesculap. The outcome showed that the oscillating saws and drills were more or less used quite equal in the last three years (~300-550 times). But it still showed that drills were used more often in general than the oscillating saws. But the biggest surprise was the usage amount of the sternum saw. Both machines were only used (~50-70 times). It confirmed my assumption that they cannot gain the full potential of their few quality tools. Some tools are used more often which results in an inequality abrasion which is problematic if the maintenance is not done right. She was really positive about the idea to split up the sterile sets to use the motor as a single component, to allow frequent and flexible planning and to reduce surgery delays or fallouts if a machine breaks. In my case, not the whole set with important adapters would be blocked instead just a motor which could be exchanged with any other in storage. It reduces the need for rental tools and allows easier operation. But important to mention is that this case relates to a middle size hospital with an integrated CSSD department. In...
a more complex and bigger hospital, the CSSD department is often outsourced which could complicate the managing of more smaller sterile sets as well as they get charged with each cleaned set. This is the reason why some hospitals overfill their sets to save money. The outsourced CSSD department handles instruments from various providers which results in a loss of the personal relation to their own tool conditions. Also, these people are minimum wage employees and not well educated in general about medical instruments. This results into another issue.

“TOOLS ARE RATHER WASHED TO DEATH THAN USED TO DEATH”

Especially if two machines are on a single set. Often only one tool is used for a simple surgery. In general, the washing including chemicals is worse for the tools than the usage itself. We also came to the conclusion that the usage data of a set delivered not precise information of each device inside. For me, it was important to follow the best case scenario and not solving a problem with another problem. I decided to follow the idea to split up the sterile sets to increase flexibility and reduce unnecessary cleaning routines.

SURGEON EVALUATION

In the following interviews with three surgeons, I showed them the initial concept directions and tested the different mock-ups. The second concept direction was most convincing as well. The third direction includes too many single parts which can break or get lost. Also, it doesn’t fit into a professional and high-quality setup. Mostly hobby craftsmen are using this kind of modular set for their usage once or twice a year. But if it is used daily it should be perfect in each of its own function. This led to the question of concept direction one. Could a specialized tool only for sawing improve their work routines? In general, it is a good idea to perfect a tool for the best use case. But regarding the saw handle which is known in the commercial equipment, it would be maybe better in some scenarios but worse in others. In the same time, the further back the handle is, the higher they need to raise their elbow for example in artificial knee surgery. Normally this kind of handle is used to put much force on the target. This doesn’t correlate to the surgical environment. The goal is to cut with less force and more cutting speed and precision because the body is still fluid and the bones would move too much. That’s why a pistol handle helps to bring little force but much precision to the target area. Even Aesculap thought they mostly cut with one hand but the surgeons supported my goal to include a second hand as far as possible on the front for better guidance and precision without the danger of destroying the gloves. It also shouldn’t add to much space or be clumsy because of its universal use which could make specific cuts impossible.

Very well received was the new adapter for the sternum cut procedure. The included second hand allows much better guidance and straight movement through the chest for an accurate and less invasive cut. This results in a better and faster healing outcome which could also reduce the scar afterward. Also, a smaller body diameter, lighter tool and a more ergonomic firm grip and trigger placement are mandatory for a new generation of power tools. To focus on the obvious issues in particular on the adapters and to integrate a second hand in the design as soon as it is needed would create a convincing and very well thought through design which could already have a big impact in their daily life. This was, in general, the overall opinion from the surgeons. If the tool would increase at the same time the usage flexibility it could help to work more economical which could lead to more investments in the future. This can improve their daily work life step by step without breaking the habit which was for the users most important.
The previous goal was to reduce the size and any volume on the top and front. The result is a lack of space for a second safe and stable grip. Also, the edgy handle diameter is too big, includes many pressure points and reduce the reachability of the front trigger. The tiny lock mechanism is hard to reach and rarely used.

This hand position was showcased by the engineers. But the double hand grip doesn’t offer a better control through the position on the same handle axis and was rarely used by the surgeons.

The top diameter is slippery and small for a grip around the cylinder. The biggest contact area is on the second hand. But the rounded backside is comfortable for the hand and still offers a stable grip if the thumb is placed on it.

Due to the reachability of low cuts on the body where the operation table is in the way, surgeons sometimes rotate the tool to easily reach the spots without an extra effort to move the patient too much. But it reduces the control and guidance of the tool.

Even with my relative big hands I just touch the side edge of the trigger. The backside cut out for the palm of the hand feels forced. Due to the hard metal surface, the backside edge is pinching inside the hand from my conviction. The tool is not weight balanced well enough from the bottom to the top part and more bottom heavy.

The second hand around the front was the most common position I observed. In this scenario, the surgeon receives all the vibration on his front wrist. It doesn’t offer a safe and stable grip. But the front hand can better spread the upcoming swing forces.

Even with my relative big hands I just touch the side edge of the trigger. The backside cut out for the palm of the hand feels forced. Due to the hard metal surface, the backside edge is pinching inside the hand from my conviction. The tool is not weight balanced well enough from the bottom to the top part and more bottom heavy.
My first focus was to improve and test a better and safer grip on the front. This minimal change was already well received from the users but from my perspective not enough for a true change.

I created and tested several trigger options. In this scenario, two fingers could be used inside a ring trigger for better support and sensitive control. But in the end, all surgeons were not convinced enough and mentioned the old architecture with better placement and shape would be perfect. Drilling is still one of the main application scenarios. A supportive grip on the front is missing today and useful in many scenarios and a must have from the surgeons perspective.

I also tested a straight saw more known by the commercial power tool market. As mentioned before it gives a better grip in some scenarios but worsen them on a downside cut by an unnecessary high placed elbow to hold and control the trigger.

In this scenario, the handle with the battery is placed backward with an increased angle to enhance the usability for low and narrow cuts. The front can be easily rotated to allow various hand positions and at the same time allow the index finger to reach the trigger without losing control.

The surgeons were interested in this concept with increased flexibility and would like to test a working prototype. At the same time they mentioned it could be a nice additional device but it wouldn’t be strong enough to replace the current system.

The outcome could be a redesign and improvement of the current system by implementing a second hand grip on the front. A smaller handle diameter and a lighter tool by reducing the batteries.

If an adapter change should be possible there will always be two triggers needed for the drilling and screwing usage (left, right rotation). It is important for a robust device not to break the main shell with an integrated switch. Therefore the upper and bigger trigger always includes the main function.
The oscillating saw adapter allows more freedom for various hand positions and still allows a safer grip. The closed top offers a better thumb position without being exposed to swing vibrations.

By balancing the tool centralized, it is hard to cut straight or even hold the tool in a 90° angle to the body. In the same time, the cut must be done quickly because the artificial respiration is stopped in between to not endanger the lung.

The upper diameter is minimally increased to allow a better firm grip for the second hand. The backside of the device is placed further down to offer more space for the thumb and straighten the index finger orientation to reach the trigger quality.

The architecture is better balanced from the handle to the upper body. Small improvements around the tool will support the surgeon without breaking their habits or interrupting their work routines.

The upper diameter is minimally increased to allow a better firm grip for the second hand. The backside of the device is placed further down to offer more space for the thumb and straighten the index finger orientation to reach the trigger quality.

By balancing the tool centralized, it is hard to cut straight or even hold the tool in a 90° angle to the body. In the same time, the cut must be done quickly because the artificial respiration is stopped in between to not endanger the lung.

The architecture is better balanced from the handle to the upper body. Small improvements around the tool will support the surgeon without breaking their habits or interrupting their work routines.

For better control, many surgeons place the second hand on the front which blocks the visibility to ensure a clean cut. Therefore, they need to lean over the patient in an un-ergonomic working posture which improves the front view but complicates the control of the 90° orientation.

The new architecture allows the surgeon to place the second hand under the device for better orientation and balance. It doesn’t block the visibility and leads to a better working posture.

The upper diameter is minimally increased to allow a better firm grip for the second hand. The backside of the device is placed further down to offer more space for the thumb and straighten the index finger orientation to reach the trigger quality.

This concept was well received from the users and clearly improves their working ergonomics and the outcome. The cut out on the front ease the orientation for a straight cut.

The new architecture allows the surgeon to place the second hand under the device for better orientation and balance. It doesn’t block the visibility and leads to a better working posture.

An integrated step on the front cap improves the friction and ease the adapter change. (Good design is invisible). Small changes can allow a better performance and work-flow.

STERNUM SAW

The sternum saw is used to open the chest for interventions beneath. This is a serious and important cut during the operation and can influence the outcome.

Today the architecture and application allow too many degrees of freedom which can negatively affect the cut. The surgeons need to hold the tool in space without touching the inner or outer chest.

For better control, many surgeons place the second hand on the front which blocks the visibility to ensure a clean cut. Therefore, they need to lean over the patient in an un-ergonomic working posture which improves the front view but complicates the control of the 90° orientation.

STERNUM ADAPTER

The new architecture allows the surgeon to place the second hand under the device for better orientation and balance. It doesn’t block the visibility and leads to a better working posture.

This concept was well received from the users and clearly improves their working ergonomics and the outcome. The cut out on the front ease the orientation for a straight cut.

An integrated step on the front cap improves the friction and ease the adapter change. (Good design is invisible). Small changes can allow a better performance and work-flow.

STERNUM SAW

The sternum saw is used to open the chest for interventions beneath. This is a serious and important cut during the operation and can influence the outcome.

Today the architecture and application allow too many degrees of freedom which can negatively affect the cut. The surgeons need to hold the tool in space without touching the inner or outer chest.

For better control, many surgeons place the second hand on the front which blocks the visibility to ensure a clean cut. Therefore, they need to lean over the patient in an un-ergonomic working posture which improves the front view but complicates the control of the 90° orientation.

STERNUM ADAPTER

The new architecture allows the surgeon to place the second hand under the device for better orientation and balance. It doesn’t block the visibility and leads to a better working posture.

This concept was well received from the users and clearly improves their working ergonomics and the outcome. The cut out on the front ease the orientation for a straight cut.

An integrated step on the front cap improves the friction and ease the adapter change. (Good design is invisible). Small changes can allow a better performance and work-flow.
COMPANY PRESENTATION
After I summarized the gained knowledge from the user evaluation and reviewed and tested by myself the mock-ups again, it was time to present my impression and conclusion to Aesculap. During a meeting with the director, engineers and marketing people I presented the current outcome. They appreciated the close integration of the users during my design process. My goals, as well as the wish from the company, was to define a new surgical instrument which is closely focused on the users’ behavior and needs and in the same time still realistic and feasible. The focus of creating business value for the hospitals and also envisioning a successful future path for Aesculap is from my perspective essential. I also suggested that it is not enough to test their tools by cutting wood in an optimal position. It is important to follow the users and recreate their working routines to recognize and understand the current issues. Together we came to the conclusion that the new generation of Acculan machines has to be an evolution of the current systems and in the same time be revolutionizing in terms of the overall architecture including the usage of a new battery constellation. Improvements of the main issues regarding usability and ergonomics are urgently needed. Minimal change can already have a big impact on users. Therefore, it is key to disrupt the current status quo and not follow the competitors. But also don’t break the behavior and habits of the users. In the past, the goal was to simplify and minimize the tools as much as possible to stay most cost-effective and universal in usage as possible. There is a fear to dance out of line in comparison to their competitors and lose the users connection. This is also the reason why all surgical power tools are almost identical and from my perspective, this field lacks behind. The tools are almost too simplified which makes it, of course, universal for all kind of usages but worsen and endanger the overall handling. Like an engineer mentioned before: “Even we don’t know how and in which scenarios the user handles our machines, this is what makes it hard to specify the machines for specific applications!” Today, it feels like they simply attach a different part on a device which is not adapted to the upcoming needs. Of course, it would be possible to tighten a screw with a scalpel or saw with a screwdriver if a saw blade would be attached but is it really the way how it should be done in the future?
On the previous page were an image collection of the main adapters which I think need a deeper examination and adaption in the future. For example, image 1 shows the reamer which is used for hip surgery to clean up the hip socket. Often at the end of this procedure, the reamer gets stuck during rotation which transfers all rotation forces on the surgeons’ wrist. This can lead to serious injuries or the tool gets even dropped on the floor which can also injure the patient and makes the tool unusable for the current procedure. This doesn’t happen frequently at all but even if it could happen it is an objective to integrate a second fixed handle or even a torque wrench. It is to mention that a torque wrench has been tested already and it stopped to sometimes to early which hinders a smooth procedure or the surgeon wouldn’t use it after while. This comes down that there is still room for improvements and awareness needed.

The oscillating saw (image 2+3) is one of the most used adapters and worth to focus on further during my thesis. A simple upgrade can have a far-reaching impact and is a good starting point to start a discussion around the leftover adapters. So far there is not enough and safe room for a second hand on the front. Additionally, the open mechanism is on the same position which could endanger an unintentional opening during sawing.

The sagittal saw (image 4) has for me the most frightening appearance. I understand the reason to make the front as slim as possible to reach narrow spots with less invasive cuts through the tissue but I think even here is room for a change.

The sternum saw (image 5) was the second adapter I focused on during the thesis. The reason was the positive feedback I gained from the users and the effect on the patient itself. For health insurance, this cut is just a number which should be as small as possible. For the surgeon, it is just a cut to continue a surgery inside the chest and every ergonomic and eased way is very well appreciated. But for the patient, this cut is a whole life experience like a tattoo which will stay there forever. The better the outcome is, the better and invisible the scar will be.

The image above showcases the decision for a new battery architecture. Together with Aesculap the decision went from 8 Ni-MH Batteries to 3 Li-Ion Batteries (21700 - cell 21mmx70mm). It is a big reduction of cells which could deliver the needed energy in the future. By doing this, the needed handle diameter can be reduced as well as the weight of the tool.

On the right side are further thoughts about accessories which could be added to the new adapters smooth and ease various operations.
After the final concept direction was defined it was important to find the right balance between surgical equipment with a “fresh” but reasonable appearance which should carry the traditional heritage of Aesculap’s surgical tools but also show its evolutionary change. It was also a wish from Aesculap to place their design language closer to the B.Braun identity. Aesculap is the fourth department from B.Braun and the only one which still has their original heritage. For the upcoming products, it is a business decision to position the companies closer together. On the next page, I created a common core and brand board to understand their main identity. As the B.Braun language is clean and reduced to its main functions with the integration of a swing curve, Aesculap is totally using a more dynamic edge approach. The appearance is more robust and heavy in comparison to the lighter appearance. The main differentiation is the distinction application field and its users. While B.Braun products are mainly used inside the hospital ward and exist primarily of plastic parts, Aesculap is only placed inside the surgical theaters and exists of many metal components and many handheld devices. It would be unprofessional to simply put on the B.Braun appearance on these. It needs to be functional reasonable but even though Aesculap needs to depart a bit of their identity. But not only the aesthetical components are essential also the functional similarities and company values can be aligned.
CHAPTER 05

B.BRAUN - DESIGN ELEMENTS

AESCULAP - DESIGN ELEMENTS

Stationary

Handheld

Grip

Pattern

Graphic

Print

Digital

Product

Grip / Handles

Graphic

Print

Digital

Product
B.Braun medical has historical connections to the Braun language or the also known Bauhaus design guidelines. The design follows function not more and not less. All decisions are done regarding their main functions starting from material choice, iconographic similarities to visually understand the usage and features. Especially for the handheld tool of the new Acculan machines, this allows not a lot of room for change. It needs to transport the original heritage and at the same time be modern. It is to consider that the visual identity even for a surgical instrument plays a bigger role than someone would think. Acculan 3 was the start around eight years ago for the current appearance. Acculan 4 which was just released last year is visually identical and users are questioning the value to invest in the new more expensive system, without seeing from the outside a significant change. Of course, they include a stronger motor and a more solid gear system but the Acculan 3 could also do the job. Still, it is not a lifestyle product and the internal features value a lot more in this field but the surgeon also wants to work with the latest tool and sees it as prestige in comparison of having the latest sneaker to be proud of. This is surely a minor factor but if it is possible to introduce a visual change it should be done right.

As a designer it is also my goal to create a product which makes the surgeon proud as well as introduce aesthetic product design inside the hard and strict daily routines.

A main characteristic is the cut at the front to integrate the adjuster lock and the trigger mechanics. It was important to differentiate from the competitors and reduce the cut size to allow a higher qualitative appearance. It feels like this cut could be possible without adding to much production costs but this needs to be reviewed later on from the engineers.
Aesculap sees themselves not as a product provider more than a service provider. The sale vendors are the principal contact persons between the company and their customers. Their goals are to optimize their customers’ working processes and to solve upcoming problems in close and almost personal contact and communication. In this sector, instruments are not just bought online or in catalogues. There is much forward planning needed to foresee the prospective situations and to invest reasonably in the most needed issues. More knowledge about their current tools conditions and progress in the following years is essential. Even a simple power tool can play an important role in the middle of the complex hospital structure. Therefore, data can have a big value for Aesculap and their customers. If the future tool can provide more precise data, it would be possible to plan and invest more accurately. If a few tools are used more often in a year than recommended, it could be beneficial to invest in additional instruments to reduce the burdens on the existing ones. In average it could reduce the maintenance and repair costs and in the long run be economical beneficial for the customer. At the same time if a tool or instrument on a sterile set is rarely used but often washed, is it not optimal. Generated data over one year period can offer them a clear overview to customize their needed tools and sterile sets more efficiently.

This is where the new Acculan system can offer more value than the current systems. With the possibility to create accurate data inside the battery CPU and store it either inside the tool or on a small data chip, which can be reviewed from the CSSD instrument management or from the outsourced repair and maintenance departments. The optimal solution is then a data integration inside the current instrument management software which is cloud-based inside the locked hospital network. But to achieve the optimal solution several steps are needed to reach the goal. First, not all hospitals around the globe use similar software. In addition, each hospital is on a different innovation level. If a hospital would purchase a new Acculan system but cannot use its full potential because of its outdated infrastructure the extra costs would be pointless.

The solution is a way to allow both cases to gain the full potential of this new system approach by first allowing a locally based data collection which can be reviewed from the hospital personnel and the sales vendors from Aesculap. At the same time integrate the possibility to wireless transfer the data inside the cloud if their software and infrastructure allows it. The idea is to use the battery as a USB stick to transfer the created data of the used tool to the battery charger. From there on, all data of each tool and adapter can be stored and structured and later retrieved via phone or computer or already transferred into the cloud. In the minimal value way, the sales person who is usual coming twice a year to their customers could read out the data and use it wisely to consult together with the hospital administration the future planning. (Aesculap does not only sell power tools but also several hundred of various simple surgical equipment and implants). Because of the overburdened customer, the provider could support them so they do not need to care about their system after they purchased it. At the same time, the important maintenance could be scheduled not on assumption every year which hasn’t worked out in the past, instead this could be done on the basis of clear data to optimize the customers’ expenses. The battery charger today has already integrated the technology to analyze the battery power and to warn the user if the performance goes down. It reduces the possibility of an unnecessary surgery interruption if the battery power breaks down during usage. The additional technology could be worth to be integrated without adding too many costs. Overall, this scenario could be a starting point to, later on, integrate additional tools from their portfolio into this updated tool service cycle.

All technologies and sensors are inside the battery. During each procedure, the battery can save the relevant information about the specific tool and adapter. It can recognize the usage time and appearance of problems.
WHAT WAS MY LEARNING OUTCOME?

- For me, it was important to understand the healthcare sector in general and to get a holistic overview of the bigger picture to see how it would affect my creation phase.
- I could experience the burdens each department in a hospital (surgical environment) is facing every day and smaller changes can already positively affect their outcome.
- It is impossible to create a bigger change right now. Smaller steps are needed to create a path for the bigger end result.
- The medical world is a conservative field which is caused by the complex interconnected issues and it is impossible to rapidly change the system (you can not change wheels on a moving car).
- It is easier to propose a better future but it is much harder to create the path to achieving the future vision. That’s what my project is all about.
- I wanted to be disruptive in areas my collaboration partner hasn’t thought about and also respect and follow their bigger goal.
- It was important to increase the value of a high-quality tool and to make it more valuable without interrupting the current workflow and habits.

WHAT WAS MY DESIGN WORK?

- As a designer, it is important for me to not accept the current situation but also stay realistic to the existing problems.
- My goal was to design and follow the process closely to the daily users and to design an outcome which can be adapted in the near future but still consider that there will be a bigger change possible or even needed in the future.
- I wanted to improve the working routine, ergonomics of the surgeon and envision a better tool cycle by adding smaller changes to gain advantages now and describe future updates which can be applied later on.
- Be disruptive and encouraging for better working routines without breaking the current habits.
- I wanted to start the project more around the overall system but the complexity is hard to handle in a short time. Furthermore, companies are aware of many of the issues and a vision is already there but the integration is costly, complicated and slows down many improvements.
- As a designer, it was more interesting to open question and interrupt where I have the knowledge and where I can have an impact by broadening the view of the company.

WHAT IS THE CURRENT PROBLEM ON THE MARKET?

- Money is the biggest factor today. In addition, each hospital and nation are on a different level of innovation which hinders the change in a broader and global perspective. People are fighting each day in the healthcare sector to fulfill their daily work. There is a level of fear of change which could break their habits and interrupt their work at the beginning. Clarification is needed that a change can partly disrupt in the first stage but improve the general outcome in a longer run.

WHAT SHOULD PEOPLE MAINLY UNDERSTAND FROM MY PROJECT?

- Medical design is a complex undertaking to understand and to work for. To create value, the first outcome can often not be too futuristic and more defined and improved in smaller steps which will only often be visible for the end-users.
- It also tried to combine the gained knowledge to showcase to my collaborative partner that there is much more to explore, improve later on.
A surgical power tool needs to meet many requirements in case of usability, cleanability, and safety. In addition, the tool comes in touch with different users during the hospital tool cycle and each of them has specific needs which must be considered. At the end of the funnel, the tool gets reduced to its minimum to fulfill in the best case all requirements. The outcome is that many tools in different price ranges are almost the same from usability and functions. Not much has changed over the years and the reason is a fear to interrupt the habit of the users.

Orthopedic surgery is the most physically demanding sector. Surgeons are suffering under wrist pain, joint damage, tendinitis, etc. In the future, physically demanding working steps should be reduced by increasing the usage of power tools. But there is a need for less weighty tools and batteries to approach these issues. As a result, the focus must be on increasing the ergonomics and safety for the surgeon.

The healthcare sector is constantly under cost pressure and investments are not used equally over various fields. In case of a surgical power tool, there is the decision of investing in quantity or quality. Today, unavailable instrument sets or tool failures are among the ten most frequent causes of operation delays. With more available tools, hospital management can plan more flexibly. But to improve the work-life for the surgeon more quality tools are needed which increases the investment costs and fewer tools need to do the same amount of work.

Research summary which led to the result

1. Orthopedic surgery is the most physically demanding sector. Surgeons are suffering under wrist pain, joint damage, tendinitis, etc.

2. In the future, physically demanding working steps should be reduced by increasing the usage of power tools. But there is a need for less weighty tools and batteries to approach these issues. As a result, the focus must be on increasing the ergonomics and safety for the surgeon.

3. The healthcare sector is constantly under cost pressure and investments are not used equally over various fields. In case of a surgical power tool, there is the decision of investing in quantity or quality. Today, unavailable instrument sets or tool failures are among the ten most frequent causes of operation delays. With more available tools, hospital management can plan more flexibly. But to improve the work-life for the surgeon more quality tools are needed which increases the investment costs and fewer tools need to do the same amount of work.

4. To approach the current situation a quality tool needs to be worth the money. First, it must improve the work-life for the surgeon. The tool needs to be flexible to use for various applications by allowing to change the adapters. Now, the motor unit can be used for any procedure and in case of a tool failure the motor unit can be easily replaced without blocking a full instrument set. Second, the tool needs to be maintained over time which doesn’t happen regularly today. By creating data during the usage, the maintenance can be customized and planned instead of assumption.
REDESIGN OF THE ACCULAN 3/4 GENERATION

The result of this master thesis led to a redesign of the former Acculan 3 architecture with the main focus on ergonomics around the pistol grip as well as specific adapters for various applications. The main benefit is a reduction of pressure points around the handle for a comfortable and stable grip during usage. The thinner handle diameter caused by the usage of Li-Ion batteries as well as the trigger position and architecture allows a good grip even for smaller hands to gain a gender-neutral tool. The tool offers visually several possibilities for a second grip by highlighting the areas through a texture change which increases the slip resistance. The overall body is smooth and rounded without edges or sharp corners. The interactions with the device are in focus and clearly outlined.

Oscillating saw adapter
OSCILLATING SAW ADAPTER

The oscillating saw is one of the most used features for surgical power tools. The new adapter allows a second grip on the front of the device to counterbalance the oscillations which offer more control of the tool and a better cut outcome. The covered sawblade prevents the surgeon to come in contact with the saw blade edge and harming vibrations which previously could lead to destroyed gloves. An RFID chip is placed in all adapters to adjust the motor CPU settings to the appropriated adapters without additional steps. By allowing to rotate the adapter, a flexible usage can be guaranteed without the need to change the front grip position. A release button is placed on the front bottom to remove or change saw blades. The top lid can be rotated for cleaning to prevent hidden areas.

DRILL/SCREW ADAPTER

The upgraded drill adapter offers a second grip position for accurate targeting. The wave shape prevents the fingers from slipping over the front tip. Most of the drill bits have a flat area for the propulsion. A groove on the front visualizes the right direction when placing the bit to prevent unnecessary rotation of the bit to find the right direction. The black lid is getting wet and slippery during operation. To allow an enhanced grip the recess offers enough friction to pull back the lid to remove or change the adapters. For a safer tool exchange between the scrub nurse and surgeon, the lock is placed on the bottom trigger to ease the usage and highlight the lock to ensure safe usage.
ADJUSTABLE OSCILLATION

There is a wide variety of saw blades for specific procedures. The main differentiation is the length of the blades. The longer the blade the higher is the oscillation radius of the front. It results in uneven cutting speed and feedback. To achieve an accurate outcome the experience for the surgeon is decisive. But the feedback of saw blades differs as well as the bone structure of each patient. But to realize a tissue change it is important to apply the appropriate pressure on the target without damaging areas behind the bone.

The solution is to align the oscillation end radius of all saw blades by adjusting the rotation axis based on the length of the blades. In general, the saw blades can be ordered in two main lengths. Smaller differentiations in between aren’t too obvious. A mechanical solution was invented which can withstand the extreme environment of a hospital. Two green pins are used to change the swing plate radius. The new saw blades include two additional wholes on the front or back of the swing mechanism to activate one of the mechanical the swing radiuses.
The sternum cut is an important procedure for various interventions under the chest. It is decisive for the operation process and straight and clean-cut results in a better healing outcome for the patient. For this reason, it is necessary to integrate a second hand under the adapter. The surgeon can guide the tool over the patient’s body by a 90° angle. It offers a better cutting feeling and supports a straight orientation.

The visibility of the saw blade is improved and allows an ergonomic position of the surgeon. The release button of the saw blade serves also for a vertical orientation indication.

The pistol handle is optimal for precision work. The surgeon shouldn’t apply pressure on the target because of moving bones. Instead, high-speed tools should ease the work. The pistol handle is designed for a one-hand grip but in real life, the surgeon places a second hand on the front of the tool which could be dangerous. Therefore, safety and ergonomics need to be applied on the adapters to allow a second grip when it is needed without hindering the visibility and reachability.

Summary

STERNUM SAW ADAPTER

The pistol handle is optimal for precision work. The surgeon shouldn’t apply pressure on the target because of moving bones. Instead, high-speed tools should ease the work. The pistol handle is designed for a one-hand grip but in real life, the surgeon places a second hand on the front of the tool which could be dangerous. Therefore, safety and ergonomics need to be applied on the adapters to allow a second grip when it is needed without hindering the visibility and reachability.
BATTERY EXCHANGE

The Acculan 3/4 series required an additional funnel to place the battery inside the tool before every procedure. The unsterile battery needed to be held from the surgery assistant and placed inside without touching the tool or the sterile person. A problem often occurred by changing a battery during operation when the funnel has been already used and a second time is forbidden. This situation can happen and forces surgery personnel to improvise. They need to remove and place a new battery carefully inside.

By attaching the lid to the battery, the sterile person can place and remove the battery alone. It is possible to take the battery with the new lid from the charging station or a second person puts the battery on the lid. An integrated funnel supports the operator and prevents the outer part of the tool to get unsterile. Also by changing the battery the lid can be easily removed and eases a battery exchange without additional accessories.
The huge amount of instruments which needs to be cleaned and sterilized each day makes it hard to keep an overview. Lack of knowledge about the condition of the tools as well as insufficient maintenance causes unnecessary interruptions and increases the economic pressure. Now, created information inside the battery during usage can be used later on for a more precise diagnosis and prognosis.

The smartness is inside the battery

- Tool can recognize which adapter is used
- Battery can save information about which tool and adapter was used
- Application time and frequency can be saved
- Data can be used for maintenance prognosis/diagnosis
- Battery overview and control about the system
- The battery can adjust the motor to specific demands of each adapter
- The measured current flow can give relevant information about the tool’s condition.

Summary

The battery station serves as a data bank and can share the information into the tool management software.
The data can be transferred in two ways from the charging station. If the infrastructure allows an integration inside the instrument management software, the knowledge can reduce upcoming tool failures during procedures. The second way is a customized service from Aesculap. A sales representative can transfer the data via Bluetooth to a computer/tablet and offer customized maintenance services as well as uses this knowledge for process optimization.
07 | APPENDIX

Timetable
References
Week 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23

**Research**
- Desktop research
- Expert interviews
- User interviews

**Analysis**
- Pain points
- Opportunity areas
- Project definition
- Goals & wishes

**Ideation**
- Further interviews
- Brainstorming
- Visualization
- Mock-ups
- Co-creation workshop
- Concept scenarios

**Evaluation**
- User evaluation
- Expert evaluation
- Concept selection

**Refinement**
- Concept refinement
- Cad modelling
- Physical model
- Presentation material

**Deliverables**
- Presentation
- Uid talks
- Thesis report

**Presentations**
- Ideation session Aesculap
- Off-Campus Aesculap / Hospitals
- Off-Campus

**关键时间**
- **JANUARY**
  - Kick-Off
  - Research

- **FEBRUARY**
  - Research Presentation
  - Ideation
  - Presentation

- **MARCH**
  - Ideation Presentation (St. March)
  - Evaluation
  - User evaluation
  - Expert evaluation

- **APRIL**
  - Concept selection
  - Refinement
  - Concept refinement
  - Cad modelling
  - Physical model
  - Presentation material

- **MAY**
  - Thesis
  - Final Revision

- **JUNE**
  - Final Revision
  - Uid talks
  - Thesis report
**CHAPTER 01**

**CONTENT**

**PROJECT SETUP**

**SCOPE**

**ACTION**

- Expert interviews + Hospitalization
  - Examine the company structure
  - Who is in touch with the Acculan system?
  - Interviews with (Engineers, Designer, Marketing, Production employees, Service - Maintenance ...)
  - Meeting with surgeons (young, old, female)
  - Assistance employees
  - Follow the product's life cycle
  - Find common interests and problem areas
  - Pain points - opportunities

- Analysis / Ideation / Evaluation / Testing
  - User Journey / Product journey
  - Find common areas
  - Defining the scope
  - Build Frameworks
  - Ideate with users / company
  - Create several concepts
  - Test first concepts and ideas
  - Evaluate directions
  - Get visual

- Concept testings / Refinements
  - Co-creation workshop
  - Define concepts
  - Build prototypes
  - Organize role plays
  - Decide final direction
  - Develop concept
  - Create common core language (design)
  - Last check in with users, company

- Finalization
  - Define Product language
  - Solve details
  - CAD modelling
  - Model making (2D, 3D)
  - Thesis report
  - Presentation

**STEPS**

- Start broad desktop research about the application area to learn more about the history, current status quo and future trends, to get a broad view.

- Interviews with designers, engineers and marketing people of the company

- Early user interviews are necessary to find relevant areas to explore during the following field research.

- Field research at several hospital sights will be important to meet the users at their workspace, to get a deeper understanding and to ask relevant questions.

- User journey & product journey will be helpful to collect and order the gathered information. It allows me to find open questions and to go back the users to present visually my point of view and to highlight pain points and opportunity areas.

- Secondary desktop research to fill missing gaps and to get a deeper understanding of possible opportunity areas.

- Ideation “How might we” / “how&why board”

- Pain point and opportunity board will be relevant to identify 2-3 interesting approaches

- Create a framework of the overall system which can give me a holistic view.

- Co-creation workshop with the users to ideate together around the pain points and opportunity areas.

- Brainstorm & ideation session at Uid together with students

- Following interviews with users to talk more in detail around solutions and validate ideas

- Rapid prototyping

- Role plays with prototypes are essential to design a holistic system with different components included.

- Second Co-creation session would be beneficial to test defined prototypes/ideas together with the users to find the final direction.

- Get visual is necessary to select and improve specific concepts to present and decide together with the client in the final direction.
REFERENCES (CONTENT)

CHAPTER 01 | INTRODUCTION
7. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4436841/
10. https://futureofsurgery.rcseng.ac.uk/?_ga=2.186300586.20918842.1547818234-852601048.1546877626
12. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4045684/
18. Aesculap Power Systems...get the speed you need | Catalogue 2009 | p.2
23. https://www.futureofsurgery.rcseng.ac.uk/?_ga=2.186300586.20918842.1547818234-852601048.1546877626

CHAPTER 02 | EXPLORATION

CHAPTER 04 | IDEATION
1. Dr. med. Thomas P. 2019
2. Markus Siller (Director R&D Power Systems) 2019

INTERVIEWS
Aesculap
1. Markus Siller (Director R&D Power Systems and Devices)
2. Markus Schäfer (Director Global Marketing Orthopaedic & High Speed)
3. Roland Högerle (Director Motor Development)
4. Stefan Gathier (Senior Manager I&I)
6. Erich Barchia (Director Technical Product Services)
7. Thomas Klabou (Sales Representative, Motor Systems)
8. Dr. Sven Kluge (Sales Specialist, Motor Systems)
9. Christoph Albers (Sales Representative, Motor Systems)

Hospital
1. Gabriele Klaus (Interface Management, OP-CSGD)
2. Dr. med. Thomas Paffrath (Senior Physician, Specialist in Orthopedics)
3. Dr. med. Dafa Mural Alas (Senior Physician, Specialist in Orthopedics)
4. Leonhard Ott (Assistant Physicians)
5. Moltz Falkenroth (Assistant Physicians)
6. Dr. med. Christoph Christakos (Chief Physician, Specialist in Orthopedics)
7. Petra Rowendant (CSGD Management)
8. Short interviews: Scrub nurses, Assistant nurses, CSSD staff members
REFERENCES (GRAPHICS)

p. 5  Photo by Tomasz Frankowski on Unsplash

p. 9-9  https://unsplash.com/photos/6t7G8k8Treach/4-angiography-pearl-case-by-case

p. 13  https://th堑ruslife.net/

p. 15  https://www.blogger.de/de/site/mediatheken/medien/medienmanagement/erstellen/mehrstellige-dateinamenerstellen.html


2. Anest; https://synergynorthamerica.com/power-tools/hall-max_600

p. 20-21  Photos by Hudson-Writer on Unsplash


3. https://synergynorthamerica.com/power-tools/hall-max_600

p. 26-29  Photos by Alexander Abele 2019

p. 30-31  Photos by Alexander Abele 2019


p. 40-41  Photos by Alexander Andrews on Unsplash

p. 43-44  Screengrabs of Youtube videos about orthopedic surgeries

p. 48  Icons; https://thenounproject.com/

p. 52-53  Photo by Karl Shou on Unsplash

p. 54  Graphic by Alexander Abele (images of surgical power tools by Google search)

p. 56-57  Photos by Alexander Abele, Simon Linge

p. 60-61  Photos by Alexander Abele

p. 70-71  Photo by Mike Konovoc on Unsplash

p. 72-73  Photos by Alexander Abele

p. 76-81  Photos by Alexander Abele

p. 78-80  Photos by Alexander Abele

p. 94-95  Framework by Alexander Abele; Icons by https://thenounproject.com/

p. 100-101  Photo by Alexander Abele


p. 132-133  Framework by Alexander Abele; Icons by https://thenounproject.com/


Surgeons always want to give their best and treat patients with diligence. The instruments should be designed in the same way.