Cast Saw Cooling Device

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Abstract

The application of hard plaster or fiberglass casts is common in clinical settings to immobilize appendages or larger sections of the torso and aid in the healing process. Casts are most often used in long bone fractures which occur with the greatest frequency in adolescent and elderly patients. Friction between casts and cast saws used in cast removal is known to heat the vibrating saw blade. While burns can occur at temperatures as low as 44 °C, cast saw blades can reach 101°C during the removal process[C]. While studies have attempted to use extra padding, different cutting techniques, heat sinks, pressurized air/water, blade material, and vacuums to cool saw blades, no solution has been practical and effective enough to change hospital practices. Our goal is to design a system that cools saw blade temperatures below 44 °C and is adaptable enough to function for the various cast saw models used in hospitals. Preliminary testing of water-tubing conduction, pressurized air, and water misting methods have shown that misting cools the blade fastest.

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I.Introduction

1. Motivation

In Orthopedics, casts are commonly applied to patients to immobilize healing structures. Cass are removed with cast saws. While cutting the saw generates heat and the blade can often get quite hot. This has resulted in the burning and blistering of patients with a frequency of up to 0.72%[A]. While this may seem rare, it is not only bad practice to ever inflict unnecessary harm to a patient, but the costs associated with cast saw related injuries have been reported to be as high as USD 15,898 per patient for one year[A].

The specialties that use casts with the highest frequency are orthopedic pediatrics and geriatrics. Casts are most commonly used to immobilize bone fractures which are most common in youth and elderly patients. The most frequent major injury among children are extremity fractures[B]. Some children experience a significant amount of fear during the cast removal process due to the loud vibratoy nature of the cast saw itself, proximity of what the physician has just called "a saw" near their recently injured body, unfamiliarity in hospitals, or other factors.

Problem Statement

During the removal of the cast, oscillating cast saws are used to cut through the plaster or fiberglass material. As it is cutting through the material, friction between the blade and cast material generates heat and the blade can reach temperatures of up to 101°C[C]. As temperatures as low as 44°C and 60°C can result in second and third degree burns respectively, there exists a great need to design a system that prevents heat damage to patients' skin[D]. Because a large client base is pediatric orthopedics, the fear factor of the saw removal process also implicates a need to minimize the level of stressors imposed on the patient during cast removal. Possible burning of the skin is a key factor to address in reducing patient worries during cast removal.

II. Background

1. Team Research

The cast saw is a vibratory tool that is used to remove orthopedic casts. Unlike circular saws with rotating blades, cast saws have sharp, small-toothed blade oscillating back and forth over a very small arc to cut the material. The general design enables the saw to cut through rigid cast materials but not through soft tissues such as skin. An orthopedic cast is frequently made from plaster or fiberglass along with a cotton bandage as a padding to skin. Plaster cast consists of a fine white powder (calcium sulfate hemihydrate), which can be hardened after contacting water. Fiberglass, on the other hand, is often impregnated with polyurethane, therefore it can change shapes by altering temperature. It is lighter and more durable than plaster and it is water resistant. Both materials offer high heat resistance and low thermal conductivity, but plaster seems better than fiberglass overall. For both however, the cast saw will generate friction with the cast during cutting process, which would be the major cause for heat burn.

Skin burns are the most common problem that occurs when using a cast saw. Because of the vibration of the cast saw blade, high temperatures can result from the friction of the blade against the cast material. If the blade heats up and contacts the skin, a burn can occur. However, some safety procedures that could prevent burn include applying lighter pressure when cutting the cast or waiting several minutes before the next cut to allow blade to cool[E]. Also, replacing old blades would reduce friction. Moreover, previous research has examined methods to reduce blade temperature. According to Puddy et al., cooling the cast saw blade with 70% isopropyl alcohol or with water spray resulted with the fastest cooling times for the blade as opposed to air cooling[F]. And Moreover, Shuler and F. N. Grisafi suggested that applying more layers of the cast padding could decrease temperature change[G].

2. Discussion

Since the ultimate goal of this project is to cool the temperature of the cast saw, to successfully reach the goal, the team must make sure the cast saw temperature does not reach 44°C. Therefore, the team will find a medium, such as water or alcohol that prohibits the cast saw from reaching high temperatures. Although applying more layers to the cast can also result in lower cast saw temperatures, the client came to the team asking them to modify the cast saw, not the cast itself. In addition, adding more layers to a cast increases costs for hospitals and clinics. Overall, the team will focus on cooling the bottom one-third of the blade, the only part making contact with the cast itself.

III. Preliminary Designs -

Design Idea 1- Cold Tubing

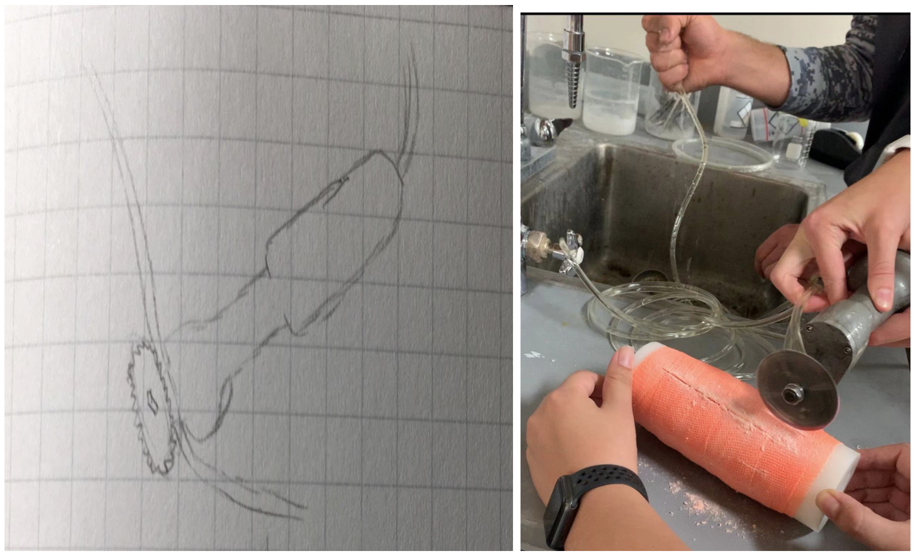

Fig 1 Initial Cold Tubing design with 1mm diameter PVC tubing wrapped 360° to the blade attachment (Left); The preliminary testing procedure following the initial design idea.

Cold Tubing design basically uses high heat capacity of water and the thermal conductivity of the PVC tubes to cool the blade down. The design includes a running water system that flows water through the tube then down into a reservoir so that water could continuously carry heat away from the blade. The idea comes from the cooling system for PC computers where the coolant is used to cool down a copper metal (high thermal conductivity) then copper cools the computer drive. One of the advantages of the cold tubing design is that it would not make additional mass to the saw and the cast. Water does not directly contact with the blade or the cast so that it prevents further wetting of the device. Also, the replacement of the tubing design is really convenient.

<u>Design Idea 2:</u> Mist+Vacuum

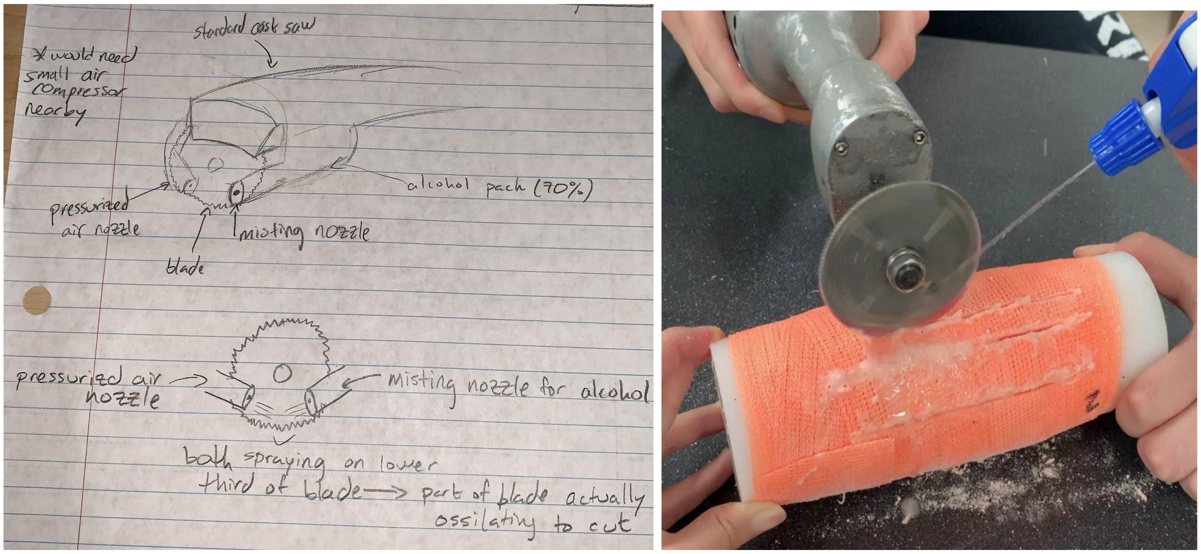

Fig 2 Sketch idea of the mist and vacuum design (Left) with one misting nozzle spray either water or alcohol and the vacuum nozzle sucks mist in. The right graph shows the preliminary design where the team used a spray bottle to mimic the misting effect.

According to Cast Saw Burns: Evaluation of Simple Techniques for Reducing the Risk of Thermal Injury by Puddy et al., cooling the saw with alcohol along with Stryker Cast Vacuum shows the better result when the saw is oscillating. The mist and vacuum idea comes directly from this research where the team has a vacuum nozzle and a misting nozzle installed in front of the blade where the blade cuts the cast. Two nozzles face each other in order for the vacuum to immediately suck the mist without leaving any alcohol on the blade. The advantage of the design is that it can rapidly cools down the blade and the cast without impeding the oscillation. Also, the oscillation of the blade would not cause an early deterioration of the cooling device as there should be no friction from the saw on the misting device. However, the two nozzles may block physicians views when they are performing the cutting process. At the same time, the design may include huge annexes (the vacuum and the alcohol pump) that is very hard to carry.

Design Idea 3: Compressed Air + Vacuum

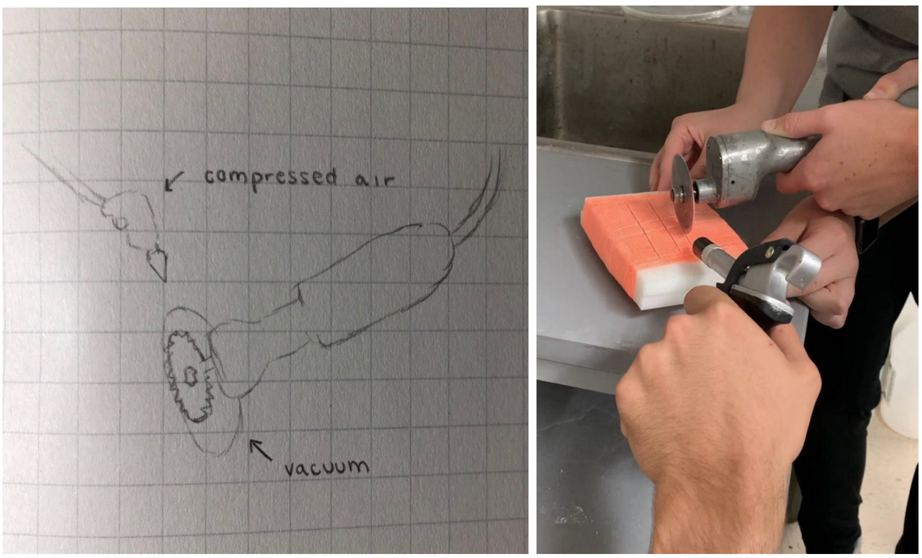

Fig 3 Compressed air design with an air compression nozzle blowing directly into the cast following along with the saw, while vacuum sits facing the air nozzle (Left/Right).

The design aims at taking away the heat by blowing cold air directly towards the cutting site. Due to the high pressure the air blows, the device can be cooled within a few seconds. However, the major concern for this design is that the air may blow the dust in all directions which may be hard for the vacuum to gather them. Moreover, the compressed air needs to be carried with a compressed air tank, which is very hard for storage.

IV. Preliminary Design Evaluation

1. Design Matrix

	Design #1	Design #2	Design #3
Design Criteria	Cold Tubing	Mist + Vacuum	Compressed Air + Vacuum
Cooling Reliability (35)	4/5 28	5/5 35	4/5 28
Ease of Fabrication/Assembly (15)	5/5 15	4/5 12	3/5 9
Ergonomics/Ease of Use (10)	3/5 6	2/5 4	2/5 4
Durability (10)	2/5 4	4/5 8	4/5 8
Aesthetics (10)	3/5 6	4/5 8	3/5 8
Cost (10)	4/5 8	4/5 8	3/5 6
Safety (5)	5/5 5	4/5 4	3/5 3
Fear Factor (5)	4/5 4	2/5 2	1/5 1
Total (100)	76	81	67

2. Justification of Criteria and Weight

Cooling Reliability

The team ranked cooling reliability (weight: 0.35) as the most important criteria because that is the main problem that the client has communicated with us. The team's main goal is to redesign a cast saw that eliminates the possibility of cast saw burns.

Ease of Fabrication/Assembly

Team gave ease of fabrication/assembly weight of 0.15 because we only have one semester to complete this project, so the product idea should be feasible to fabricate and assemble.

Ergonomics/Ease of Use

Removal technician should be able to remove cast using our reinvented saw with relative ease. As engineers, we make things simpler for clients. Therefore, we gave it a weight of 0.10.

Durability
The cast saw cooling mechanism should have the ability to withstand wear and tear due to normal use. We gave it a weight of 0.10.

Aesthetics
Aesthetics has a weight of 0.10. Although it is important to our design, we are unaware what shape the designs will take when implemented and have therefore chosen to not consider them in great detail.

Cost
Cost has a weight of 0.10. Although it is important to our design, we are still unaware of our budget, so the cost is not a large concern at the moment.

Safety
While safety is perhaps the most important consideration in any health related design, we gave it a low weighting because the main danger to the patient is caused by the saw itself. Our design shouldn't add a significant amount of safety concern so the weight is low (0.05).

Fear Factor
Fear factor is rated as 0.05 in our design matrix. As the client mentions, the device will be pediatric uses so it would not cause any discomfort for children. Some of the designs include the vacuum system and mist, which may scare children.

3. Proposed Final Design

Table 1. Preliminary testing results for all three proposed designs. The testing was performed following the client's procedure and the temperature was recorded using an infrared camera.

	Blade Temp (°C)	Cast Temp (°C)
Stationary	22	22
Control	113	47
Cold tubing	50	46
Mist	32	45
Compressed air	43	25 (after 30s)

Before proposing a final design, the team did a preliminary test mimicking each designs. An HDPE rode was used to represent the patient's arm, and the temperature was recorded after two cutting processes in a row (the cast is too short). The stationary result was recorded by placing the cast and the saw directly on the table, so they were nearly room temperature. The control trial was performed without any cooling system installed. Each of the designs was able to cool the blade temperature to half of the control, but only mist and compressed air met the requirement that having below 44°C (Burning temperature of skin). For the cast temperature, all of the three designs had very close results with the control, meaning that the cast temperature was hardly cooled done. The reason may be due to the thermal conductivity of the plaster is really low, while the blade (made by stainless steel) had very high thermal conductivity. One thing to mention was that the team forgot to take cast temperature for compressed air trial immediately after testing, thus the temperature for the last trial was taken after 30s. However, after 30s, the temperature was only 25. This provides an insight that, if physicians change their procedure by waiting a few seconds before doing another cut, the patient would decrease the possibility of getting burnt. Based on the preliminary test result, the team decides to install mist + design.

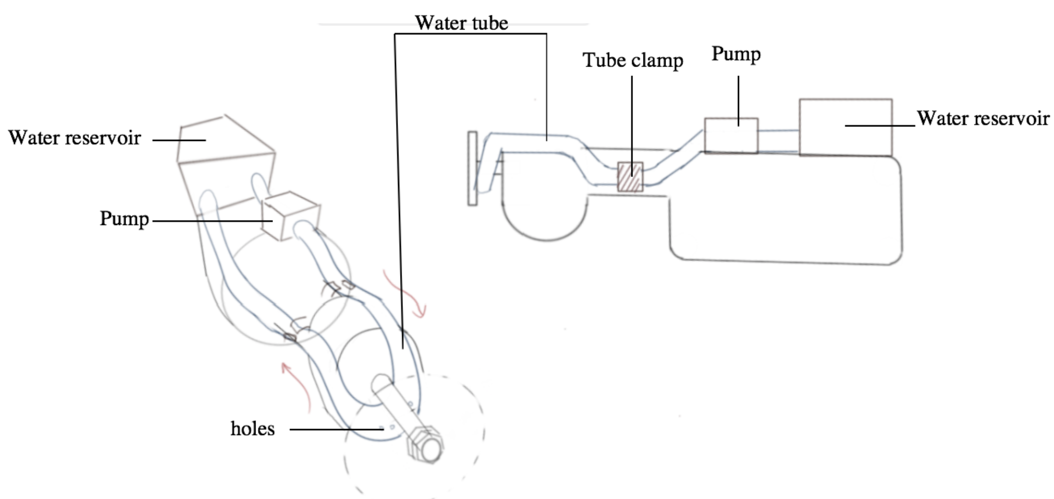

Fig 4 Preliminary design that incorporates mist and cold tubing idea. The tube was attached to the blade attachment point, wrapping approximately 360°. The tube was connected to a pump and reservoir used to provide constant flow and recycle water.

Our proposed final design is the mist + vacuum design. This design faired best among the criteria listed. Overall, the mist + vacuum design has the highest potential for cooling reliability, the largest factor in the design matrix. Although there are cons to this design, such as a greater fear factor and usage difficulty, the main priority is solving the client's issue. It is likely that the final design will include aspects of all three designs to eliminate other issues. Fig 4 shows a preliminary design that combines mist and cold tubing together. The mist can be generated from the holes of the tube. The whole device can be easily detached from the saw for carry.

V. Fabrication/Development Process

1. Materials

In our final design, we intend to use high temp plastics. These plastics are capable of withstanding the heat generated by the blade when cutting and remain lightweight as to not affect the user's ability to effectively employ the saw. The heat may be an important factor if the cooling device is improperly used or not used entirely; we do not want that to destroy the device. Velcro (hook and loop fasteners) will likely be used to attach the device to the saw because it is very adjustable and can be used to accommodate many different saw models.

2. Fabrication Methods

While we do not have a final design yet as to show any possible fabrication issues, we will likely utilize 3d printing. Epox is the probable option for mating separate components.

VI. Conclusion

The main problem the client presented to us is that cast saws have the potential to burn patients who are having a cast removed. After thorough research, it was determined that there are various cast saw cooling methods. Many methods involved using different mediums to reduce the temperature of the blade. Through testing, misting with water proved to be the most effective at reducing the temperature. However, the water can become quite messy quite easily, so a vacuum was added to the potential design so that water does not spray all over the patient.

For the future, the team decided to install a combination of the three designs and hopefully to do more testing on the cold tubing because it would create less dust. Moreover, after proposing the final design, the team should consider the weight and convenience of the design as the saw itself is pretty heavy. What is more, the team should find material that could mimic skin's thermal properties for testing.

VII. References

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VIII. Appendix

1. PDS

Function:

In Orthopedics, casts are applied to patients all the time. During the removal of the cast, an oscillating cast saw is used to cut through the plaster or fiberglass material. As the saw is cutting through the material it generates heat so the blade can often get quite hot. This may result in the burning and blistering of patients at times. Burning a patient during the removal of a cast should be a "never event" but unfortunately due to the amount of friction generated by the saw against the fiberglass or plaster, this occurs.

Client requirements:

- A saw blade/cooling device that eliminates the possibility of cast saw burns for the patient

Design requirements:

1. Physical and Operational Characteristics
    - **a.** Performance requirements: The cooling device should keep the saw blade at a safe temperature, no higher than approximately 44°C when using a prescribed technique.
    - b. Safety: Cast saw should be unplugged from electrical outlet when not in use. Keep the saw blade away from the power supply cord to avoid damaging the cord. Unplug power cord before blade removal [H].
    - c. Accuracy and Reliability: The device must reliably cool the saw 5 degrees Celcuis under the temperature needed to develop 2nd degree burns (43C). If a temperature measurement is taken, the temperature measured should be within 5% of the actual temperature on the blade or skin.
    - d. Life in Service: The life in service will depend on whether the device can be useable and how many times it could be used. Because the design is implanted into the medical device, it should be replaced after using several times to prevent contamination.Polyethylene may be used in our device.
    - e. Shelf Life: The design will be exposed to ambient clinical conditions. For the majority of locations, the temperature during storage will be near room temperature and within a humidity controlled hospital, however the device should ideally be able to withstand a range of conditions so that its use isn't limited to indoor clinical settings. As the design will likely be stored with the cast saw, it should at least last as long as the average cast saw (at least 5 years without use)
    - f. Operating Environment: The design will be exposed to ambient clinical conditions. For the majority of locations, the temperature during storage will be near room temperature and within a humidity controlled hospital, however the device should ideally be able to withstand a range of conditions so that its use isn't limited to indoor clinical settings. As the design will likely be stored with the cast saw, it should at least last as long as the average cast saw (at least 5 years without use)
    - g. Ergonomics: The cast saw should be able to be comfortably held in one hand and cooling system should not impede cutting ability. The entire assembly should be no more than 6.5lbs.
    - h. Size: We would want the device to be small enough to attach itself to the head of the cast saw and be light enough that it does not add much weight to the saw already. The device should be portable as the cast saws themselves are portable and we would not want to confine or restrict the location of the saw due to the cooling device.
    - i. Weight: The cooling device should be no more than 5 lbs to keep the additional weight from the device on the saw to a minimum.
    - j. Materials: We should aim to use solutions that would not cause shorter lifespan of the metal blades i.e. would not rust the saw blade. Materials that may melt or emit toxic fumes below temperatures of 215 degrees should not be used.
    - k. Aesthetics, Appearance, and Finish: Most cast saws have blue or white cases so creating a device with a blue or white finish would be ideal to have it match the finish

of the manufactured saws. Having a texture similar to the plastic finish of the saw cases would be best as it would be smooth and not pose any harm to potential small cuts to operators.

2. **Production Characteristics**
    a. Quantity: Currently, looking to provide one model but eventually would want to supply all of the UW Hospital and other hospitals in the United States
    b. Target Product Cost: approximately around 100

3. **Miscellaneous**
    a. Standards and Specifications: At this time, the device will be used only as a prototype for more advanced modifications. However, if the device is going to put into market, FDA approval may be needed.
    b. Patient-related concerns: The device should not cause any discomfort to the patient and will not cause secondary injury under appropriate use. The device needs to be sterilized as the saw may cut skin. There is no storage of patient data incorporated in this device. Ideally the device will not increase patient anxiety during cast removal. This may entail keeping additional noise, dust, or equipment bulkiness to a minimum.
    c. Competition: Currently, no competing designs. However, there are some designs that may be applicable to the device.

1. Cooling system for rotary blade used in sawing of concrete (patent:WO2000023234A1)[I]. The cooling (water) medium is led to into the gap between the blade body and the cover then water is being removed by inlet pipes. Through the design, a large quantity of water is not required and water is able to carry away some of the sawing waste.

2. Patent for vacuumized surgical cast saw cutter (US3103069A)[J]: According to Boardman and Bharathan (2018) ,the inbuilt vacuum dust extraction system reduced the temperature of cast material being split[K]. Therefore, designing an efficient vacuum system may decrease burning effect. The new vacuum design aims to remove sawing dust during operation, but it can still be used as to decrease saw temperature. This design allows air flow passes directly from the cutting region, along the power motor shaft axis and ultimately to a collection bag or receptacle adjacent the motor end of the tool.

2. Materials List

Material Name	Part Number	Place Purchased	Cost ($)	Quantity
Cast Saw	N/A	Received from client	0	1
Plaster	N/A	Received from client	0	10