Ring Removal Methods on Fingers with Edema

BME 400

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ABSTRACT

If swelling on a digit is allowed to persist with a ring on the finger, blood flow can be constricted and possible nerve damage can lead to necrosis in the finger, requiring amputation of the digit. Trauma surgeons face the challenge of removing rings made of hard metals, such as Tungsten Carbide and Titanium, from injured fingers with edemas. Blade ring cutters can cut soft metals such as gold and silver but tungsten carbide is too strong. Current methods of ring removal, such as string wrapping and finger lubrication for hard metal rings are time consuming, manual and an existing device called 'The Ring Cracker', used to break tungsten carbide rings, are unsafe for patients and physicians because it allows metal shards produced from breaking the ring, to fly upto 70 cm. [2] To combat these issues with the current methods, three possible designs have been explored. The first design is an automatic string wrapper, that would use a motorized device to loop the string around a finger automatically. The second design is an automated ring cracker, that would be similar to the existing ring cracker but it would include a protection system to contain shards and it would be automated to increase efficiency of use. The third design idea is an iced lubricant that would reduce swelling to allow the ring to slide off the finger. The idea that the team has chosen to pursue is the automated ring cracker as it is an effective method for injured fingers with high swelling and is the most efficient and safe solution.

1. INTRODUCTION

1.1 Motivation

Emergency physicians face the need to remove rings from swollen fingers. Patients may present with an initial primary complaint that they cannot remove a ring using intact methods, such as ice packs or elevating the finger to induce blood circulation, or that the ring has become painful. A variety of conditions may require the urgent removal of a ring, including swelling from extremity trauma and infections. Swelling of the digit can rapidly progress, causing the ring to become a constricting band and compromise blood flow to the digit. [1] Nondestructive removal of the ring is always preferred, as the ring may be of great sentimental value to the patient. However, this is not always possible if the swelling is severe. It may be necessary to cut through the ring. In such cases, tungsten carbide rings present a special problem, as they are extremely hard to cut through.[2] When removing tungsten carbide rings, the goal of emergency physicians is to remove the ring in a timely manner and not cause additional injury.

1.2 Existing devices & Current Methods

a. Power Ring Cutting Kit for Titanium [3]

This ring cutting kit for titanium contains a diamond coated disc that will cut through titanium in less than five minutes without heat or discomfort. The process involves sliding the lower jaw of the cutter between the ring and the finger and the circular saw is turned by the cordless power driver to cut through the ring.

Figure 1.Battery Powered Titanium Cutting Tool [3]

b. The Gem Ring Cutter Emergency Ring Removal System [4]

The Gem ring cutter works on its unique cutting discs to abrade successive layers of material until a cut is made. It requires only light pressure for best results, and the handpiece is passed back and forth across the constriction allowing the slowly-turning abrasive disc to make cuts through soft and hard metals. The Gem ring cutter is available in both AC corded and battery-powered cordless models. A carbide disc is included for softer metals, and the diamond disc is included for harder metals like Titanium, Chromium Cobalt, and Tungsten Carbide ceramics. The Gem ring cutter also includes one finger guard.

Figure 2. The Gem Ring Cutting System [4]

c. Tungsten Carbide Ring Cracker

It is used for very hard and resistant materials, like tungsten carbide ceramics. A ring cracker typically makes use of a sharp, hardened point that is slowly tightened against the ring until enough pressure is applied to safely crack the material.

Figure 3. Ring Cracker for tungsten carbide rings [4]

1.3 Problem Statement

Current methods of removing rings made of hard metals, such as Tungsten Carbide, from injured digits when edemas prevent them from being removed, are manual and can be dangerous to both patients and physicians. The existing devices, blade ring cutters for gold and silver or the ring cracker for titanium rings, have safety concerns due to metal pieces flying up when they are operated. The goal is to find safer ring removal methods that can protect both the physicians and the patients and can remove rings in a timely manner.

2. BACKGROUND

2.1 Common causes of edema

The most common reason for finger swelling at emergency rooms would be edema, also known as fluid retention. Edemas occur when body fluids gather at joints and surrounding tissues. [5] They can occur locally, often affecting the extremities or the entire body. In the body, there are two main compartments between which fluid is exchanged: the intravascular and extravascular compartments. Intravascular compartments include the cardiac chambers and the vascular system, and extravascular compartments include the rest of the body. [6] Normally, fluid can move easily between these compartments, and these movements are balanced between hydrostatic and oncotic pressure. When balanced, about 1% of the plasma filters into the extravascular compartment, and the lymphatic system will transport the extra fluid back through the thoracic duct. Upper limb injury or infection can cause swelling or dependent edema in fingers and this may be further complicated by the presence of a ring. [7] Patients often appear at emergency rooms whereby these rings can be removed.

2.2 Tungsten carbide mechanical properties

Tungsten carbide is a material with very high strength, unusual hardness and rigidity. Its compressive strength is higher than mostly all melted, cast or forged metals and alloys. Tungsten carbide is two to three times as rigid as steel and four to six times as rigid as cast iron and brass. In addition, its Young’s Modulus is up to 94,800,000 psi.[8] Additionally, its high resistance to deformation and deflection is very valuable in instances where a combination of minimum deflection and good ultimate strength is desired, such as rings, spindles for precision grinding, and rolls for strip or sheet metal. Tungsten-base carbides perform well up to about 1000°F in oxidizing atmospheres and up to 1500°F in non-oxidizing atmospheres.[8] Tungsten carbide can retain toughness and impact strength in the cryogenic temperature ranges around -453°F.

2.3 Client Information [9]

Our client, Dr. Christopher Green, is a pediatrician at the University of Wisconsin Hospitals, who specializes in pediatric pulmonology. He graduated from the University of Rochester School of Medicine and Dentistry and completed his residency at the University of Wisconsin. He has been in practice for over 20 years, and has treated many children with lungs and respiratory system ailments.

2.4 Product Design Specification Summary

The client specified that the ring removal device should be able to break tungsten carbide rings, which have a breaking point of 1100 MPa, and titanium rings, which have a breaking point of 600 MPa. The budget specified by the client is $500. The ring removal procedure should be accelerated, allowing the removal to be performed between 1-2 minutes. An important requirement for the device is that it should include a complete protection system to prevent metal shards of the broken ring from being thrown over 5 cm, considering that current devices don't protect patients from flying metal shards. Minimal patient discomfort and finger manipulation should be the main considerations for the design to increase safety. Refer to Appendix 1 for the complete Product Design Specifications.

3. PRELIMINARY DESIGNS

3.1 Automatic String Wrapper

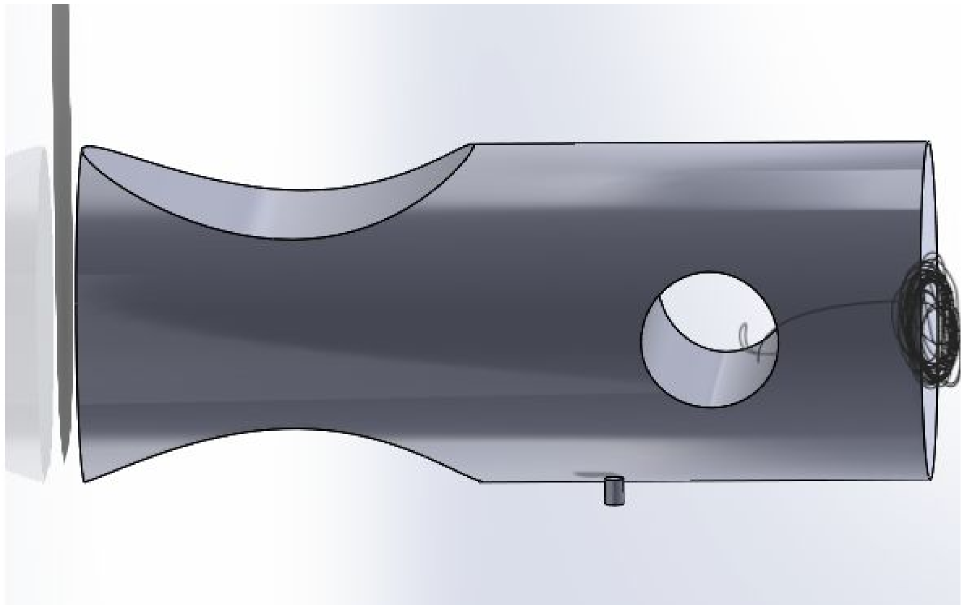


Figure 4. Solidworks Design for the Automatic String Wrapper

The first design developed by the team is the Automatic String Wrapper. This design is based off the string method used to remove rings. In the current method, one end of a string is inserted through the ring, looped around the finger above the ring and then unlooped using the end of the string under the ring. The automatic string wrapper is an improvement on the current method by making the string wrapping automatic. One end of string from a spool would wrap around a hollow motorized worm gear device, with the finger inserted in one end, and go through a small hole hole at the other end of the device, to be attached to the ring. When main button is clicked, the motorized device will rotate and loop the string around the finger. Once the looping is done, another button is clicked to reverse the movement of the motorized device and unloop the string automatically, moving the ring up the finger.

An advantage of this design is that the ring will not be damaged. This is one of the main concerns that patients have is that the rings have sentimental value and they want to keep them intact. Another advantage is the automation of the wrapping gets rid of manual string wrapping. This reduces the time taken for the ring removal procedure. Lastly, the design works for rings made of all metals which reduces the need for multiple devices for different types of rings based on metal strength.

A disadvantage of this design is that it is ineffective if there is a large amount of swelling and injury on the finger. In these cases, the ring cannot slide up the finger. Another disadvantage of this design is that the fabrication of the automation would be a challenge. A small motor would need to be obtained to keep the device small and efficient to use, and it would need to be inserted in a manner that it isn't visible and won't interfere with the finger.

3.2 Automated Ring Craker Protection System

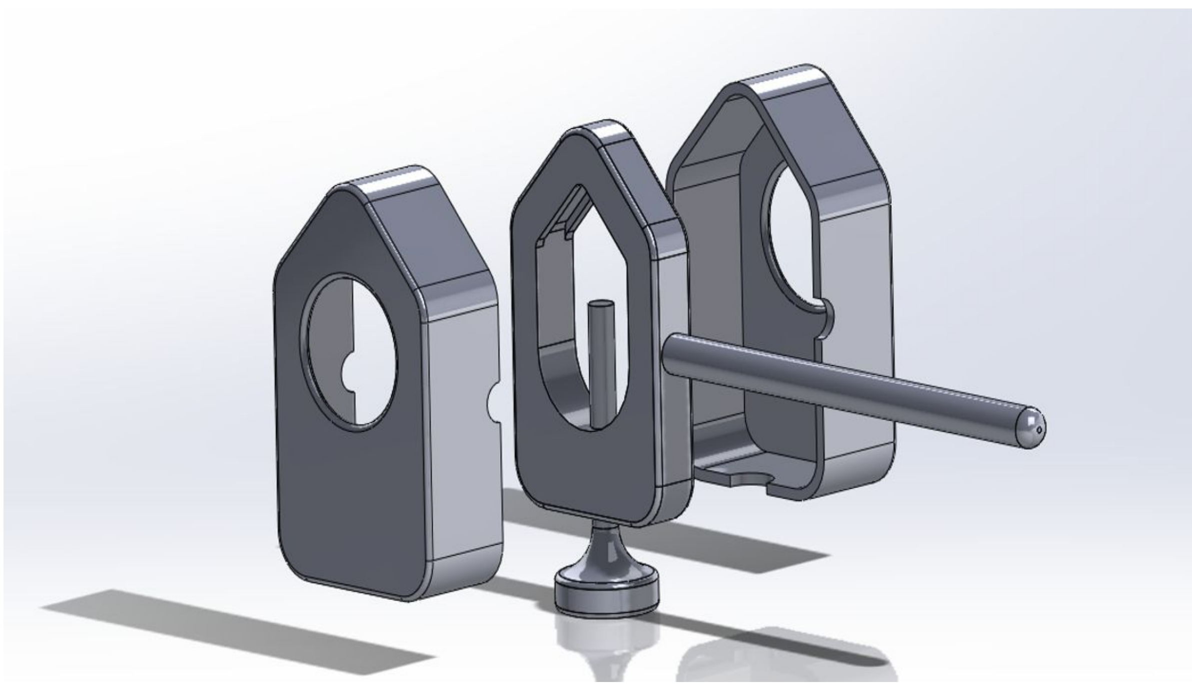


Figure 5. Solidworks Design of Ring cracker protection

The second design the team developed is the automated ring cracker protection system. This design is based off of a current existing device that is used for rings made of titanium or tungsten carbide. The main improvements from the current device are the two halves of protecting shields added on both sides of the ring cracker. It also has two holes on either sides for the swollen finger to go through. The protecting shield will be made using 3D printing with a rubber material and it will attached on the main cracker by purchased hinges. The bottom of the current device will be made into a screw head that could be fit into an automated screwdriver, providing the needed rotation. These modifications will not only protect patients and physicians from the flying pieces when the rings are cracked, but will also automate the process which could lessen manual mistakes and procedure time.

An advantage of this design is the protection shield, since the biggest problem with the current device is the flying pieces from the cracked ring. Furthermore, the addition of the protecting shield will not increase the total device's weight and size significantly, increasing the overall adaptation of the device. Also the ring cracker could apply to all materials, so physicians won't have to switch tools for rings made from different materials. With the help of an automated twisting handle and a matched bottom of the screw, the removal process will be automatic thus lessening the manual force required from the physicians as well as the duration of the procedure.

However, there are also some disadvantages with this design. Firstly, the team will have to decide whether the automated twisting handle is to be purchased directly from the manufacturer to fabricate the bottom of the cracker to match the handle, or the motor handle will be manufactured by the team. The manufacturing process will take a lot of effort since it will require a lot of components for motors and instrumentation. Additionally, the size of the holes on the protecting shields are not adjustable, so if the patients' fingers are too swollen to fit in, then the device can not be utilized, and t if the holes are too big, there is a chance that the flying pieces will get out the protecting shields through the hole.

3.3 Iced Finger Shrinking Lubricant

Figure 6. The potential container of the iced finger shrinking lubricant.

This design is an improvement of current existing skin lubricants by applying a thermal contraction mechanism. Changes in temperature, alter the physical properties of substances which lead to the shrinkage of blood vessels in fingers [10]. In addition, cold temperatures help reduce the sensation of pain. [10] The major functions of this design are the ability to smooth the surface between the patient's finger and ring, to shrink the finger in size which leads to easier removal of the ring, and to reduce the pain on the finger during removal process. The usage of this method is simple, so doctors will not need to learn special skills or apply considerable forces compared to other methods. Instead, the doctors will apply the lubricant to patients' swollen fingers in the same manner used for regular lubricants.

Patients are able to obtain many benefits from this design. The first benefit would be that the iced finger shrinking lubricant can rescue patients' sentimental and expensive rings because it will not damage the ring. Additionally, this method does not cause as much pain to the patients as the ones requiring compression of the fingers. Furthermore, this method benefits doctors too because it does not require extra knowledge or unique skills to perform.

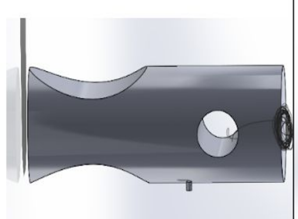
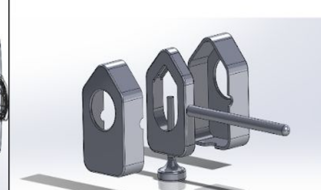
However, there are a few problems with this method. In some situations, the patients may have injured fingers with lacerations, which are sensitive and fragile. The application of the iced finger shrinking lubricant can lead to infection and future damage of the fingers. This can result in patients losing their fingers because thermal contraction of blood vessels in fingers will lead to lack of blood flow. In addition to the risks of ending blood flow, thermal contraction also has limits on how much the finger can shrink. As a result, this method may not work effectively enough for situations where patients have extremely swollen fingers.

4. PRELIMINARY DESIGN EVALUATION

4.1 Design Matrix

The preliminary design matrix, shown in Table 1, includes three possible designs. Each design was scored out of 100 with the use of weighted design criteria, ordered from the most important to the least important.

Table 1. The design matrix with categories on the left, their weights in parentheses, and each design labeled in the first row. The pink cells represent the designs that won in each category and the red cell represents the design that won overall.

	Automated string wrapping		Ring cracker protection		Finger Shrinking Lubricant	
						
Chemical Stability & Safety (25)	4/5	20	5/5	25	4/5	20
Patient Comfort (20)	3/5	12	3/5	12	5/5	20
Effectiveness (15)	3/5	9	5/5	15	2/5	6
Ease of Fabrication (15)	3/5	9	3/5	9	2/5	6
Patient Ease of Mind (10)	4/5	8	3/5	6	5/5	10
Ease of Operation (10)	5/5	10	4/5	8	5/5	10
Cost (5)	4/5	4	3/5	3	3/5	**3**
Total (100)	**72**		**78**		**75**	

1. Chemical Stability and Safety: The ring cracker protection design has the highest score since it is the only device that has a complete protection system. The cover over the ring cracker will protect both the patient and the physician from flying metal pieces. Additionally, the ring cracker is made of stainless steel glass, which is chemically stable.
2. Patient Comfort: The Iced lubricant received the highest score in this criteria since the patient will not experience any discomfort, and the cold sensation that the lubricant will cause can help patients with pain from swelling.
3. Effectiveness: The ring cracker protection design also received the highest score since it has a nearly 100% success rate of removing a ring from a swollen finger. Unlike the string wrapping and lubricant methods, the ring cracker is effective even when fingers have severe injuries or open wounds.
4. Ease of fabrication: Both the automated string wrapping and the automated ring cracker protection designs received the highest score in this criteria. Both designs will use 3D printing for fabrication. However, for the iced finger lubricant, a new chemical formula is needed to both cool the finger and act as a lubricant, which is hard to fabricate.
5. Patient Ease of Mind: The iced finger shrinking lubricant method received the highest score. Patients are more likely to accept putting a lubricant on their swollen fingers than using an automated machine.
6. Ease of Operation: Both the automated string wrapping design and the iced finger shrinking lubricant methods received the highest score in this criteria. Both designs are refined from current intact methods to remove rings, and do not require any force to be applied on the rings.
7. Cost: The automated string wrapping method earned the highest score of this category because it only involves 3D printing the wrapping device and drilling the insertion hole to add a motor. It does not require expensive titanium that will be used for the ring cracker design. The device can also be used for years.

4.2 Proposed Final Design

The proposed final design is the automated ring cracker protection because it fulfills the client's expectation of protecting physician and patient safety while being applicable to harder metals, including tungsten carbide. The automated ring cracker's protecting shield will be printed using thermoplastic elastomers (TPEs), which simulate rubber's elasticity and hardness property. Our design could improve the quality and efficiency of the ring removal procedure with the automation modification.

5. FABRICATION/DEVELOPMENT PROCESS

5.1 Materials

Materials were chosen based on their compatibility with tungsten carbide mechanical properties, such as maximum stress and elasticity, so that the broken pieces from the ring won't go through the protection shields. Thermoplastic elastomers, which are 3D-printable, will be used to manufacture the protection cover on both sides of the automated ring cracker design. The other parts, including the tungsten carbide ring cracker and hinges, used to combine the cracker body and the shields, will be directly purchased from the manufacturer. In order to maintain the mechanical stiffness of the ring cracker device, the hinges must be made from titanium.

5.2 Methods

3D printers will be the team's main resource to fabricate the ring cracker protection box at the TEAM lab. The protection device will first be designed using SolidWorks and software packages such as Cura [11] will be used to refine the details of the design. The hinges will be soldered directly on both sides of the protection box.

5.3 Testing

Ideally, testing procedures will be performed on tungsten carbide rings on a simulated swollen finger model. Multiple trials will be performed to ensure the stability of the device. Statistical analysis will be performed using Rstudio or MatLab to evaluate the device's effectiveness in breaking the tungsten carbide ring while protecting the patient and physician from flying metal pieces.

6. REFERENCES

[1] “Chapter 101. Ring Removal,” Chapter 101. Ring Removal | Emergency Medicine Procedures, 2e | AccessEmergency Medicine | McGraw-Hill Medical. [Online]. Available: https://accessemergencymedicine.mhmedical.com/content.aspx?bookid=683&Sectionid=45343743. [Accessed: 08-Oct-2019].

[2] Moser, Alexandre, Exadaktylos, Aristomenis, Radke, and Alexander, “Removal of a Tungsten Carbide Ring from the Finger of a Pregnant Patient: A Case Report Involving 2 Emergency Departments and the Internet,” Case Reports in Emergency Medicine, 06-Mar-2016. [Online]. Available: https://www.hindawi.com/journals/criem/2016/8164524. [Accessed: 08-Oct-2019].

[3] C. L. Gardiner, K. Handyside, J. Mazzillo, M. J. Hill, E. F. Reichman, Y. Chathampally, and B. R. King, “A comparison of two techniques for tungsten carbide ring removal,” The American Journal of Emergency Medicine, vol. 31, no. 10, pp. 1516–1519, 2013.[Accessed: 10-Sep-2019].

[4] “Can Titanium or Tungsten Carbide ring be cut off?,” Titanium Ring Cut Off | Tungsten Rings Emergency Removal. [Online]. Available: https://www.titaniumstyle.com/titanium-tungsten-ring-cut-off.htm. [Accessed: 08-Sep-2019].

[5] “Edema,” Mayo Clinic, 26-Oct-2017. [Online]. Available: https://www.mayoclinic.org/diseases-conditions/edema/symptoms-causes/syc-20366493. [Accessed: 08-Oct-2019].

[6] “Edema,” WoundSource, 30-Jul-2019. [Online]. Available: https://www.woundsource.com/patientcondition/edema. [Accessed: 08-Oct-2019].

[7] A. Kumar, H. Edwards, S. Lidder, and P. Mestha, “Dangers of neglect: partially embedded ring upon a finger,” BMJ case reports, 09-May-2013. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3669852/. [Accessed: 08-Oct-2019].

[8]“Carbide Processors, Woodworking Tools,” Tungsten Carbide Properties. [Online]. Available: http://www.carbideprocessors.com/pages/carbide-parts/tungsten-carbide-properties.html. [Accessed: 10-Sep-2019].

[9] Philadelphia Carbide Company: Precision manufacturer of tungsten carbide, ceramic, silicon carbide wear parts, machine parts & dies, ceramic and carbide grinding to .0001", the tightest

tolerances in the industry, and polishing to 1 RMS. [Online]. Available: https://www.philacarbide.com/Properties.php. [Accessed: 08-Oct-2019].

[10] U.S. News & World Report. [Online]. Available: https://health.usnews.com/doctors/christopher-green-2376. [Accessed: 08-Oct-2019].

[11] C. Sissons, “What are the causes of swollen hands?,” *Medical News Today*. [Online]. Available: https://www.medicalnewstoday.com/articles/325207.php. [Accessed: 14-Sep-2019].

[12] “Ultimaker Cura 4.2: First choice for 3D printing professionals worldwide,” ultimaker.com. [Online]. Available: https://ultimaker.com/learn/ultimaker-cura-4-2-first-choice-for-3d-printing-professionals-worldwide. [Accessed: 08-Oct-2019].

7. APPENDIX

Appendix 1: Project Design Specifications

The Ring Cutter Design for Emergency Department

Project Design Specifications

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Date: September 20th, 2019

Function: Emergency physicians commonly face the challenge of removing a metal ring from an injured digit when an edema prevents it from being removed. [1] Under such circumstances, a ring cutting tool must be used to remove the ring from the finger. The most commonly used ring cutters are made of steel and are either manually operated or battery powered. These devices work well on rings made of gold or silver but physicians often have a difficult time removing modern rings made of hard metals such as titanium and tungsten carbide. The goal is to design an automated device that could potentially remove rings made of tungsten carbide and contain a protection system for patient safety.

Client Requirements:

- The device should have a complete protection system that prevents metal shards from being thrown in the air.
- It should be easily able to be efficiently utilized by the physicians during emergency situations and the removal procedure should be done faster.
- All ages of patients should be included for this design.
- The device must be able to break Tungsten Carbide and Titanium rings.
- The device should not exceed the size of the current devices, around 25cm in length.
- Minimal finger manipulation, patients discomfort and jewelry damage.
- The cost of the device must be under $500.

Design Requirements:

1. Performance Requirements: The device should be able to be utilized by the physicians in the ER to remove rings made of hard metals, such as titanium and tungsten carbide. The

procedure should be done between 1-2 minutes. The device should be able to break tungsten carbide rings, which have a fracture point of 1100 MPa, and titanium rings, which have a breaking point of 600 MPa, while not hurting the patient's already injured digits during the removal process.

2. Safety: The device must meet the general safety standard for medical devices and try to minimize discomfort for patients. Broken ring components must not be thrown above 5 cm in height. The materials used for the device must be sterile, and mechanically as well as chemically stable, such that additional harm to the patient is avoided.

3. Accuracy and Reliability: The device must be able to estimate the thickness of the ring and the gap between the ring and the finger. The cutting blade in the device should be able to meet the same standard after each use and be able to cut through hard metals such as titanium and tungsten carbide.

4. Life in Service: The desired ring cutting device should be able to last for years and the cutting blade should not be easily burned off.

5. Shelf-Life: 5-10 years

6. Operating Environment: The device should be operated under a general physician in the emergency department after simple training and it should be kept under dry environment to avoid rust formation.

7. Ergonomics: Our device will aim to keep the force required by the physician to the minimum. It's also crucial that the device is lightweight and easily secured to ensure stability and avoid injury during use.

8. Size: The relative size of the device should be small in order to be operated by a single physician, estimated at 20 x 8 cm.

9. Weight: The relative weight of the device should be light enough so that it does not require more than one person to operate (device weight: < 5 kgs).

10. Materials: The body of the device should be made from plastic to minimize excess weight usage and cost. 3D printing can be used to make plastic components of the device since it is relatively cheap. The cutting blade will be made from a metal stronger than titanium. All materials of the device should be sterilized before use.

11. Aesthetics
    a. The design shape should allow the operator to use the device efficiently and have a comfortable grip during the ring cutting process

Production Characteristics:

1. Quantity: Our client has requested for one piece of the device, however, in the future there is potential for mass production of the device after successful testing. Following this, the quantity of the products might be increased.

2. Target Product Cost: Our targeted budget will be limited to 500 dollars, which is also subject to change depending on the metal choice of the device. The current competing designs cost around 200-500 dollars.

Standards and Consumer Characteristics:

1. Standards and Specifications: The device specifications will have to comply with the FDA's Federal Register, as well as the Code of Federal Regulations. The FDA also requires a number of approvals and clearances to ensure that a device is safe and effective before used on patients in hospitals. These include a 510(k) Premarketing Submission and Premarket Approval (PMA).
2. Customer: The product will be operated by trained mechanical professionals. The product should be usable on a wide range of ring users who have difficulty removing rings.

3. Patient or User-related Concerns: The device should have safety guard to avoid cutting patient's body. There is little room for error during the cutting procedure which makes it even more important that the design is safe and effective so it does not cause discomfort to patients or bring pain to the patients, and make the procedure duration longer than needed.

4. Competition
    a. Power Ring Cutting Kit for Titanium [1]
        i. This ring cutting kit for titanium contains a diamond coated disc that will cut through the titanium in less than five minutes without heat or discomfort. The process involves sliding the lower jaw of the cutter between the ring and the finger and the circular saw is turned on by the cordless power driver to cut through the ring.
    b. The Gem Ring Cutter Emergency Ring Removal System [2]
        i. The Gem ring cutter relies on its unique cutting discs to abrade successive layers of material until a cut is made. It requires only light pressure for best results, and the handpiece is passed back and forth across the

constriction allowing the slowly-turning abrasive disc to make cuts through soft and hard metals. The Gem ring cutter is available in both AC corded and battery-powered cordless models. A carbide disc is included for softer metals, and the diamond disc is included for harder metals like Titanium, Chromium Cobalt, and Tungsten Carbide ceramics. The Gem ring cutter also includes one finger guard.

c. Ring Cracker [2]
   i. It is used for very hard and resistant materials, like tungsten carbide ceramics. A ring cracker typically makes use of a sharp, hardened point that is slowly tightened against the ring until enough pressure is applied to safely crack the material.

References:

[1]C. L. Gardiner, K. Handyside, J. Mazzillo, M. J. Hill, E. F. Reichman, Y. Chathampally, and B. R. King, "A comparison of two techniques for tungsten carbide ring removal," The American Journal of Emergency Medicine, vol. 31, no. 10, pp. 1516–1519, 2013.[Accessed: 10-Sep-2019].

[2]"Can Titanium or Tungsten Carbide ring be cut off?," Titanium Ring Cut Off | Tungsten Rings Emergency Removal. [Online]. Available: https://www.titaniumstyle.com/titanium-tungsten-ring-cut-off.htm. [Accessed: 08-Sep-2019].

[3]"www.atlasprosales.com," Cast Saw, Cast Cutter, Cast Saw Blades, Cast Saw Repairs, Cast Saw Service, Cast Saw Sales. [Online]. Available: https://www.atlasprosales.com/Ring_Cutter_s/88.htm. [Accessed: 09-Sep-2019].