Tungsten Carbide Ring Removal Protection System

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Abstract

Tungsten carbide rings that are stuck on swollen fingers are difficult to break in the ER. [1] The current device used to remove tungsten carbide rings, The Ring Cracker, poses a danger of flying metal pieces and requires a lot of force. Dr. Christopher Green tasked us with modifying the existing ring cracker to increase patient and user safety. We designed a shield prototype to collect flying metal pieces on both sides. Rubber valves were added to prevent pieces from flying through the insertion points. We conducted material property testing, which showed a statistical significance in the difference between elastic resin and PLA energy absorption. We also conducted shield testing with multiple ring sizes to prove the functionality of our design, which showed that the pieces were contained.

Problem Statement

Tungsten carbide rings are difficult to remove off of patient fingers with edema in the ER. The current tungsten carbide ring removal device is manual and can be dangerous to both patients and physicians due to flying ring pieces when the ring is broken. The aim is to make the ring removal method safer, to protect both the physicians and the patients.

Figure 1. Tungsten carbide ring cracker

Background

- Edemas occur when fluid builds up in surrounding tissues.
- Prolonged edema on a finger, can constrict blood flow.
- Lack of blood flow can lead to necrosis, requiring amputation of the digit [2]
- 6 to 7 cases reported each year at UW Hospital for ring removal difficulty [3]
- Among those, 1-2 are Tungsten carbide rings.

Design Criteria

- Should be able to contain broken ring fragments
- The ring pieces should not bounce from the protection shield more than 0.5 cm
- Protection device should cover ring cracker 6.03 cm in height, 4.24 cm length and 1.27 cm in width
- Prevent metal shards from being thrown over 5 cm
- Minimal patient discomfort and finger manipulation
- The materials used for the device must be sterile, and mechanically as well as chemically stable
- Remain within the budget of $500

Material Properties

Polylactic Acid (PLA)

Tensile Strength	46.8 MPa
Flexural Strength	77.4 MPa
Tear Strength	76.7 kN/m
3D Printing Cost of Design	$2.77

Figure 2. Sample PLA print[4]

Elastic Resin

Tensile Strength	49.5 MPa
Flexural Strength	103 Mpa
Tear Strength	8.9kN/m
3D Printing Cost of Design	$19.8

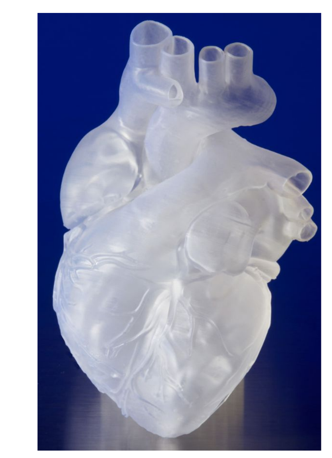

Figure 3. Sample Elastic Print [5]

Material Property Testing and Results

Material Energy Absorption Testing Procedure:

- A 3g tungsten carbide broken ring piece was placed at 25 cm and 50 cm height with a meter stick set up
- Five drops were performed on each material at each dropping height
- The total bounce back distance of the tungsten carbide ring piece was captured using a slow motion camera
- The loss of potential energy PE=Δmgh
- Maximum bounce back distance(Δh) inversely proportional to PE

Result

1. Testing analysis was performed using R studio
2. A ggplot was created with an average bounce back distance marked as red line of 3.45 cm
3. A one-way ANOVA was performed to compare PLA and Elastic material energy absorption, and a p value <0.001 was calculated

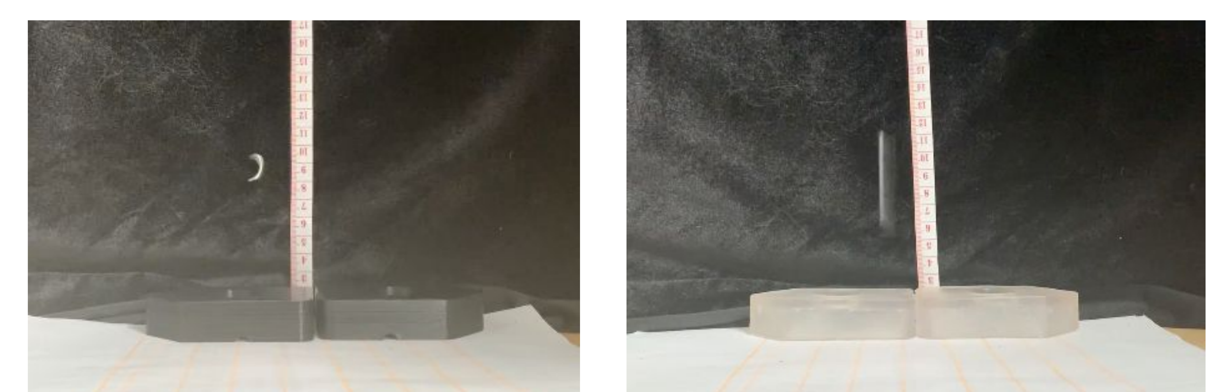

Figure 4&5. Material Testing set up. PLA tested on the left and Elastic tested on the right

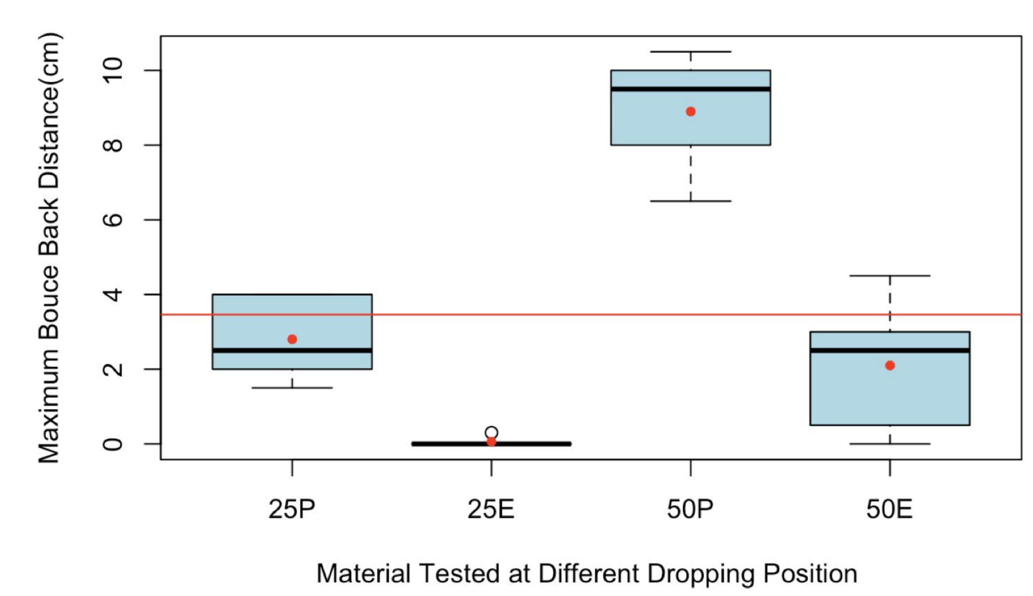

Figure 6. ggPlot for Material tested at various distances. Two at 25 cm and two at 50 cm. Elastic material shows an overall higher energy absorption due to smaller bounce back distance

Final Design and Testing

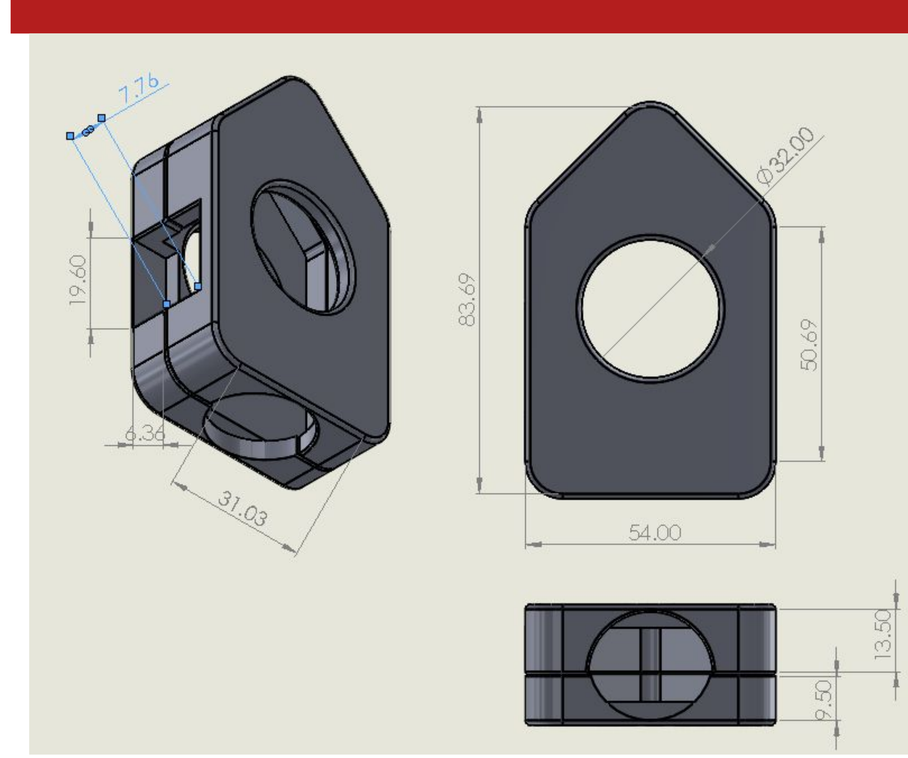

Figure 7. Final Design Solidworks Assembly

Testing Method:

- 3 tungsten carbide rings of sizes 7,9,11 were cracked with protection system
- If no flying metal pieces, then trial marked success
- Otherwise, trial marked fail

Result

- 100% Success rate for the four trials tested

Figure 8. Final Prototype Testing with carrots mimic human finger and rubber valves added on either side

Discussion

Testing Conclusion

- No metal pieces flying out with shield on the cracker
- The speed of flying piece is about 0.52m/s, which can be dangerous for humans closeby
- Statistical significance in material property testing
- Elastic resin material absorbs more energy compared to PLA
- Alterations included decreasing the thickness of protecting shield to reduce the amount of space the shields occupied.

Sources of Error

- Perpendicularity of measuring tape
- Bouncing back angle of the metal shards
- Human manipulation difference
- Small trial number

Future Work

- Decrease thickness for one side of the shield
- Automate the screwing process
- Artificial intelligence control system
- Metal shards capture system inside the shields
- Design aesthetic

Acknowledgements

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References

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

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

[3] Interview with UW-Hospital Emergency department Dr. Glazer,14-Oct-2019

[4]"Red MH Build Series PLA Filament - 1.75mm (1kg)," MatterHackers. [Online]. Available: https://www.matterhackers.com/store/3d-printer-filament/175mm-pla-filament-red-1-kg. [Accessed: 04-Dec-2019].

[5]"Introducing Elastic Resin: A Soft, Resilient 3D Printing Material," Formlabs. [Online]. Available: https://formlabs.com/blog/elastic-resin-soft-resilient-3d-printing/. [Accessed: 04-Dec-2019].