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Design and Preliminary Testing of a Multi-Use 3D-Printed Splint for Wilderness Medicine

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Design and preliminary testing of a multi-use 3D-printed splint for wilderness medicine

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Introduction

Wilderness medicine necessitates medical equipment to be both compact, as to reduce packing load, and effective, as the patient may be hours or even days away from hospital care. [1] Splints are a priority item for wilderness medicine practice; it has been reported that over 70% of nonfatal events were related to musculoskeletal or soft-tissue injury, which would include sprains and broken bones. [2] There is significant room for improvement in current splint medical devices for distal extremity injuries in wilderness medical practice that this design seeks to address.

Current splinting device options are to utilize splinting kits catered to a specific injury, such as a wrist or elbow. Although effective at fitting around the injury site, the impracticality of carrying multiple different splinting kits is a detriment to the compact travel of wilderness medicine. Next, are Structural Aluminum Malleable splints, or SAM splints, which seem to be the gold standard of emergency splints. Their padded aluminum surface can be rolled up, making for excellent portability. They are also multiuse, affordable, and reusable. [3] However, the same malleability that allows the splint to form around the injury site, leads to a lack of stability around the site, especially for long-term use, which might be necessary in a wilderness scenario.

Our design aims to be as lightweight, portable, multiuse, reusable, and accessible as the SAM splint, but as stable long-term as a traditional static splint. This is accomplished through 3D-printed thermoplastics. A thin, plate design constructed of polylactic acid (PLA) is lightweight and portable. PLA is also an ideal material choice, known for its mechanical strength, biocompatibility, and biodegradability. [4] In the case of injury, the plate should be warmed in a container of water, allowing the thermoplastic PLA to become sufficiently malleable, and wrapped around the injury in this malleable state, perfectly form fitting to the patient's body. The PLA quickly cools and returns to its strong, rigid form. The unique properties of PLA allow for a splint that improves upon both portability and structural support of current options. The 3D-printed nature additionally allows the design to be shared online and printed by anyone with access to a 3D-printer.

Design Methods

Design in OnShape

Design of the device was performed in OnShape, an online computer-aided design (CAD) software. [5] See *Figure 1* for a visual of the software in use.

Four iterations of our device were designed, with improvements made successively. The first design, Mk1, seen in *Figure 2,* was found to be unnecessarily thick, making the malleability around the extremity difficult, but still possible. To improve on this, Mk2 and Mk3 were developed, seen in *Figure 3* and *Figure 4*, respectively. These were significantly thinner than the first iteration. Although both now form-fit around the extremity much better, Mk3 had the best balance of malleability when heated, and structural stability when cooled. The final iteration, Mk4, seen in *Figure 5*, was the same thickness as Mk3, but added a ring of slots around the base, allowing for the use of wraps if the administrator desired.

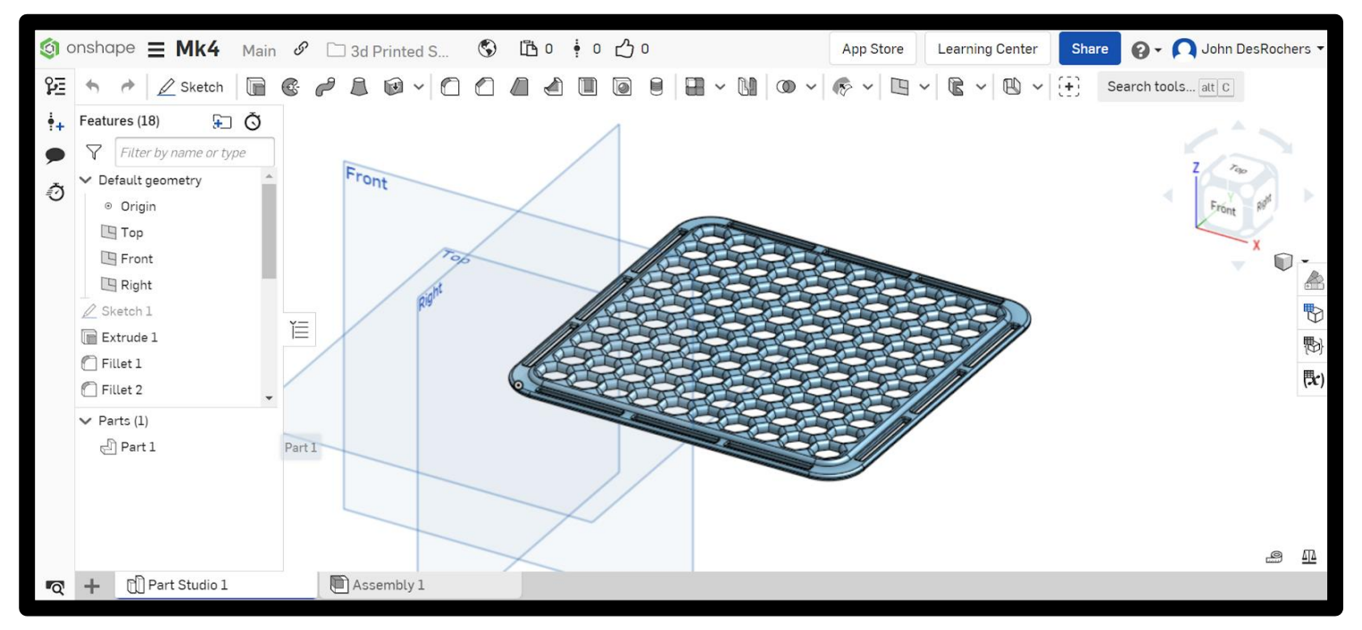
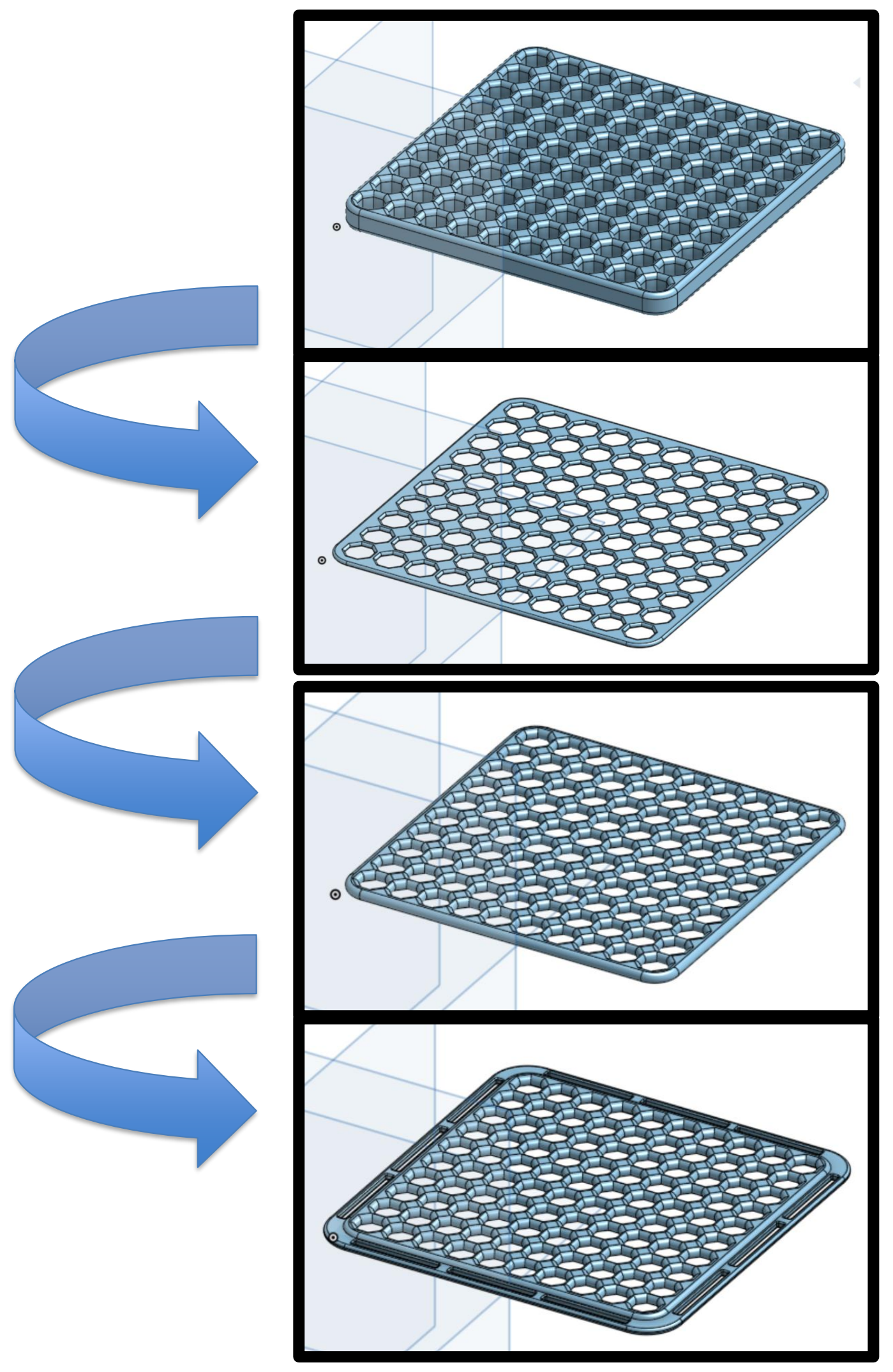


Figure 1:
OnShape CAD software in use;
design on display is the Mk4 iteration.



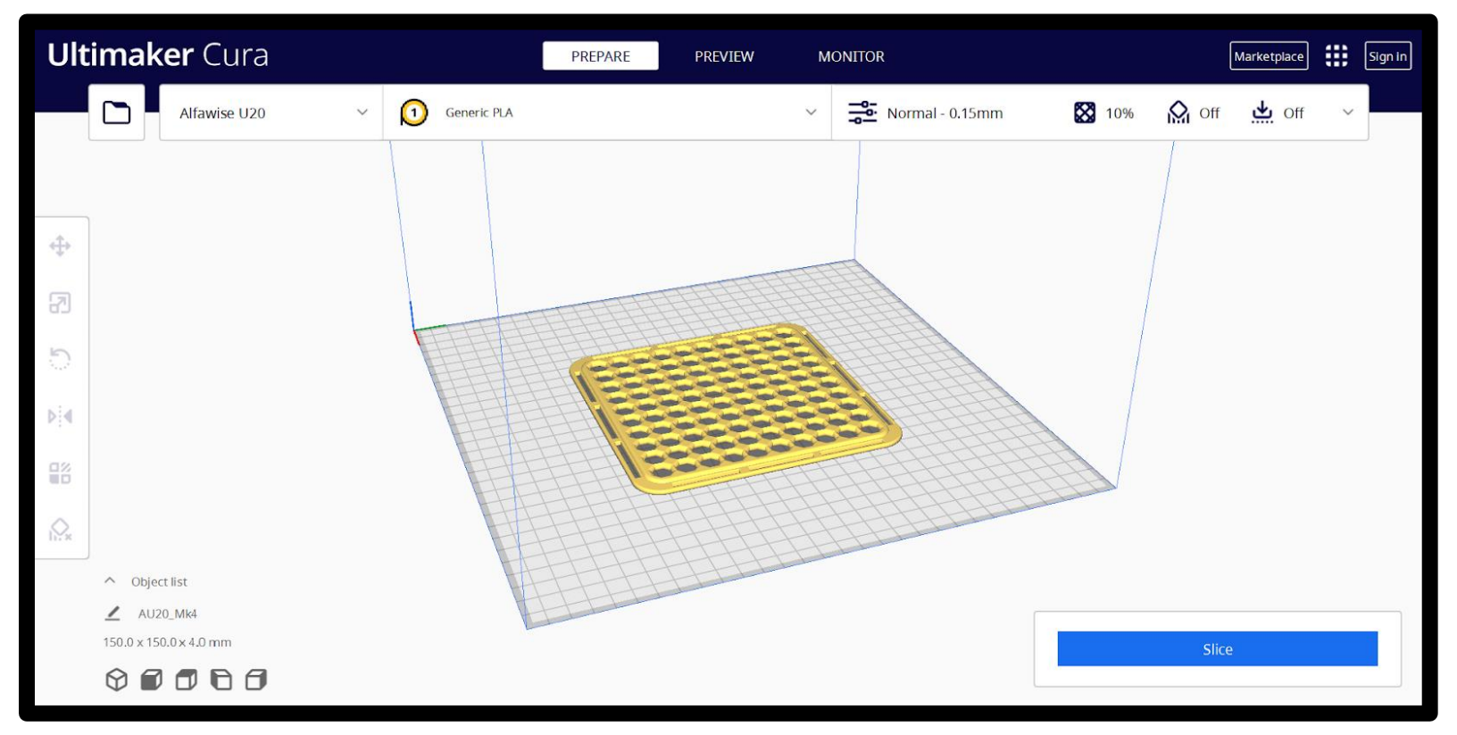
Figures 2,3,4,5:
Design iteration Mk1, Mk2, Mk3, and Mk4, top to bottom, respectively.

To print the designs, the part in OnShape is first exported as an '.stl' file to be sliced in another software package, Ultimaker Cura.

Slicing in Ultimaker Cura

Ultimaker Cura 5.2.1 was used to slice the '.stl' file, and prepare the part for printing. [6] See *Figure 6* and *Figure 7* for software footage of the preparation and preview, respectively, of the part being sliced. See *Table 1* for specifications of printer settings selected while using the software.

The '.stl' file is then exported to a '.gcode' file onto a micro-sd card and inserted into the printer.



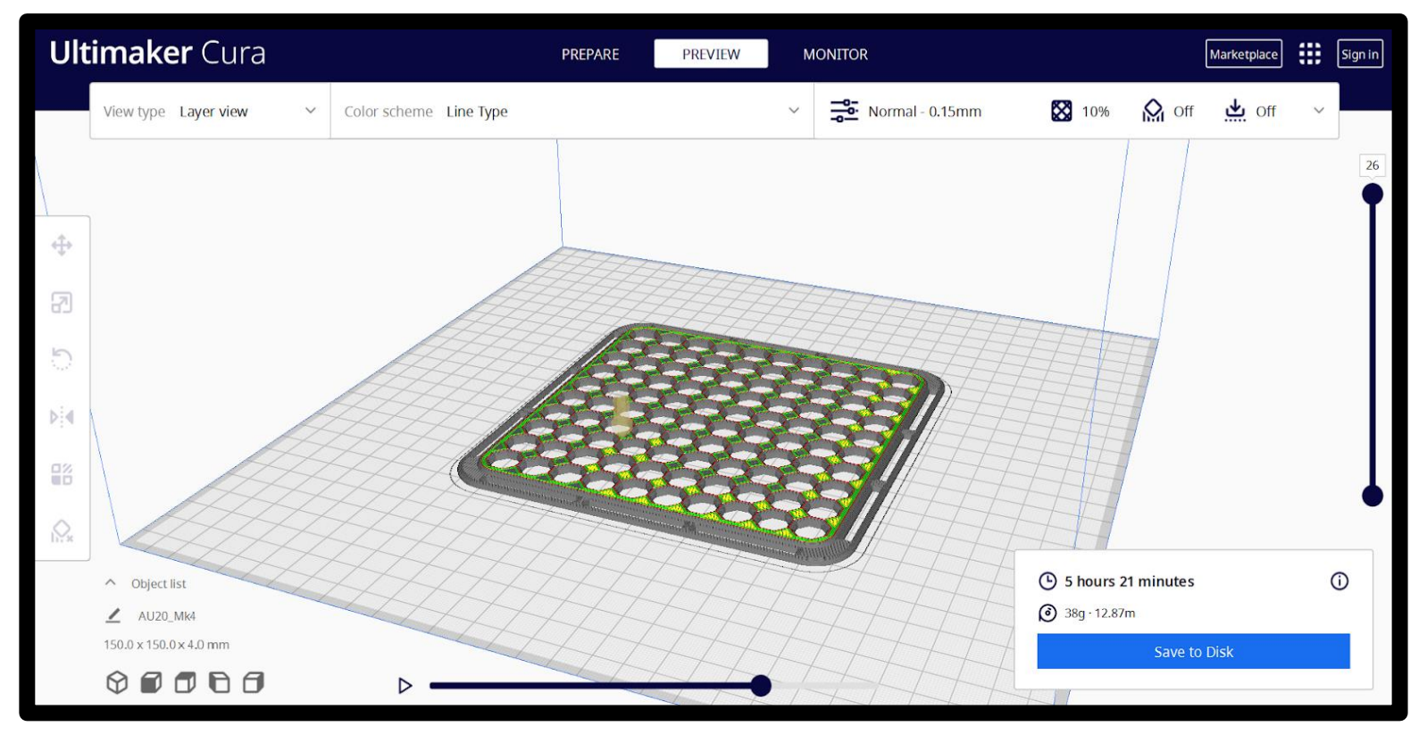


Figure 6: The Mk4 design part being prepared in Ultimaker Cura to be sliced. (Left)
Figure 7: The Mk4 design part being previewed in Ultimaker Cura before exporting the file to be printed. (Right)

3D-Printing

The designs are then printed on a 'Longer LK1' 3D-printer. [7]

Table 1: 3D-Printer Settings

Layer Height	0.15 mm
Infill	10% Grid Pattern
Wall Thickness	1.2 mm
Support	NONE
Adhesion	NONE
Nozzle Temperature	200° F
Bed Temperature	60° F
Print Speed	40 mm/s
Fan Speed	100%

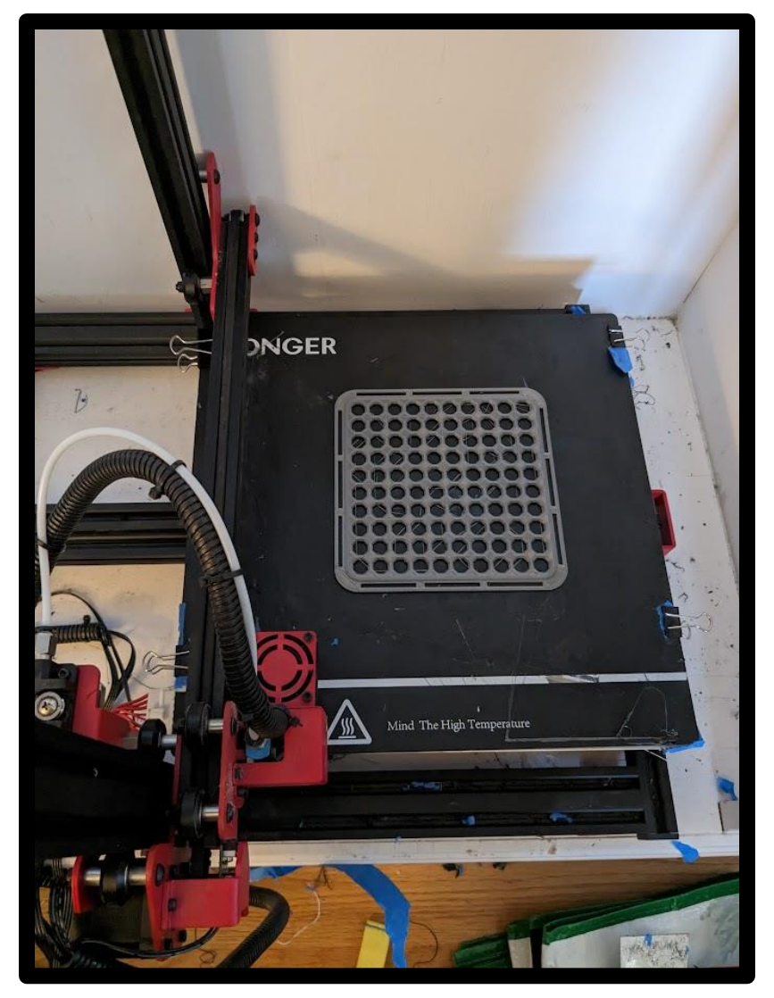


Figure 8: Mk4 design on 3D-printer bed upon print completion.

Device Testing

Instructions for Use

1) Place splint into hot water for approximately 15 seconds or until flexible. See *Figure 9.*
2) Cover area to be splinted with clothing, rag, or other material
3) Remove splint from heat, shake off water and place over desired location. Firmly compress splint to form fit the desired area. Hold for approximately 30 seconds until splint hardens. See *Figure 10* and *Figure 11*.
4) Add straps if desired through corresponding loop locations at edges of splint.

Figure 9: Splint submerged in hot water.

Figure 10: Ventral view of hand in example of a wrist splint. (Left)
Figure 11: Dorsal view of hand in example of a wrist splint. (Right)

Results

An STL file of the final iteration of the design has been uploaded to 'Thingiverse.com'. Thingiverse is a popular, free website, allowing users access to open-source designs uploaded by other creators. Other designers can now access the design and continue to offer improvements and perform testing. [8]

Figure 12: QR code access to 'Thingiverse' listing.

Conclusion

The design shows promise as a means of improving splinting treatment options for distal extremity injuries in the setting of wilderness medicine. This is just one potential example of the powerful tool of 3D-printed solutions in biomedical applications. [9] Future testing and trials are necessary. With the device design published open-source, we hope other creators continue to alter, improve, and test the design.

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