

Three-dimensional Printed Customized Adjustable Mallet Finger Splint: A Cheap, Effective, and Comfortable Alternative

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Summary: Mallet finger deformity is a common and debilitating injury of the fingertip, accounting for 10% of all tendon and ligament injuries. It involves a disruption of the terminal extensor mechanism of the distal phalanx. Patients can experience significant pain and swelling of the fingertip and have significant morbidity without treatment. Nonoperative treatment using joint immobilization with splints is the mainstay of management. Traditionally, prefabricated and thermoplastic splints have been utilized; however, issues with comfort and skin complications such as maceration can lead to patient noncompliance and eventually, poor outcomes. To address this, we demonstrate our experience with the design, manufacture, and application of individualized 3D printed mallet finger splints. The splints were found to provide advantages akin to traditional thermoplastic splints, with the addition of being low cost, easy to manufacture, and environmentally friendly. (*Plast Reconstr Surg Glob Open* 2021;9:e3500; doi: [10.1097/GOX.0000000000003500](https://doi.org/10.1097/GOX.0000000000003500); Published online 23 March 2021.)

INTRODUCTION

Mallet finger deformity is a common injury of the fingertip, accounting for up to a tenth of all tendon and ligament injuries in the body.¹ It involves a disruption of the terminal extensor mechanism, either due to tendon rupture or bony avulsion of the distal phalanx. Patients can experience considerable pain and swelling of the fingertip, and without treatment, have a significant morbidity due to the inability to extend the distal interphalangeal joint and eventual development of a swan neck deformity. Joint immobilization using splints is the mainstay of treatment, while surgery, usually with the extension block Kirschner-wire technique, is advocated only for a small number of cases.^{2,3}

For nonoperative management to be successful, splints must be worn full-time for at least 8–10 weeks, with radiographic follow-up (when necessary) during this period.^{4,5} This presents a case for the ideal splint to be tailor-made and comfortable, whilst being radiolucent to obtain radiographic

images without removal of the splint. Custom-made thermoplastic splints are associated with fewer complications (such as pressure sore, skin maceration, poor fit, splint breakage, or pain/discomfort) than prefabricated ones such as Stack splint or Zimmer splint, and are significantly less likely to result in treatment failure.^{6,7} The manufacturing of traditional thermoplastic splints, however, is material-intensive and expensive, and the quality is highly dependent on the skill level of the therapist preparing the splint.⁸

Advancements in additive manufacturing have allowed computer-aided design and 3D printing technology to provide a standardized and efficient approach to manufacturing of surgical instrumentation and customized orthotic devices.^{9–12} This study demonstrates our experience with the design, manufacture, and testing of individualized 3D printed mallet finger splints. We show that these splints provide a comfortable, radiolucent, and low-cost alternative to the traditional options available.

DEVICE PRODUCTION

Stereolithography files (.stl) of the dorsal blocking splint were designed on Autodesk's Fusion 360 software (Autodesk, San Francisco, Calif.) and manufactured

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Disclosure: Dr. Papavasiliou and Dr. Chatzimichail own Stelth Ltd, a company that specializes in 3D printing. They declare no intention in commercializing this device. All the other authors have no financial interest to declare in relation to the content of this article.

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

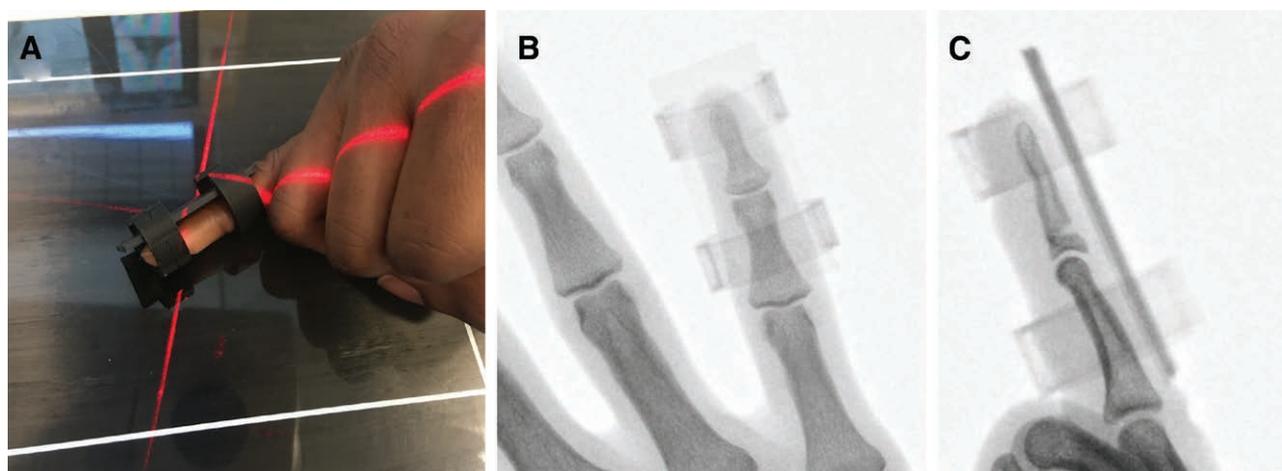


Fig. 1. 3D printed neutral dorsal blocking splint. Application of our 3D printed neutral dorsal blocking splint on a patient with the right little finger base of distal phalanx fracture (A), successfully correcting the deformity. The radiolucency of the device is evident on the anteroposterior (B) and lateral view (C).

on a commercial Fusion Deposition Modelling Ender 5 3D printer (Crealty, Shenzhen, China) in polylactic acid (PLA) sourced from RS UK (1.75mm filament by RS, Northants, UK). The dimensions of the device were calculated directly on the anatomy of the patient so that the final splint was patient-precise. (See figure 1, Supplemental Digital Content 1, which displays bespoke measurements of the customized dorsal blocking splint design. The designed .stl file can be scaled up based on those measurements to provide a customized fit for each patient. <http://links.lww.com/PRSGO/B605>.) (See figure 2, Supplemental Digital Content 2, which displays the application of our 3D printed customized splint on the left little finger on different views. <http://links.lww.com/PRSGO/B606>.)

Based on these anatomical measurements, the device design was scaled to size and printed. The device shown in Figure 1 weighs 5g and requires 15 minutes of printing time (Table 1), with the overall process from patient assessment to application of the splint lasting, on average, 25 minutes. Variations of the neutral dorsal blocking splint were manufactured, providing joint angles from neutral to 15degrees,

as shown in Figure 2, allowing for adjustments to be made for different fracture patterns. The splint can be adjusted to improve fitting once positioned on the injured finger, as shown in the Supplemental Video. (See Video [online], which displays assembly and positioning of our 3D printed dorsal blocking neutral splint on the left little finger.)

DISCUSSION

The flexibility in design afforded by additive manufacturing technologies renders 3D printing a great tool for the preparation of patient-precise anatomical devices. We showcase the application of a dorsal block splint that was produced based on the anatomy of the patient providing an excellent fit.

The total cost of material for our 3D printed dorsal blocking splint, shown in Figure 1, is estimated at 0.2 GBP/0.25 USD. On the contrary, traditional thermoplastic splints that are also anatomically based are generally more expensive. Furthermore, those cannot be reused to other patients owing to their patient-precise dimensions, thus producing waste. Our choice of material allows for recycling of the device after completion of the treatment protocol owing to its biodegradable nature.

Due to the light weight, open-access, and design of the splint, the patient exhibited better use of their injured hand while the finger was splinted. Furthermore, the open-access design of the splint allows feasible cleaning of the splint, while also improving the breathability of the recovering finger. The choice of material was made based on its radiolucency as it is important that the healing process and the position of the fracture is monitored with x-ray imaging. Such instances are demonstrated in Figure 1. Depending on the nature of the fracture, certain cases might require application of the splint in a hyperextended position.¹³ In those instances, we produced 3D printed splints with dorsal blocking components exhibiting joint angles in the range of 5–15degrees to allow the recovery process to proceed with a more suitable reduction of the fracture. This

Table 1. Parameters and Settings for 3D Printing of the Dorsal Blocking Splint (Including the Rings), with the Overall Material Cost for the 3 Parts

	Manufacturing Parameters	
	Dorsal Block	Rings (x2)
Material	PLA pro (40 GBP/kg)	PLA pro (40 GBP/kg)
Max speed (mm/s)	80	80
Nozzle diameter (mm)	0.4	0.4
Filling density (%)	20	20
Infill pattern	Cubic	Cubic
Printing time (min)	10	5
Layer height (mm)	0.28	0.28
Weight (g)	3.8	1.2
Nozzle temperature (°C)	220	220
Bed temperature (°C)	70	70
Cost (GBP/USD)	0.20/0.25	

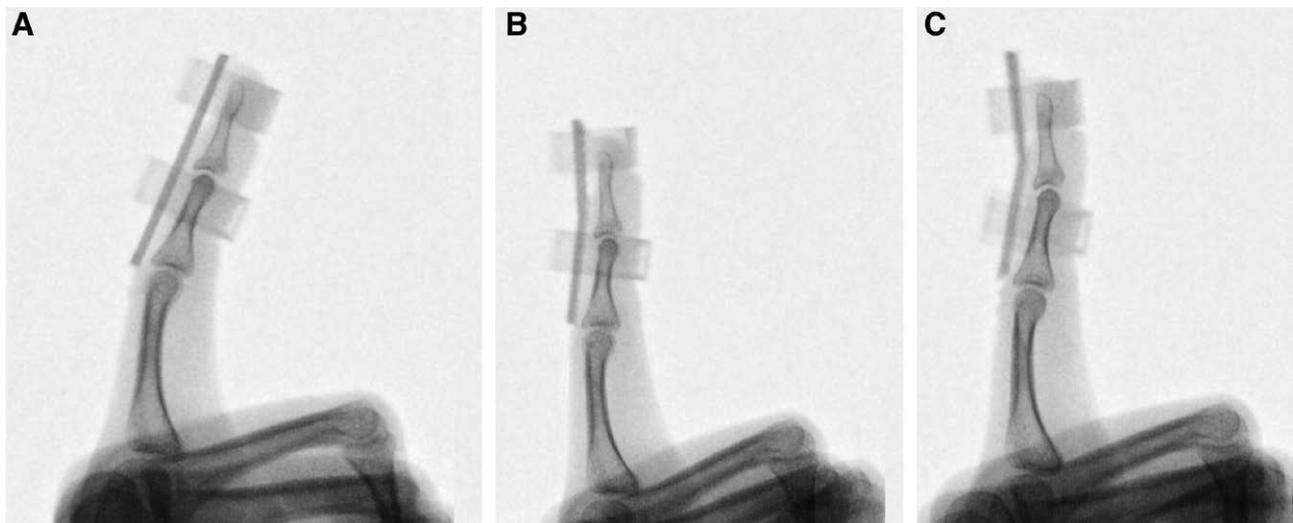


Fig. 2. Application of our 3D printed dorsal blocking splints. Variations of angles are provided due to adjustment of the blocking component. The angles of the dorsal block are 0 (A), 10 (B), and 15 degrees (C).

approach also allowed for more conservative treatment options to be adopted.

CONCLUSIONS

Positioning of the developed 3D printed dorsal blocking splint is simple, comfortable, and allows for adjustments under radiographic guidance. The device was found to be effective in the use of mallet finger deformities as well as the base of the distal phalanx fractures. Therefore, other fracture patterns can be treated by adopting similar 3D printed solutions.

Small optimizations such as the production of bespoke splints for hand trauma patients can have a big impact when considering the overall running costs of a hand trauma clinic unit. To that end, the rapid-prototyping cycle of 3D printing renders it a promising new in-house technology to explore how these optimizations can be achieved.

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The study conforms to the ethical principles stated in the Declaration of Helsinki.

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