



## CASE REPORT

## 3D printing technology in the management of carpal tunnel syndrome: A care report

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### ABSTRACT

A 35-year-old individual with carpal tunnel syndrome presented with tingling and numbness in the left thumb, index, and middle finger. A 3D printed CTS splint was crafted to immobilize the affected wrist joint, aiding pharmacotherapy. At six weeks, evaluations included the Boston Carpal Tunnel Questionnaire (BCTQ), Visual Analogue Scale (VAS) for pain, and Evaluation of Satisfaction with assistive Technology (QUEST) version 2.0.9. Substantial improvements were observed in Bangla-BCTQ scores (symptom severity scale: 3.68 vs. 1.27; functional status scale: 2.74 vs. 1.31), VAS (70 vs. 30), and QUEST scores. 3D printing technology may contribute to better personalized musculoskeletal care enhancing quality of life.

**Keywords:** 3D printing, carpal tunnel syndrome, carpal tunnel syndrome, splint

### INTRODUCTION

3D printed orthoses are increasingly recognized as a viable choice within the realm of Physical Medicine and Rehabilitation for creating traditional casts and orthoses. Orthoses are rigid or semi-rigid devices used to support, restrict, mobilize, or immobilize injured body segments, aiding healing and function improvement. They can be custom-made, prefabricated, or custom-fitted by clinicians. Splints or braces, synonymous with orthoses, can be made from plaster, fiberglass, or 3D printed materials.<sup>1</sup> Several studies have demonstrated the efficacy of wrist splinting in relieving the symptoms of Carpal tunnel syndrome however, the chosen angle of immobilization has varied.<sup>2</sup>

### CASE DESCRIPTION

A 35-year-old woman presented to the Physical Medicine and Rehabilitation outpatient department at Bangabandhu Sheikh Mujib Medical University with

tingling and numbness in left hand for three months, diagnosed clinically, and confirmed with electrophysiological findings as CTS.

CTS results from median nerve compression within the carpal tunnel, a common upper limb entrapment neuropathy.<sup>3, 4</sup> Management focuses on alleviating pressure on the median nerve through conservative or minimally invasive approaches. Mild to moderate symptoms are typically addressed using wrist splinting, carpal canal steroid injections, exercises, yoga, therapeutic ultrasound, ergonomic adjustments, and oral vitamin medication.<sup>5, 6</sup> Along with conventional pharmacological therapy, she was advised a 3D printed carpal tunnel splint for 6 weeks. Advantages of 3D printed splints compared to conventional ones include easier modification and faster fabrication.<sup>2</sup> The 3D printing technique makes it possible for physicians to easily create individual-tailored products.

## LEARNING POINTS

1. Custom 3D printed splints are effective for carpal tunnel syndrome treatment.
2. The splint, combined with medication, improved symptoms, reduced pain, and increased patient satisfaction.
3. Collaboration among patients, clinicians, and engineers enhances personalized musculoskeletal care, improving quality of life.

## CASE MANAGEMENT

Physiatrists from Bangabandhu Sheikh Mujib Medical University (BSMMU) and Kurmitola General Hospital, Dhaka collaborated with engineers from the Department of Robotics and Mechatronics Engineering (RME), University of Dhaka to develop a solution. The required CTS splint is needed to immobilize the wrist

**TABLE 1** Properties of the materials

Property	Polylactic acid	Acrylonitrile butadiene styrene
Young's modulus (GPa)	4.107	2.87
Density (g/cc)	1.25	1.4
Modulus of elasticity (GPa)	2.3	2.4
Yield strength (GPa)	0.06	0.05
Poisson's ratio	0.3	0.37

joint of the patient for 6 weeks. It was deemed that a personalized, 3D printed CTS splint was the best way to meet these criteria. The entire process from solution conception, through design, and manufacture was done in the RME Lab of Dhaka University with point-of-care manufacturing facilities and clinical testing was completed within the BSMMU campus. This process involved:

- The lightweight and durable material used in 3D printed CTS splint provides comfortable supports for the patient's wrist. After careful consideration of two available 3D printing material—poly lactic acid (PLA) and acrylonitrile butadiene styrene (ABS), PLA was selected because of its durability (**TABLE 1**).
- Patient's hand was scanned using a setup with various sensors.
- Red green blue images were captured by the setup.

- A deep learning model was implemented to extract two separate scaled 3D meshes of palmar and dorsal parts of the hand from the RGB images.
- The 3D meshes were further processed to obtain a 3D printable format.
- The separate parts of the orthosis were printed using an fused deposition modeling 3D printer.
- The parts were attached using adjustable straps to create the final custom-made orthosis.

The 3D printed CTS was evaluated for fit and efficacy and underwent minor adjustments based on patient and physician's feedback. The patient completed the validated Bangla version of the Boston Carpal Tunnel Questionnaire (Bangla-BCTQ)<sup>8</sup> and Visual Analogue Scale (VAS) and reviewed by two physiatrists and an orthopedic surgeon to measure the impact of this device on the patient's symptom severity and functional status. Patient's satisfaction with the splint was assessed by Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) version 2.0.9 Outcome measures were completed before, and after three and six weeks of device use.

**TABLE 2** Patient-reported outcome measures

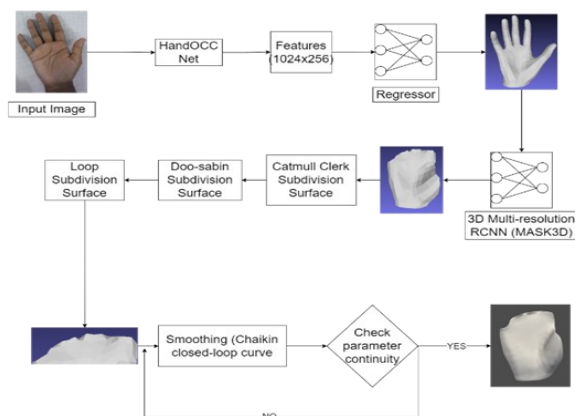
Time frame	Boston Carpal Tunnel Questionnaire - Bangla version		Visual analogue scale <sup>b</sup>
	(SSS) <sup>a</sup>	(FSS) <sup>a</sup>	
0 week (baseline)	3.68	2.74	70
6 weeks	1.27	1.31	30

<sup>a</sup>A higher score indicates more limitations. Scored out of 5 points. SSS indicates symptom severity scale; FSS, functional status scale

<sup>b</sup>A lower score indicates a better health status (scored out of 100 points).

The chosen outcome measures, including the BCTQ, VAS, and QUEST version 2.0, were selected for their established validity and relevance in assessing symptom severity, pain intensity, and patient satisfaction, respectively, providing a comprehensive evaluation of the patient experience in managing carpal tunnel syndrome with the personalized, 3D-printed splint.<sup>8, 9, 10</sup>

After six weeks of device use, the patient had not experienced any kind of tingling or numbness, whilst demonstrating clinically significant improvements in Bangla-BCTQ and VAS scores (**TABLE 2**). The



**FIGURE 1** Deep learning algorithm to extract 3D model

BCTQ scores for the 3D printed CTS splint at baseline were 3.68 functional status scale, 2.74 functional status scale, and 70 visual analogue scale, and in the 6<sup>th</sup> week were 1.27 symptom severity scale, 1.31 functional status scale, and 30 visual analogue scale. Bangla version of The Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) version 2.0 was used to evaluate patients' satisfaction with the 3D printed orthosis.<sup>10</sup> QUEST is a self-report or interview-based scale designed to evaluate a person's satisfaction with a wide range of assistive technology. The calculated total QUEST score was 4. The results suggest that 3D printed orthosis is a feasible option for CTS patients.

## DISCUSSION

Decreased VAS scores suggest 3D printed orthoses effectively alleviate CTS symptoms, enhancing patients' quality of life. Improved BCTQ scores affirm the efficacy of customized orthoses, enhancing daily activities by providing tailored support and stability. Positive feedback on customized orthosis comfort and usability, reflected by high QUEST scores, underscores its potential to enhance patient satisfaction.

This marks the inaugural implementation of a custom-made 3D printed orthosis for CTS patients in Bangladesh. Collaborative point-of-care design and manufacturing of personalized devices can significantly enhance clinical outcomes and quality of life for individuals with musculoskeletal conditions, underscoring the untapped potential of 3D technologies in physical medicine and rehabilitation.

While this case study offers valuable insights into personalized splinting for CTS, limitations exist. The single-case design limits generalizability, warranting further research with larger cohorts. Additionally, outcome measures, while standard, may not fully capture symptom complexity. Potential biases, including placebo effects and concurrent treatments, require consideration in future studies. Moreover, while collaborative efforts enhance innovation, scalability and accessibility challenges persist. Addressing cost-effectiveness, regulatory hurdles, and technological constraints is crucial for widespread adoption. These limitations underscore the need for a robust investigation to validate findings and optimize personalized musculoskeletal care approaches.

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## Author contributions

*Conception and design:* MIH. *Acquisition, analysis, and interpretation of data:* MT, SMA, SAD. *Manuscript drafting and revising it critically:* MIH, TM, MT. *Approval of the final version of the manuscript:* MIH, SMA. *Guarantor of accuracy and integrity of the work:* MIH.

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## Conflict of interest

We do not have any conflict of interest.

## Ethical approval

Ethical approval was not sought because this is a case report. However, consent was obtained from the patient to prepare this manuscript.

## Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

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