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Customized Hand Plaster Cast by using 3D Printing Technology

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Abstract - This research explores a more personalized approach to hand casting by using 3D printing technology as an alternative to traditional plaster casts. The goal was to improve the overall comfort, fit, and usability for patients while maintaining the necessary support for healing. The process began with a 3D scan of the patient's hand, followed by the creation of a custom design using computer-aided design (CAD) software. The final cast was produced with fused deposition modeling (FDM), using lightweight and breathable materials. The customized casts were tested for durability and comfort, and the results showed notable improvements over standard plaster casts. Patients reported better ventilation, reduced weight, and a more secure, personalized fit. These findings suggest that 3D-printed casts not only provide the required support but also enhance the overall patient experience. This method has the potential to modernize orthopedic care, especially in settings where comfort, speed, and customization are priorities.

Key Words: 3D printing, orthopaedic cast, hand support, custom fit, CAD design, patient experience.

1. INTRODUCTION

Casts have been a standard solution for treating broken or injured limbs for decades, with plaster and fiberglass being the most used materials. While effective in providing support and immobilization, traditional casts often come with drawbacks. Patients frequently report discomfort due to the cast's weight, poor ventilation, and the lack of a personalized fit. These issues can lead to skin irritation, reduced mobility, and general dissatisfaction during the recovery period.

With advances in digital technology, 3D printing is emerging as a promising alternative in the medical field, particularly for producing customized orthopedic devices. Using tools like 3D scanning and computer-aided design (CAD), it is now possible to design casts that match the exact shape of a patient's limb. These casts are typically lighter, more breathable, and more comfortable than traditional ones, without compromising structural support.

This research focuses on designing and producing a customized hand cast using 3D printing technology. The goal is to explore how this approach can improve patient comfort, usability, and treatment effectiveness. The study outlines the steps taken—from scanning and modeling to printing and testing—and evaluates the performance of the final product compared to traditional casting methods.

2. Body of Paper

2.1 Methodology

The process followed in this project was methodical and user-centered, aiming to develop a 3D-printed hand cast that is comfortable, lightweight, and tailored to each user. The workflow included understanding real-world problems, defining clear design goals, developing digital models, selecting suitable materials, and finally fabricating and testing the cast. Each step is described in the sections below.

2.1.1 Problem Identification and Market Survey

To get a clear picture of existing issues with conventional plaster casts, we spoke directly with orthopedic doctors and patients who had experienced injuries requiring immobilization. Several pain points came up repeatedly — traditional casts were heavy, lacked ventilation, caused itching or skin irritation, and made everyday tasks quite difficult. Also, since they aren't customized, the fit isn't always perfect, which can impact both comfort and recovery. These real-life insights helped us understand what the new cast design needed to solve.

Table-1: Cost and Feature Comparison Between Traditional and 3D Printed Plaster Casts

Sr. No.	Parameter	Traditional Plaster Cast	3D Printed Custom Cast
1	Material Used	Plaster of Paris (POP), gauze, cotton rolls	PLA filament
2	Material Cost (per unit)	₹150 – ₹250	₹180 – ₹300
3	Labor Cost (per unit)	₹250 – ₹400 (skilled technician)	₹0 – ₹50 (minimal assembly/post-processing)
4	Total Fabrication Time	30–45 minutes (manual)	4–6 hours (automated printing + 15 mins assembly)
5	Weight	1000-1500 grams	150 – 250 grams
6	Fit Customization	Standard sizes, not personalized	Fully customized to patient's anatomy via 3D scanning
7	Comfort & Ventilation	Poor ventilation, potential skin irritation	Highly breathable, open mesh design
8	Aesthetic Appeal	Bulky and outdated appearance	Sleek, modern, and customizable designs
9	Ease of Application	Requires wet application and drying time	Tool-free assembly with Velcro fastening
10	Ease of Removal	Requires cutting tools and supervision	Easily removable and reusable
11	Environmental Impact	Non-biodegradable POP waste	PLA is biodegradable under industrial conditions
12	Reusability	Single-use only	Reusable and adjustable
13	Average Total Cost (INR)	₹1500– ₹2000	₹250-300(excluding 3D printer cost)

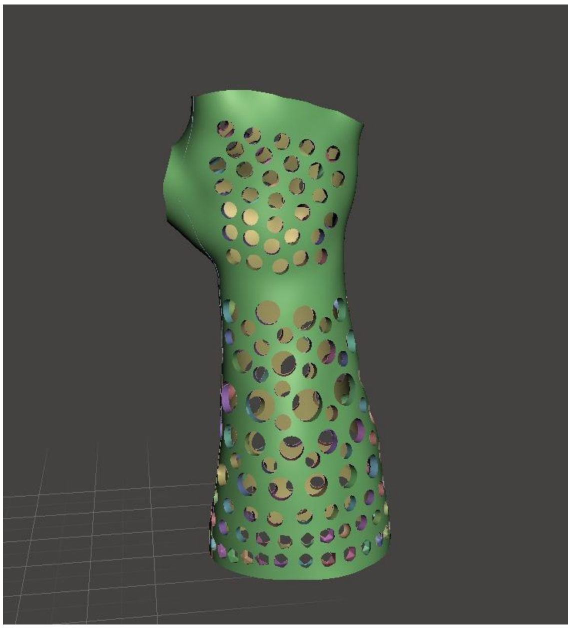
2.1.2 Requirement Specification

From the feedback gathered, we came up with a set of design goals for our customized cast:

- It should fit the patient's hand perfectly using a digital scan.
- The structure must be lightweight and breathable to improve comfort and hygiene.
- Materials used must be safe for skin contact and environmentally friendly.
- The cast should provide sufficient support to immobilize the hand effectively.
- It must be easy to wear and remove, even without special tools.
- Finally, it should be affordable and quick to make, especially for use in clinics or emergencies.

2.1.3 Conceptual Design

Once the design requirements were in place, we started working on the digital model. We scanned a user's hand using a 3D scanning tool to get an accurate digital representation. This 3D scan was imported into CAD (computer-aided design) software like Mesh Mixer. The actual cast was designed as a shell around this scan, using an open lattice or honeycomb pattern to allow ventilation and reduce weight. Care was taken to keep pressure points away from sensitive areas like joints and swelling zones.



2.1.4 Material Selection

Choosing the right material was crucial to making the cast safe, comfortable, and easy to print. Here's what we picked:

- **PLA Filament (Polylactic Acid):** A biodegradable and skin-safe plastic that prints well and holds its shape.
- **3D Pen (PLA-based):** Instead of mechanical fasteners or Velcro straps, we used a 3D pen loaded with PLA filament to bond multiple printed sections of the cast. This technique allowed seamless joining, preserved aesthetics, and maintained material consistency throughout the structure. It also ensured that the cast remained lightweight and fully customized.
- **3D Printer:** We used the Anycubic Kobra, a reliable FDM (Fused Deposition Modeling) desktop printer that offers a good balance of print quality and speed.

Table 2: Comparison of Common 3D Printing Materials for Medical Applications

Sr. No.	Material Type	Property	PLA (Polylactic Acid)	TPU (Thermoplastic Polyurethane)	ABS (Acrylonitrile Butadiene Styrene)
1		Printability	Very easy / minimal	Moderate	Difficult (warping issues)
2		Strength	High	Medium	High
3		Flexibility	Low	High	Medium
4		Biocompatibility	Excellent (plant-based)	Good (generally safe)	Low
5		Surface Finish	Smooth	Good	Good (post-processing)
6		Heat Resistance	Low (< 60° C)	Moderate	High
7		Durability	Low to Moderate	High	High
8		Applications	Medical sample models	Orthotic supports, flexible models	Medical braces, devices

2.1.5 Fabrication

Once the final design was ready, we prepared it for printing using Ultimaker Cura — slicing software that converts CAD files into machine-readable code. The following settings were used for optimal print quality:

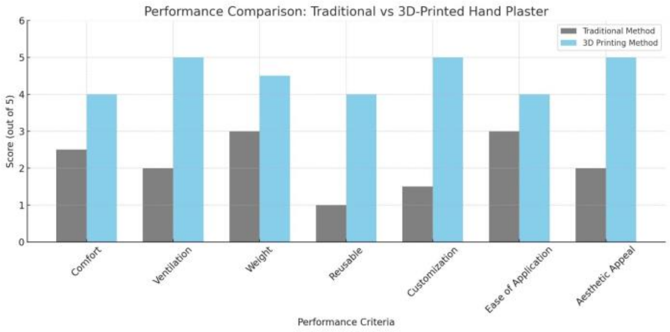
- **Layer Height:** 0.2 mm for good detail without making the print too slow
- **Infill:** 75% depending on the load-bearing areas
- **Nozzle Temperature:** 210°C
- **Bed Temperature:** 60°C

The cast was printed in two sections, depending on size. After printing, we smoothed out any sharp edges.

2.1.7 Finalization

Based on testing results, we made some final changes — rounded edges were improved, straps were repositioned for better support, and the design was tweaked for easier printing. We documented the entire process, including the list of materials, assembly steps, cleaning instructions, and suggestions for clinical use. The final prototype is ready for extended field testing and possible clinical trials.

2.2 PERFORMANCE ANALYSIS



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Their stories and insights helped us understand the real-world problems we were trying to solve and shaped our design in a meaningful way.

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