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Research Article

Exploring Mechanical Properties of Additive Manufactured Patient-Specific Finger Splints through FEA and Experimental Testing

S. M. Kennedy[1,*]
K. Amudhan[2]
R.B. Jeen Robert[3]
A. Vignesh Moorthy Pandian1[1]
[1] Department of Mechanical Engineering, AAA College of Engineering and Technology, Sivakasi 626005, Tamilnadu, India
[2] Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi 626005, Tamilnadu, India
[3] Department of Mechanical Engineering, Sri Krishna College of Technology,Coimbatore 641042, Tamilnadu, India

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Abstract:
The primary objective of the study is to assess the mechanical suitability of each filament material for finger splint applications and to determine their behaviour under compressive loads. Several filament materials were used in the design and Additive Manufacturing of patient-specific finger splints. Finite Element Analysis simulations were then used to forecast mechanical responses. The simulation results are then verified and the mechanical characteristics of the splints are measured through experimental compression testing. The study's main conclusions highlight the unique mechanical properties of each filament material, such as differences in stiffness, strength, and resilience. Nylon splints showed good flexibility and toughness, while PLA and ABS splints showed differences in flexibility and moderate strength. PC splints are ideal for applications needing strong support because of their high strength and rigidity. The study has implications for the choice of filament materials for patient-specific finger splints, taking into accounts the desired mechanical properties and clinical needs. By offering useful data for improving the design and manufacture of customized finger splints, these findings advance orthopedic care.

Keywords: *Finger Splint, Additive Manufacturing, Finite Element Analysis, Compression*

1. Introduction

Finger splints are orthopedic devices designed to provide support, immobilization, and protection to injured fingers, as well as to aid in the rehabilitation process. Orthopedic devices known as finger splints are made to protect, immobilize, and support injured fingers while also assisting with the healing process. They are frequently used to treat a variety of finger ailments and injuries, such as fractures, dislocations, injuries to the ligaments and tendons, and post-operative care. Finger splints are primarily used to keep the injured finger or fingers in the proper alignment and to stop more damage or displacement while the injury heals. Splints help minimize pain, swelling, and inflammation while fostering optimal healing and functional recovery by immobilizing the injured finger or fingers [1,2]. Finger splints can be made in a variety of sizes, forms, and styles to suit the needs of each patient as well as the particular injury or condition being treated. They can be manufactured specifically to fit the patient's hand and fingers, or they can be prefabricated [3,4].

It is impossible to exaggerate the significance of patient-specific splints in orthopedic treatment. Custom-made splints are made to fit the specific anatomy of each patient, taking into account their hands and fingers.

* Corresponding author: S. M. Kennedy
E-mail address: maharaj@aaacet.ac.in

By ensuring a precise fit, pressure points and discomfort are reduced and comfort and effectiveness are maximized. Comparing customized splints to generic, one-size-fits-all splints, the former effectively immobilizes injured fingers or joints. This aids in stabilizing the injured area, halting additional damage, and encouraging appropriate healing. If a splint fits well and does not hurt, patients are more likely to wear it as prescribed. Patient-specific splints increase adherence to the recommended treatment plan because they are made to the patient's specifications and preferences. Faster recovery from finger injuries or conditions can be facilitated by patient-specific splints, which offer optimal support and immobilization. They facilitate faster tissue healing by lowering pain, edema, and inflammation. Specialized splint designs may be necessary for some conditions in order to address particular difficulties. Optimizing treatment outcomes, patient-specific splints can be made to accommodate things like tendon injuries, joint deformities, or post-operative concerns [5,6]. Complications like pressure sores, skin irritation, or impaired circulation can result from ill-fitting splints. Patient-specific splints reduce these risks by evenly dispersing pressure and precisely fitting the patient's anatomy. When rehabilitation calls for dynamic splinting or controlled motion, patient-specific splints can be made to offer the right amount of support while still enabling therapeutic movement. This enhances muscular strength, joint mobility, and functional recovery. Customized splints for each patient can be made to fit their activities and way of life. Splints can be made to offer protection and support for daily activities, sports, or the workplace without compromising functionality [7,8].

Creating individualized and customized solutions for patients is one of the biggest benefits of 3D printing in medicine. Medical professionals are able to customize surgical guides, prosthetics, implants, and even anatomical models to fit each patient's unique anatomy and set of needs [9,10]. Complex and intricate structures that would be difficult or impossible to create using conventional manufacturing techniques can now be created thanks to 3D printing. In orthopedic and craniofacial surgeries, where patient-specific implants and prosthetics are frequently needed, this capability is especially helpful. Medical-grade 3D printers are capable of producing precise anatomical models from patient imaging data, including MRI and CT scans. Surgeons can use these models to simulate complex surgeries before operating on patients, better plan surgical procedures, and view the anatomy of patients in three dimensions. Furthermore, 3D-printed models can be used by medical students and trainees for practical experience and surgical instruction [11–13]. In the process of developing medical devices, 3D printing makes rapid prototyping and iterative design processes easier. Prototypes of medical devices, implants, and instruments can be made and tested quickly by engineers and researchers, who can then refine their designs in response to feedback and testing outcomes. Patients can learn more about their medical conditions and treatment options with the aid of 3D-printed anatomical models, which are useful educational resources. Patients can feel more confident about their treatment plans and make better decisions by seeing their anatomy and the proposed procedures. 3D bioprinting technologies have shown great promise in tissue engineering and regenerative medicine in recent years. Researchers are investigating the use of bioink materials and living cells in 3D printers to create scaffolds, organoids, and even functional tissues and organ [14,15]. These developments could completely change regenerative medicine and organ transplantation. Low-cost, decentralized medical supply and device production is made possible by 3D printing, especially in environments with limited resources. By producing custom orthotics, prosthetics, and medical devices quickly, 3D printing facilities can lessen the need for centralized manufacturing and distribution channels. Dental, hip, and cranial implants—among the many patient-specific implants—are being produced with the help of 3D printing technologies. By precisely fitting the patient's anatomy, these implants can enhance biocompatibility and long-term results [16,17].

This study aims to investigate the mechanical properties of finger splints customized for each patient using four different filament materials: polylactic acid (PLA), polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS). The study intends to compare the mechanical behavior of each filament material under compressive loads and assess which is most appropriate for finger splint applications by combining Finite Element Analysis (FEA), 3D printing technology, and compression testing. The focus on patient-specific design, the integration of FEA with experimental testing, the comparative analysis of filament materials for patient-specific finger splints, and the study's clinical relevance to orthopedic practice are what make it novel. By addressing these aspects, the study contributes to advancing the understanding and application of 3D printing technology in the field of orthopedic rehabilitation.

2. Materials

When choosing filament materials for finger splints, such as polylactic acid (PLA), polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS), careful consideration is given to the materials' mechanical characteristics, biocompatibility, and orthopaedic applicability. PLA is a biodegradable thermoplastic made from renewable resources that is suitable for patients with sensitivity issues because it is biocompatible and easy to print on [18,19].

ABS, which is well-known for its strength and resilience to impact, offers the toughness and durability needed for functional splints, even though printing may cause some fumes to release [20,21]. Because of its toughness, flexibility, and chemical resistance, nylon provides good support and comfort, making it the perfect material for dynamic splints that need flexibility [22,23]. The strong support and stability required for rigid splints is provided by PC, which is prized for its high impact resistance and rigidity [24,25]. Clinicians can guarantee the best fit, comfort, and performance of the splint by carefully choosing the material based on the patient's unique needs and the intended application of the splint. This will ultimately improve the patients' therapeutic outcomes [26]. The material properties of the filament were procured from the filament manufacturer as listed in Table 1.

Table 1: Material properties of Filament

Properties/Materials	PLA	ABS	Nylon	PC	Standard
Tensile modulus (MPa)	3250	2,030	2331	2307	ISO 527 (1 mm/min)
Tensile stress at yield (MPa)	52.5	43.6	63.1	62.7	ISO 527 (50 mm/min)
Elongation at yield %	3.4	4.8	6.1	6.3	ISO 527 (50 mm/min)
Elongation at break %	7.8	34	120	3.15	ISO 527 (50 mm/min)
Charpy impact strength (at 23 °C) kJ/m^2	3.9	58	13.7	3.41	ISO 180
Melt mass-flow rate (MFR) g/10 min	6.1	41	6.2	34	ISO 1133 (260 °C, 5 kg)
Vicat softening temperature °C	64.5	97	169.6	132.6	ISO 306
Melting temperature °C	151.8	225	188.4	215	ISO 294

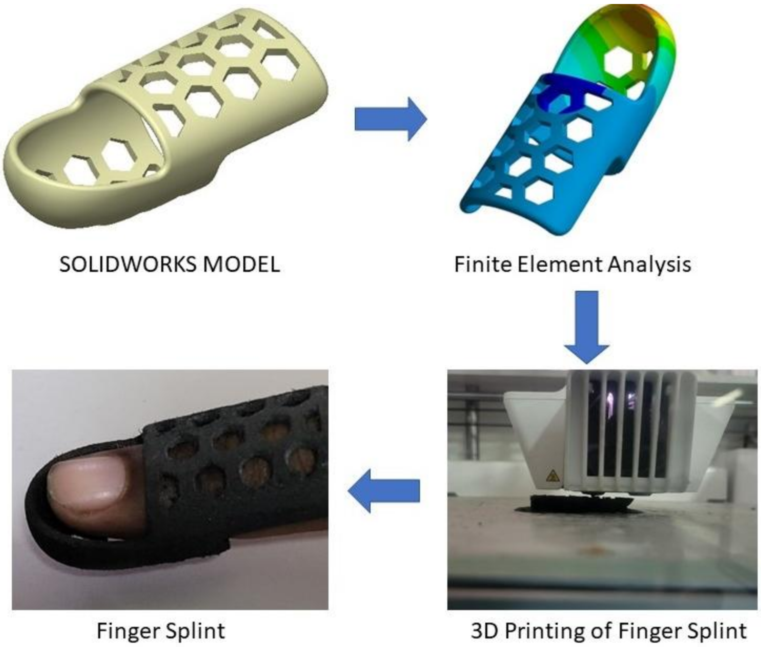

Fig. 1. Scheme of the proposed work

The current study uses a methodical approach to examine the mechanical characteristics of finger splints customized for each patient that are made from four different filament materials: polylactic acid (PLA), polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS). The study's plan includes multiple crucial steps, as shown in Figure 1. First, using anatomical information gleaned from medical imaging, finger splint designs tailored to each patient are created. Subsequently, 3D printing technology is employed to fabricate the splints, with each material chosen based on its distinct characteristics and appropriateness for orthopaedic uses. Next, simulations using Finite Element Analysis (FEA) are used to forecast how the splints will behave mechanically when subjected to compressive loads. Experimental compression testing is then carried out to confirm the simulation results and measure the splints' mechanical characteristics. In order to better understand how well and whether or not the splints are appropriate for clinical use, the study intends to compare the stiffness, strength, and resilience of the splints made from various materials. This all-encompassing method enables a comprehensive examination of the mechanical properties of finger splints customized for each patient, advancing orthopaedic care and individualized treatment options.

3. Modeling, Additive Manufacturing and Finite Element Analysis

3.1 Modeling of Finger Splint

In order to precisely capture the anatomical details of the patient's hand and fingers, a number of steps were involved in the patient-specific modeling of finger splints using a Shining 3D scanner. The patient's hand and fingers were cleaned to remove any oils or debris that might interfere with the scanning procedure before the procedure began. Then, in accordance with the manufacturer's instructions, the Shining 3D scanner was calibrated to guarantee exact and accurate measurements. This involved adjusting settings like resolution and accuracy. The scanner was used to take three-dimensional pictures of the patient's hand and fingers after it had been calibrated. The hand was exposed to a light or laser beam from the scanner, which was reflected back and picked up by the device's sensors. In order to produce an intricate 3D model of the hand and fingers, the scanner gathered data points as it moved over the hand. Following scanning, the raw data gathered by the scanner needed to be processed in order to create a 3D model that could be used. To do this, specialized software from Shining 3D had to be used to clean up the scan, get rid of any noise or artifacts, and produce a smooth, precise representation of the patient's hand and fingers. The creation of the finger splint came after the patient's hand and fingers were captured in a 3D model. A virtual model of the splint was created directly on top of the 3D scan of the patient's hand using SOLIDWORKS 2023® software. This allowed for precise customization of the splint to fit the patient’s anatomy perfectly. Once the finger splint design was finalized, it was necessary to validate the fit and functionality of the splint before proceeding to fabrication. This could be done using virtual simulations or by 3D printing a prototype of the splint for physical testing and evaluation [27].

3.2 Additive Manufacturing

Using the Ultimaker S5 3D printer, additive manufacturing of finger splints involved a methodical procedure to create personalized splints from filament materials like polylactic acid (PLA), polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS). The Ultimaker S5 3D printer was ready for fabrication prior to printing. This required filling the printer with the proper filament material (PLA, ABS, Nylon, or PC) in accordance with the intended splint design, as well as making sure the build plate was clean and level. Using computer-aided design (CAD) software, the finger splint model was created initially. The patient's hand and finger requirements and unique anatomy were taken into consideration when designing the design [28]. Size, shape, and thickness were among the parameters that were changed to maximize functionality and fit. After the splint model was created, it was divided into layers using Ultimaker S5-compatible slicing software. The 3D model had to be sliced into a number of 2D layers that the printer could comprehend. To get the appropriate print quality and mechanical qualities, parameters like layer height, infill density, and printing speed were set. The finger splint was printed using the Ultimaker S5 3D printer after the slicing was finished. In accordance with the sliced layers, the printer deposited successive layers of molten filament material onto the build plate [29]. High accuracy and dependability were provided by the Ultimaker S5, which made it possible to fabricate complex and personalized splints with reliable results. The finger splint was post-processed to eliminate any support structures, smooth out uneven surfaces, and guarantee correct fit and finish after printing was finished. To attain the intended appearance and performance, the printed splint had to be manually sanded, cut, or polished. Following post-processing, the printed finger splint was subjected to quality control inspections to confirm overall quality, structural integrity, and dimensional accuracy. To make sure the splint complied with the necessary requirements and standards, this required visual inspection, measurements, and functional testing [30].

3.3 Finite Element Analysis of Finger Splint

The CAD model is imported to ANSYS WORKBENCH 2023® for FEA. The splint model is meshed to discretize the geometry into smaller elements. Meshing is the process of dividing the geometry into finite elements, such as tetrahedral or hexahedral elements, to facilitate numerical analysis. The model was discretized into 20188 nodes and

36333 elements with an element size of 1 mm, Figure 2(a). Material properties such as Young's modulus, Poisson's ratio, and yield strength were defined based on the properties of the filament material used to fabricate the finger splint. These properties govern the mechanical behavior of the material under loading conditions [31]. Boundary conditions were applied to the model to replicate the experimental setup of the compression test, Figure 2(b). This includes fixing the bottom surface of the splint to simulate constraint against movement and applying a uniform displacement to the top surface to simulate compression. In ANSYS, a remote displacement boundary condition is a type of boundary condition that allows you to apply displacements at a specific location on a model without directly applying the displacement to the associated nodes. This can be particularly useful in situations where the displacement is not directly applicable at the node level. The boundary conditions represented the loading conditions experienced during the physical compression test. Once the model is prepared with appropriate geometry, mesh, material properties, and boundary conditions, it was solved using finite element analysis software [32]. The solver applies mathematical algorithms to solve the equations governing the behavior of the material under loading conditions, resulting in predictions of stress, strain, and deformation throughout the splint geometry. After the simulation was completed, post-processing techniques are used to analyze the results and extract relevant information. This includes visualizing stress and strain distributions, determining maximum stresses and displacements [33].

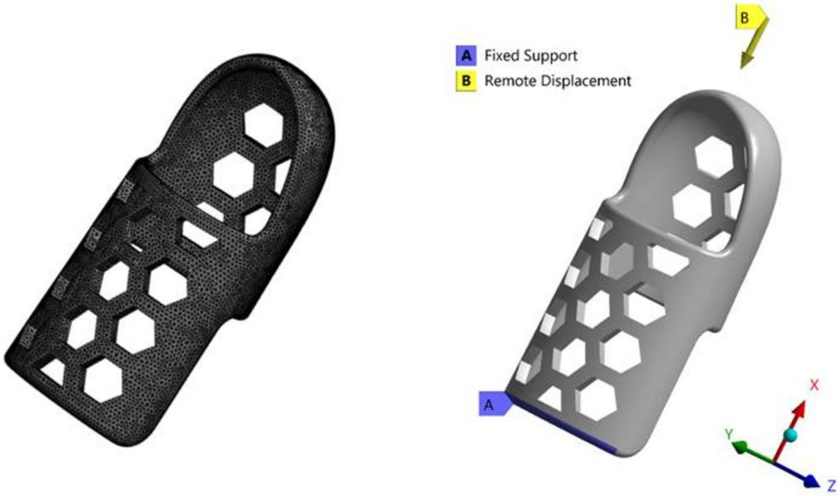

Fig. 2. Loading conditions in Finger Splint

4. Experimental Testing

The compression test was selected to evaluate the finger splint's performance because finger splints often experience compressive forces during daily activities such as gripping, pressing, or holding objects. Assessing the material's ability to withstand these forces is essential for ensuring the splint provides adequate support without deforming or failing under typical use. While the compression test simulates a specific type of load, it provides a controlled method to gauge the material's mechanical properties, such as compressive strength and deformation resistance. However, in real-world conditions, finger splints may experience a combination of compression, tension, and shear forces. The compression test focuses on the splint's resistance to forces perpendicular to the surface, which is common in many hand movements but may not capture every scenario. Nonetheless, it offers a useful baseline for understanding the material's behaviour under one of the most frequent loading conditions. Currently, there are no widely established industry standards specifying minimum force endurance or maximum displacement under specific forces for 3D-printed finger splints. However, splint designs and materials must adhere to general medical device regulations, and many healthcare providers rely on clinical trials or in-house performance testing to ensure safety and functionality. Future research may benefit from establishing standardized benchmarks for the performance of finger splints under various loads.

A structured approach was used in the experimental compression testing of finger splints using a Digital Compression Testing Machine (CTM) - DIG - 40DIG to assess the splints' mechanical characteristics and performance under compressive loads (Figure 3). The finger splints were carefully prepared for testing prior to the compression test. This involved making certain that the splints were consistently and reliably mounted or positioned on the platform of the testing apparatus. The DIG-40DIG Digital Compression Testing Machine underwent calibration to guarantee precise and dependable measurements. During calibration, it was confirmed that the machine's load and displacement sensors were calibrated accurately and that it was operating within predetermined tolerances. The testing parameters were calibrated and then set up in accordance with the experiment's requirements. This required defining the maximum load limit, compression rate, and any other pertinent testing parameters. After everything was set up, the compression test process started. With the finger splint, the testing apparatus applied a compressive force at a predefined rate, usually expressed in millimeter per minute (mm/min). The machine recorded information about the applied load and corresponding displacement as the splint was compressed. The digital compression testing machine continuously recorded data on the load and displacement that the finger splint experienced during the compression test. Usually shown in real-time on the computer's digital display, this data could also be recorded for review at a later time.

Fig. 3. Compression Testing of Finger Splint

5. Results and Discussion

5.1 Experimental Results

Following the completion of the compression test, the gathered data is examined to assess the finger splint's mechanical characteristics and functionality. The maximum load that failed was noted. The structural integrity, load-bearing capability, and deformation behaviour of the finger splint under compressive loads are evaluated by interpreting the compression test results. This data offers insightful information about the splint's functionality and appropriateness for orthopaedic uses. Before failing, the PLA finger splint could withstand a maximum load of 1145.25 N. This suggests that PLA might not have the same load-bearing capacity as other tested materials, despite having good rigidity and being easy to print. Before failing, the ABS finger splint showed a maximum load of 1285.32 N. Given its reputation for strength and impact resistance, ABS was probably able to support heavier loads than PLA. With a value of 1322.86 N, the nylon finger splint displayed the highest maximum load of all the materials tested. Nylon's superior load-bearing capacity in the compression test was probably aided by its toughness, flexibility, and chemical resistance. The PC finger splint failed after displaying the highest maximum load of 1396.74 N. PC is prized for its high rigidity and impact resistance, which makes it ideal for applications needing strong support and stability. The maximum load of finger splint made of each filament is indicated in the Figure 4.

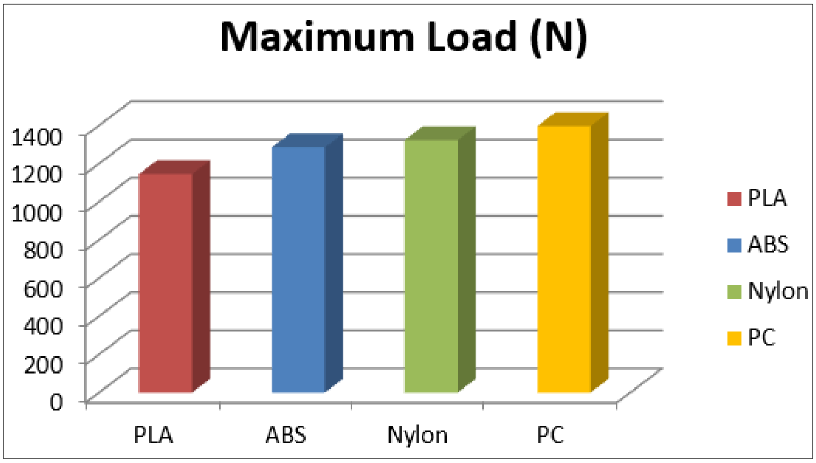

Fig. 4. Compression Test Graph

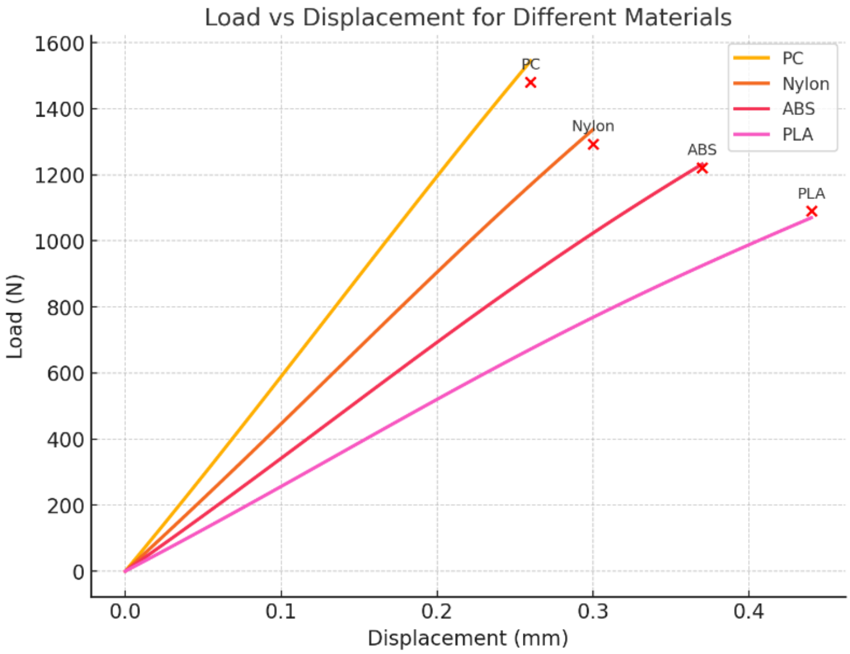

Fig. 5. Load vs Displacement Graph behaviour for splints

The Figure 5 shows the load vs. displacement behaviour for splints made of PC, Nylon, ABS and PLA highlighting their stiffness through the slope and curvature. PC exhibits the highest stiffness with the steepest curve, showing minimal displacement for the highest load. Nylon follows with a slightly less steep curve, indicating slightly lower stiffness but still good resistance to deformation. ABS displays moderate stiffness, with more displacement for a similar load compared to PC and Nylon. PLA has the flattest curve, reflecting the lowest stiffness, as it undergoes the largest displacement under the smallest load. The overall trend indicates that as stiffness decreases from PC to PLA, the curves become less steep, and the materials exhibit greater deformation under load. PC tends to exhibit brittle failure, breaking abruptly with minimal deformation under high loads. Nylon shows ductile failure, allowing significant plastic deformation before yielding or breaking. ABS demonstrates a mixed mode, where either brittle or ductile failure can occur depending on the stress and strain conditions. PLA undergoes ductile failure with noticeable deformation prior to fracture, though it lacks the toughness of the other materials. The progression from brittle to ductile behavior indicates varying energy absorption capacities across the materials under load.

5.2 FEA Results

The maximum principal stress and directional deformation in the Finite Element Analysis (FEA) results of the compression test for the finger splints made from various filament materials (PC, Nylon, ABS and PLA) offer important information about the mechanical behaviour of the splints under loading conditions. In comparison to the other materials, the FEA results for the splints made of PC filament usually displayed the highest maximum principal stress values. This suggests that during compression, PC splints had higher stress concentration and better load distribution throughout the structure. Furthermore, the directional deformation analysis showed that there was less localized distortion or deformation and a tendency for PC splints to deform more uniformly. Nylon filament splints typically showed the next best results in terms of maximum principal stress and directional deformation, after PC. Nylon splints showed good load-bearing capacity and deformation characteristics, although they were slightly less stressed than PC splints. According to the directional deformation analysis, Nylon splints distorted fairly uniformly, exhibiting mild localized deformation in regions where stress concentrations were higher. Figure 6 indicates the maximum principal stress for different materials results obtained through FEA.

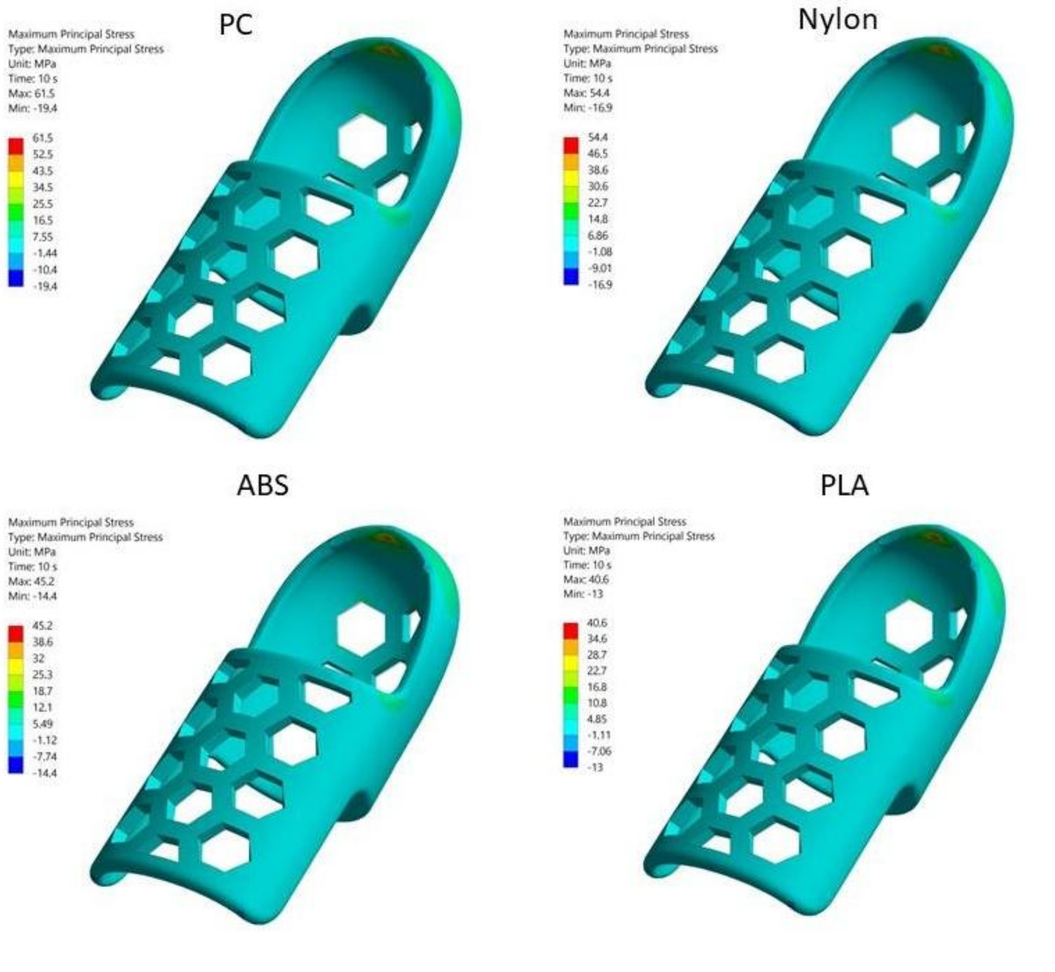

Fig. 6. Maximum principal stress results

When compared to PC and Nylon, ABS filament splints generally displayed lower maximum principal stress values, indicating reduced stress concentration in specific splint structure areas. ABS splints had more noticeable localized deformation, especially in low-stress areas, according to the directional deformation analysis. PLA filament splints generally showed more noticeable directional deformation and the lowest maximum principal stress values among the materials tested. This implies that, in comparison to PC, Nylon, and ABS splints, PLA splints underwent more uniform deformation and less concentrated stress under compressive loads. In terms of stress distribution and deformation characteristics during the compression test, PC filament outperformed Nylon, ABS, and PLA, according to the FEA results overall. These results offer insightful information about the best filament materials to use when creating finger splints, which has ramifications for improving the mechanical qualities of orthopaedic devices and optimizing design parameters. Figure 7 indicates the directional deformation results for different materials obtained through FEA.

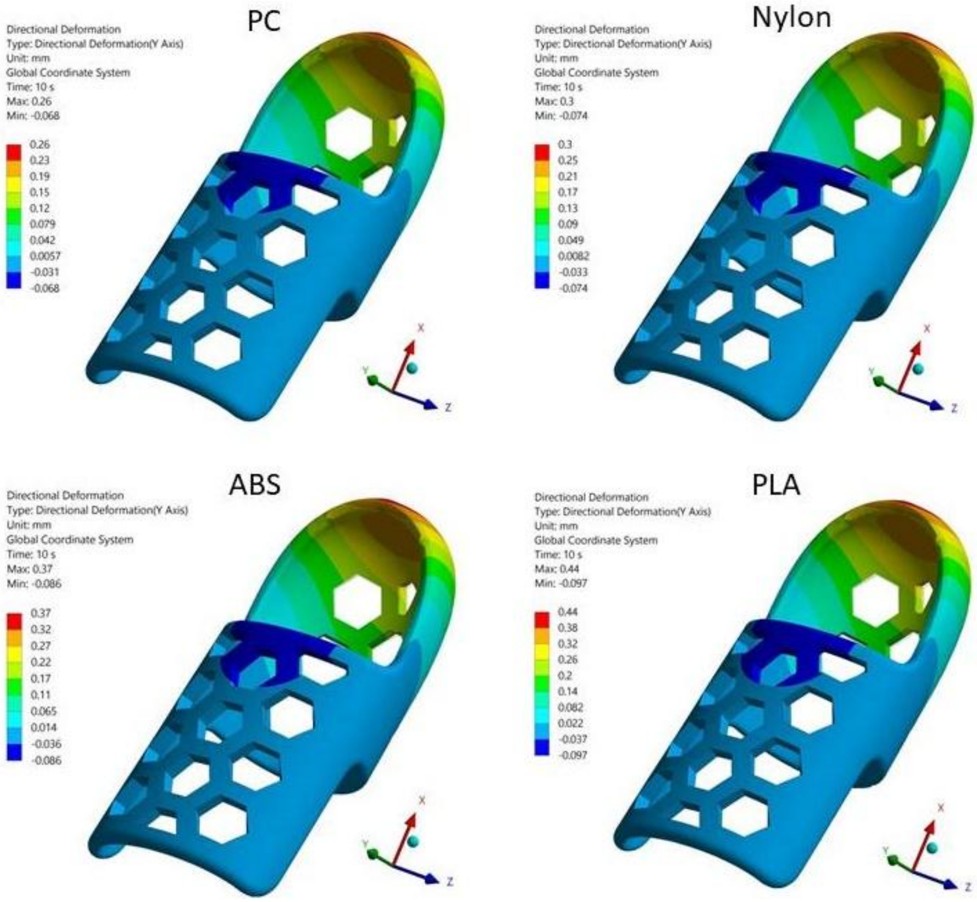

Fig. 7. Directional Deformation results

The load vs. displacement behaviour, failure modes, and the observed FEA stress results correlate closely, providing insights into each material's mechanical response and failure characteristics. PC, exhibiting the highest stress value (61.5 MPa), aligns with its steep load-displacement curve and brittle failure mode, indicating that it withstands higher loads but fractures suddenly with minimal plastic deformation. Nylon, with a stress of 54.4 MPa, supports slightly lower loads but behaves more ductile, allowing greater deformation before failure, which corresponds to its more gradual curve. ABS, showing a moderate stress of 45.2 MPa, reflects its mixed failure mode, balancing between brittle and ductile responses depending on the loading conditions, consistent with its intermediate curve. PLA, with the lowest stress value (40.6 MPa), deforms the most under load and undergoes ductile failure, as seen from its flatter curve and higher displacement at failure. The FEA results validate the load-displacement trends, as higher stresses in PC and Nylon result in stiffer responses with less deformation, while lower stresses in ABS and PLA lead to more plastic deformation before failure.

Table 2: FEA Results

Filament Material	Maximum principal stress (MPa)	Directional Deformation (mm)
PC	61.5	0.26
Nylon	54.4	0.30
ABS	45.2	0.37
PLA	40.6	0.44

Validating FEA results with experimental data is essential for several reasons, as it helps ensure the accuracy and reliability of the model used for simulation. Experimental validation helped verify the correctness of the FEA model. The reaction force from simulations was validated against the experimental obtained load valves.

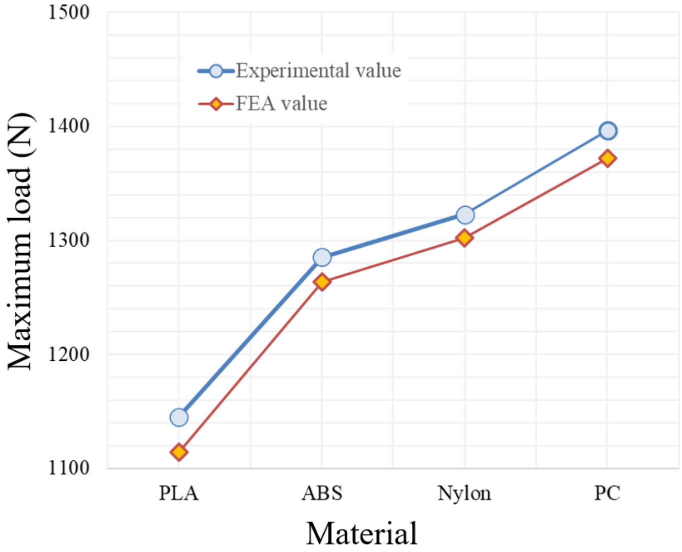

Fig. 8. Experimental vs simulation results

Validation process ensured that the geometry, material properties, boundary conditions and other input parameters in the simulation accurately represent the real-world scenario. Experimental validation mainly helped confirm that the material properties assigned in the FEA model accurately reflect the real material behaviour under loading conditions. An average of 3% error deviation was observed between the experimental and simulation results. Figure 8 is the graphical representation of simulation and experimentally observed load values.

Polycarbonate is the superior material for finger splints based on the present analysis, as it demonstrated the highest mechanical strength with a stress value of 61.5 MPa, allowing it to withstand significant loads without considerable deformation. This is reflected in its steep load-displacement curve, which indicates that PC maintains rigidity and effectively supports the finger during healing. In contrast, Nylon has a lower stress value of 54.4 MPa and allows for greater deformation, which may compromise the splint's ability to immobilize the finger effectively. ABS, with a moderate stress value of 45.2 MPa, exhibits a mixed failure mode that can lead to unpredictable performance under varying loads, while PLA, having the lowest stress value of 40.6 MPa, shows significant deformation, making it inadequate for providing the necessary support. Additionally, the brittle failure mode of PC, while potentially concerning in some contexts, ensures that it does not undergo gradual yielding, which is critical for maintaining the integrity of the splint. Overall, the data clearly indicate that PC provides the best combination of strength, stiffness, and reliability for finger splint applications.

6. Conclusion

The mechanical characteristics of patient-specific finger splints made of nylon, polycarbonate (PC), polylactic acid (PLA), and acrylonitrile butadiene styrene (ABS) filament materials are thoroughly examined in this research paper. By combining 3D printing, compression testing, and Finite Element Analysis (FEA), we have been able to gather important information about how these materials work in orthopedic applications. According to our research, Polycarbonate (PC) filament outperformed the other materials in terms of mechanical performance. During the compression test, PC filament showed more uniform directional deformation and a lower maximum principal stress value. Positive mechanical characteristics were also demonstrated by nylon filament, whereas ABS and PLA filaments displayed greater stress concentrations and less even deformation. When choosing appropriate materials for patient-specific finger splints, clinicians and designers can benefit greatly from the comparative analysis of these filament materials. While ABS and PLA filaments may be appropriate for applications where cost-effectiveness or ease of printing is prioritized, PC and nylon filaments offer promising options for fabricating splints that require optimal load distribution and deformation characteristics. Overall, by offering evidence-based insights into the mechanical behavior of 3D-printed finger splints, this study advances orthopaedic care. Through the utilization of Finite Element Analysis (FEA), 3D printing technology, and experimental testing, we have acquired a more profound comprehension of the performance attributes of various filament materials. This has enabled us to make well-informed decisions and optimize splint designs tailored to individual patients. Going forward, more research is necessary to investigate new filament materials, improve manufacturing processes, and find out how well 3D-printed finger splints function over time and are biocompatible. Through interdisciplinary research and collaboration, orthopedic devices can be continuously innovated and refined, leading to improved patient outcomes and quality of life in the field of orthopedic rehabilitation.

The analysis of different filament materials for finger splints reveals significant implications for patient care and comfort, particularly highlighting polycarbonate (PC) as the superior choice due to its optimal mechanical properties. With a maximum principal stress of 61.5 MPa and minimal directional deformation of 0.26 mm, PC offers excellent stability and immobilization, crucial for preventing complications such as malunion during healing. In contrast, materials like polylactic acid (PLA) exhibit higher deformation (0.44 mm) and lower stress (40.6 MPa), which may compromise immobilization and patient safety. The comfort associated with lower deformation materials like PC enhances patient compliance, as a secure and well-fitting splint reduces pressure points and irritation. Furthermore, the durability and impact resistance of PC ensure effective protection against external forces, while ongoing research into innovative materials and smart technologies holds the potential to improve recovery experiences. Overall, selecting materials based on their mechanical performance directly influences healing outcomes, safety, and patient satisfaction in medical applications like finger splints.

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