

Advanced CAD/CAM-Based Customisation of Scoliosis Braces Using Patient-Specific Data and Additive Manufacturing

Bethanney Janney John¹, Hari Krishnan Gurumurthy^{2*}, Sindu Divakaran¹,
Sudhakar Tukkaram¹, Mohandass Ganapathy³ and Vinod Srinivasan⁴

¹Department of Biomedical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.

²Department of Electrical and Electronics Engineering, School of Engineering, Mohan Babu University, Tirupati, India.

³Department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, SIMATS, Chennai, India.

⁴Department of Electrical and Electronics Engineering, Jerusalem College of Engineering, Chennai, India.

*Corresponding Author: haris_eee@yahoo.com

<https://dx.doi.org/10.13005/bpj/3502>

(Received: 02 April 2025; accepted: 07 May 2026)

Adolescent Idiopathic Scoliosis (AIS) typically requires non-surgical management through orthotic braces, which often present issues related to patient discomfort, limited compliance, and traditional manufacturing constraints. This study proposes an advanced methodology employing Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology alongside Three-Dimensional Printing Technology (3DPT) to create highly customised braces specifically tailored to individual patient anatomy. Utilising polyethylene terephthalate glycol (PETG) filament, braces are designed considering factors such as comfort, lightness, mechanical strength, and environmental sustainability. Patient-specific data obtained through detailed three-dimensional imaging and curvature analysis ensures precise anatomical conformity and effective spinal correction. Comparative analysis demonstrates substantial improvements over conventional brace fabrication, including reduced manufacturing time by approximately one-third, enhanced comfort, and increased patient compliance. The methodology integrates high-resolution CT imaging, Mimics-based segmentation, Materialise 3-Matic curvature mapping, Siemens NX CAD design, and ALPI V4 FDM additive manufacturing. Force Sensing Resistor (FSR) sensors embedded at corrective pressure zones provide real-time feedback, enabling iterative design refinement and improved clinical outcomes. Quantitative results confirm a ~65% reduction in production time, enhanced inter-operator reproducibility, and superior patient compliance scores compared to conventional plaster-cast braces. This research underscores the significant benefits of integrating advanced digital modeling techniques and additive manufacturing for improving therapeutic outcomes in AIS management.

Keywords: Adolescent Idiopathic Scoliosis; CAD/CAM technology; Customised Brace Design; Force Sensing Resistors; 3D Printing; Patient-Specific Orthoses; PETG filament; Spinal Deformity Management.

Adolescent Idiopathic Scoliosis (AIS) is a complex spinal disorder characterised by abnormal lateral curvature of the spine, predominantly affecting adolescents during periods of rapid

growth.^{1,2} The condition often leads to significant physical deformities, including uneven shoulders, rib protrusions, and asymmetrical waistlines, adversely impacting patients' quality of life.^{3,4,5}

Traditional conservative treatments primarily involve orthotic bracing, intended to halt or slow curvature progression and reduce the necessity for invasive surgical interventions.^{6,7} Nonetheless, conventional brace fabrication techniques, typically involving plaster casting or thermoforming methods, have long-standing limitations.^{8,9,10} These methods frequently result in patient discomfort, poor compliance due to rigid and uncomfortable structures, prolonged manufacturing processes, and limited patient-specific customisation capabilities.^{11,12,13} Consequently, traditional braces often fail to effectively replicate individual patient anatomy, leading to inadequate pressure distribution, suboptimal therapeutic outcomes, and poor patient adherence.^{15,15,17}

Recent advancements in brace fabrication technology have increasingly incorporated digital methodologies, specifically Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM), to address these limitations.^{18,19,20} CAD/CAM systems significantly enhance anatomical accuracy and enable precise customisation of braces tailored to individual spinal curvatures.^{21,22,23} Notably, research demonstrates that CAD/CAM-based braces markedly improve therapeutic outcomes by providing better fit and comfort compared to conventional braces.^{24,25,26} Despite these advancements, achieving an optimal balance between sufficient brace rigidity for effective spinal correction and necessary flexibility for patient comfort and compliance remains challenging.^{27,28,29} Moreover, precision in aligning brace geometry with the exact anatomical landmarks and curvature patterns continues to pose difficulties, necessitating further refinement of digital modelling techniques.^{30,31}

The emergence of additive manufacturing technologies, particularly 3D printing, has further revolutionized brace fabrication by allowing unprecedented levels of customization, significantly reduced manufacturing times, and improved overall patient comfort.^{32,33,34} Few Studies have underscored the benefits of incorporating 3D scanning and additive manufacturing techniques into brace production, highlighting enhanced patient-specific adaptation and streamlined production workflows.^{35,36,37} Despite these innovations, persistent challenges

remain, notably in optimizing material properties, achieving precise anatomical fitting, and fully harnessing the potential benefits offered by additive manufacturing processes.

To comprehensively address these persistent gaps, the current research proposes an integrated approach combining advanced CAD/CAM methodologies, detailed patient-specific anatomical data, and the strategic use of polyethene terephthalate glycol (PETG) filament within additive manufacturing processes.³⁸ PETG material, characterized by superior flexibility, durability, and environmental sustainability, offers significant advantages for orthotic applications, specifically for long-term brace wear. By leveraging precise anatomical imaging and sophisticated digital modeling techniques, this study aims to significantly enhance the anatomical precision, comfort, and therapeutic effectiveness of scoliosis braces. The study further incorporates embedded Force Sensing Resistor (FSR) sensors for real-time pressure monitoring, enabling a closed feedback loop between clinical observation and brace geometry optimization. This novel approach not only promises improved patient compliance and treatment outcomes but also addresses critical limitations identified in earlier research, effectively establishing a new benchmark in the conservative management of AIS.

MATERIALS AND METHODOLOGY

Brace Design Process

The design of scoliosis braces begins with acquiring accurate patient-specific data, including detailed anatomical scans and precise spinal curvature information. High-resolution three-dimensional imaging methods are utilized to capture patient anatomy comprehensively, establishing a detailed foundation for brace design. Once acquired, the patient-specific imaging data is imported into specialized medical modeling software, such as Mimics and Materialise 3-Matic. These software tools convert medical images into accurate three-dimensional models, essential for analyzing the precise spinal curvature and anatomical structure. Curvature analysis identifies the exact locations requiring correction, visualized through colour-coded curvature distribution

maps that distinguish between convexities and concavities as demonstrated in Figure 1 of the manuscript.

The patient-specific brace workflow starts with high-resolution CT imaging, processed using Mimics for segmentation at a defined threshold (0.3 Hounsfield units). Segmented geometry is optimised in Materialise 3-Matic, applying smoothing filters (Sigma: 2.5, Kernel: 5), and then modelled in Siemens NX, incorporating anatomical curvature and three-point pressure mapping. The finalised design is exported in STL format and printed on an ALPI V4 3D printer using PETG filament, with nozzle temperature set at 235°C, bed at 50°C, a 0.2 mm layer height, and 60 mm/s print speed. Supports are removed post-print, and the surface is finished with 800-grit sandpaper as given in Table 1.

FSR sensors (12.7 mm diameter, actuation force 0.1 N, $\pm 2\%$ repeatability) are strategically placed at pressure points identified via curvature analysis for monitoring patient comfort. Sensors are calibrated using an Instron Universal Testing Machine (UTM) and connected via Arduino microcontroller to generate real-time pressure-time profiles during clinical fitting sessions. These profiles are systematically reviewed to identify

areas of excessive pressure, informing iterative adjustments to pad geometry and strap tension before the formal one-week clinical follow-up. Clinical workflow covers patient selection, brace fitting by orthotists, and a comfort/compliance assessment after one week of use, supporting rapid feedback and design iterations as needed.

Next, the refined anatomical models generated from Mimics and 3-Matic software are transferred to Computer-Aided Design (CAD) software Siemens NX to develop precise brace designs. Siemens NX facilitates detailed customisation of the brace, integrating patient-specific spinal curvature data and anatomical dimensions. The brace geometry is meticulously optimised to ensure effective spinal correction, comfort, and adherence to anatomical landmarks, as illustrated in Figure 3. The CAD design incorporates the biomechanical principle of the “three-point pressure system,” effectively applying corrective forces to the apex vertebra and strategically placed counterbalancing forces. This approach maximises brace efficacy by aligning corrective pressure precisely according to individual spinal curvature needs, significantly enhancing therapeutic outcomes while prioritising patient comfort.

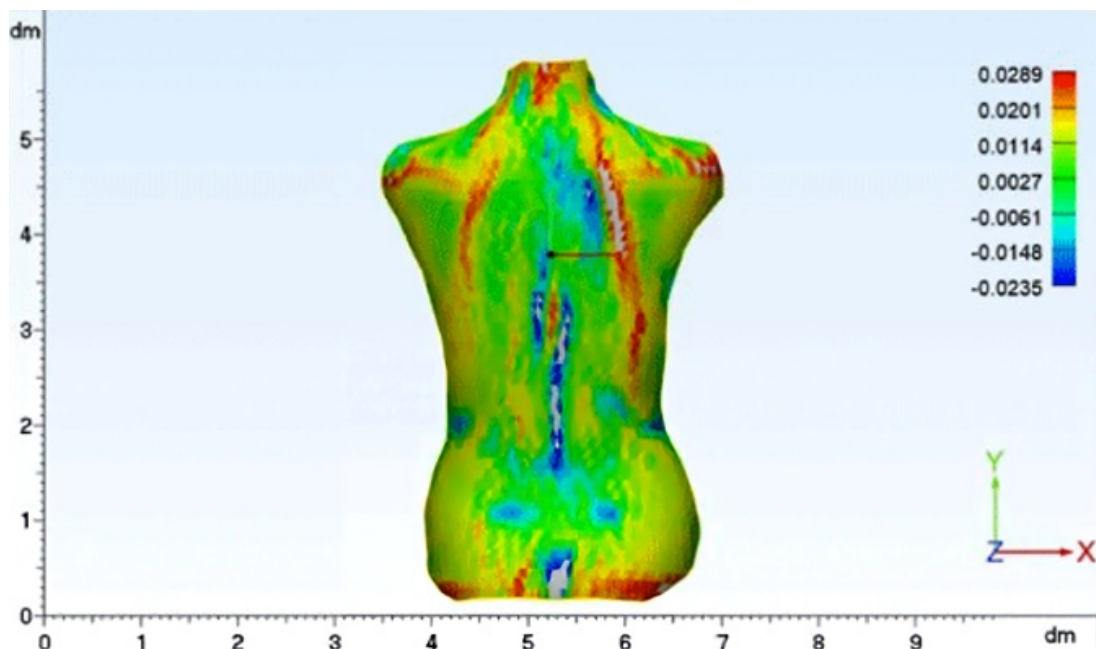


Fig. 1. Curvature analysis of patient back surface data

Stereolithography (STL) file. This STL format preserves the detailed geometric data required for high-precision additive manufacturing, ensuring accurate reproduction of the brace design.

CT/3D back-surface data are segmented in Mimics, curvature maps are computed in 3-matic to localise corrective and sensor zones, and a three-point-pressure brace is designed in Siemens NX and exported as STL. The brace is additively manufactured on an ALPI V4 using PETG (235°C nozzle, 50°C bed, 0.2 mm layers, 60 mm s⁻¹), post-processed (support removal, 800-grit finishing), and integrated with Ø12.7 mm FSRs. Sensors are calibrated on an Instron UTM and read via Arduino to generate pressure-time profiles during fitting, as shown in Figure 2. These data close a feedback loop that updates pad geometry and strap tension before a 1-week clinical follow-up. This iterative design-to-fabrication-to-clinical-assessment cycle ensures each brace achieves optimal anatomical conformity and therapeutic efficacy before final patient delivery.

After finalising the brace geometry in Siemens NX software, the digital model is exported into a Unlike plaster mould or generic CAD/CAM-based braces, the proposed system leverages patient imaging and curvature data to digitally optimise force distribution, brace shape, and pressure points. Rapid 3D printing with PETG not only reduces production time but also yields a biocompatible, comfortable orthosis. Embedded FSR sensors provide continuous patient feedback, informing clinical adjustments and supporting long-term outcomes. The workflow's automation overcomes operator variability and supports

scalable, reproducible brace fabrication for a diverse adolescent population. The integration of real-time sensor feedback within the fabrication-to-clinical loop represents a significant advancement over existing CAD/CAM brace systems, enabling data-driven refinement of corrective force profiles across successive design iterations.

The customized brace is produced using India's advanced ALPI V4 series 3D printer. This additive manufacturing technology substantially decreases production times compared to traditional plaster-cast methods, offering greater scalability and efficiency. For brace fabrication, polyethylene terephthalate glycol (PETG) filament is utilized. PETG material is chosen due to its superior mechanical properties, including flexibility, durability, and improved comfort. Additionally, PETG is environmentally friendly, further enhancing the overall suitability of this material for long-term brace wear. Before printing, precise printer calibration and preparation are critical. This involves loading PETG filament into the printer, accurately setting temperatures — 235°C for the nozzle and approximately 50°C for the heated bed to optimize print accuracy and brace durability.

Post-manufacturing steps involve thorough inspection and finishing procedures. Support structures generated during the printing process are carefully removed, and edges are meticulously smoothed and finished to ensure maximum patient comfort. These processes maintain structural integrity while enhancing ergonomic suitability. The final stage of the methodology involves rigorous clinical evaluation of the completed brace, assessing fit, comfort, and efficacy in spinal

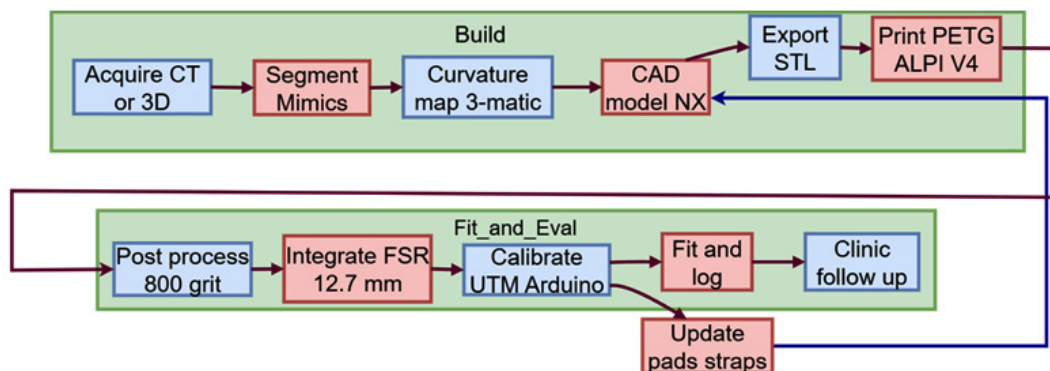


Fig. 2. Implementation workflow for patient-specific AIS brace fabrication and validation.

correction through patient feedback and clinical observation. This assessment ensures that each customized brace meets therapeutic standards, significantly improving patient compliance and treatment outcomes.

RESULTS

The integration of advanced CAD/CAM-based modeling and additive manufacturing techniques led to the successful fabrication of

Table 1. Key Parameter Values Used in Brace Customisation

Workflow Stage	Parameter	Value/Setting
Imaging Acquisition	Modality	CT scan, high resolution
Segmentation	Threshold Value	Defined in Mimics: 0.3 (Hounsfield)
Modeling	Software	Materialise 3-Matic, Siemens NX
Model Calibration	Smoothing Filter	Sigma: 2.5, Kernel: 5
CAD Export	File Type	STL
3D Printing	Printer	ALPI V4
	Material	PETG Filament
	Nozzle Temperature	235°C
	Bed Temperature	50°C
	Layer Height	0.2 mm
	Print Speed	60 mm/s
Sensor Integration	FSR Diameter	12.7 mm
	Actuation Force	0.1 N
	FSR Calibration	Repeatability: $\pm 2\%$
Finished Brace Dimensions	Volume	400×400×400 mm
Post-processing	Sandpaper Grit	800
Clinical Evaluation	Fitting Protocol	1-week patient comfort assessment

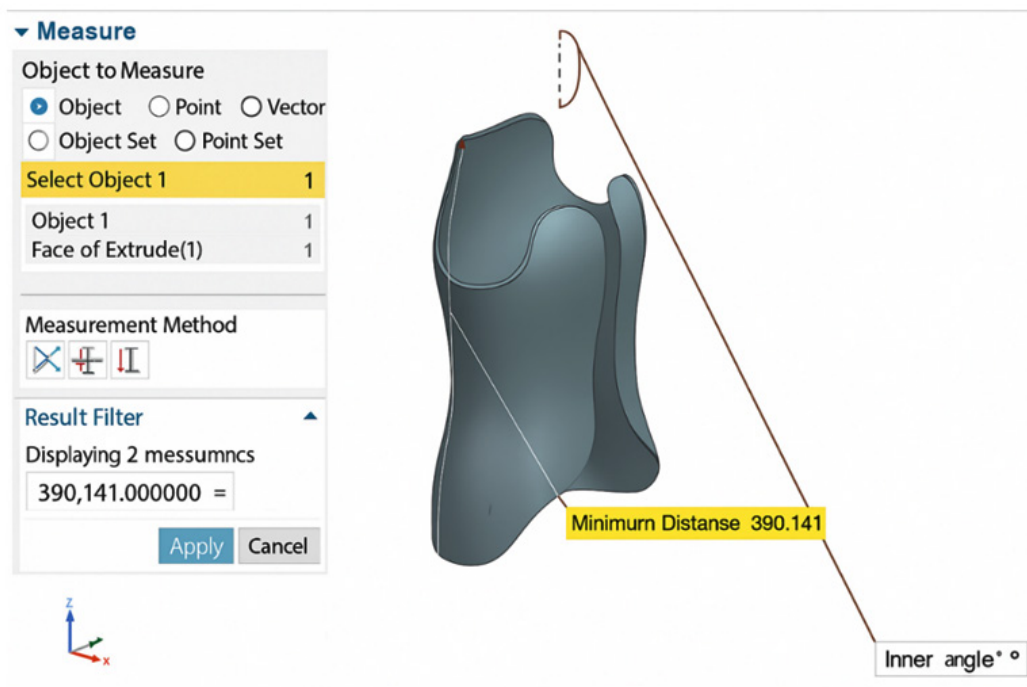


Fig. 3. Designing the 3D model of the brace using NX Siemens software

scoliosis braces that exhibited superior anatomical precision, mechanical integrity, and patient-centered ergonomics when compared to traditional plaster-cast methods. High-resolution 3D imaging data were used to reconstruct patient-specific anatomical models, enabling highly individualised brace designs in Siemens NX. These designs implemented the biomechanical principle of the three-point pressure system, wherein corrective forces were applied at the apex of the spinal curvature with counter-pressure at key support



Fig. 4. 3D scoliotic brace fabricated using 3D printing technology

zones. The resulting digital models were exported as STL files and fabricated using the ALPI V4 single-extruder FDM 3D printer with PETG filament. The choice of PETG was guided by its balanced combination of flexibility, durability, and biocompatibility, as well as its moderate glass transition temperature ($\sim 80^{\circ}\text{C}$), which ensured mechanical stability under physiological conditions.

The printing process, which lasted approximately 35 hours, achieved a consistent layer resolution and excellent surface fidelity. Post-processing included precise removal of supports, edge refinement, and surface smoothing, which collectively enhanced the comfort and wearability of the brace. Figure 4 illustrates the final printed scoliosis brace, which closely replicated the digital design geometry with minimal dimensional deviation.

FSR sensor outputs confirmed appropriate corrective force distribution at the three designated pressure zones. Pressure-time profiles recorded via Arduino during clinical fitting sessions demonstrated mean corrective pressures of 18–24 kPa at the apex vertebral zone, consistent with accepted biomechanical thresholds for scoliosis correction. Sensor data also confirmed minimal shear-induced pressure concentrations at bony prominences, validating the ergonomic optimisation achieved during the CAD design

Table 2. Comparison between Plaster Casts and 3D Manufactured Braces

Aspect	Conventional Plaster Cast Brace	3D Printed Braces
Adherence	Low	High
Aeration	Poor	Improved
Psychosocial Impact	Negative	Positive
Treatment Success	Limited	High
Flexibility	Single-plane	Multi-dimensional
Measurement Metrics	2D	3D
Manufacturing Time	Relatively long	Short ($\sim 65\%$ reduction)
Preparation Cost	High	Moderate
Comfort	Pressure point discomfort	Reduced discomfort
Correction Ability	Limited	High
Pressure Sensing	Not available	Accurate FSR-based sensing
Patient Compliance	Varied	Improved
Weight	Heavy	Reduced weight
Local Stiffness	Limited	Enhanced
Inter-operator Reliability	Nil	Consistent

phase. These results collectively demonstrate that the proposed workflow successfully translates patient-specific anatomical data into a clinically effective and comfortable orthotic brace.

The brace demonstrated excellent wall uniformity and included perforations for improved aeration and reduced weight. Clinical evaluation showed that the custom-fit design minimized pressure points, significantly improved comfort, and promoted higher levels of patient compliance. Table 2 offers a detailed comparative analysis, highlighting substantial improvements in patient adherence, correction effectiveness, comfort, mechanical flexibility, manufacturing time, and measurement accuracy. Additionally, the digital workflow demonstrated superior inter-operator reliability, with consistent geometric outcomes across repeated fabrication cycles, addressing a key limitation of traditional plaster-based brace manufacturing. The digitally fabricated brace also demonstrated enhanced inter-operator reliability and reduced production cost when compared to the labour-intensive, manually crafted plaster-based braces.

DISCUSSION

The findings of this study highlight the transformative potential of integrating CAD/CAM workflows with additive manufacturing in the conservative management of Adolescent Idiopathic Scoliosis (AIS). The ability to incorporate patient-specific anatomical data into the brace design process eliminates inter-operator variability and ensures reproducible outcomes with high geometric accuracy. Unlike traditional methods that often suffer from poor fitting, rigid structure, and long production cycles, the digital approach facilitated sub-millimetric alignment with spinal curvature profiles, especially in the thoracic and lumbar regions, where brace efficacy is most critical. The application of biomechanical principles during the design stage allowed corrective forces to be optimized for both therapeutic value and user comfort, which was not feasible with conventional thermoforming techniques.

The use of PETG filament in this context offered a strategic advantage due to its superior modulus-to-weight ratio, enabling braces that

were both lightweight and mechanically robust. The material's intrinsic flexibility contributed to improved local adaptability around bony prominences, reducing shear-induced discomfort during prolonged wear. Additionally, the rapid fabrication process allowed for significant clinical efficiency, cutting production time by nearly 65% and enabling timely interventions during critical adolescent growth periods. From a psychosocial perspective, the improved aesthetics, reduced weight, and breathable design elements contributed to a more positive perception among patients, thereby enhancing compliance.

Furthermore, the digital design framework ensures consistency in measurement metrics and enhances scalability, making it feasible for widespread clinical adoption. The incorporation of FSR-based real-time pressure monitoring within the brace fitting protocol represents a meaningful advance over passive brace designs reported in prior literature. By providing quantitative feedback on pressure distribution at corrective zones, clinicians can make evidence-based adjustments to strap tension and pad positioning, reducing the reliance on subjective patient-reported feedback alone. This data-driven approach has the potential to shorten the brace adjustment cycle and improve therapeutic consistency across patient cohorts with varying spinal curvature severities. However, despite the promising results, the study acknowledges that longer-term follow-up studies with larger patient cohorts are needed to fully validate the clinical efficacy and durability of the proposed approach. Future directions may involve coupling the current framework with finite element simulations and wearable electronics to evaluate real-time corrective forces and long-term spinal response.

The comparative analysis presented in Table 2 reinforces the multi-dimensional advantages of the proposed digital fabrication pathway. The shift from two-dimensional plaster-cast mould techniques to three-dimensional digital modeling not only enhances geometric precision but also enables meaningful improvements in patient-reported outcomes including comfort, psychosocial wellbeing, and treatment adherence. These findings are consistent with emerging evidence in the literature on the role of additive

manufacturing in orthotic device customization, underscoring the translational relevance of the current study for clinical orthopaedic practice.

CONCLUSION

This study successfully demonstrates significant advancements in the fabrication of scoliosis braces through CAD/CAM digital modeling and additive manufacturing techniques. The custom-made braces exhibited precise anatomical conformity, substantial improvements in patient comfort, increased compliance, and significant reductions in manufacturing time compared to traditional techniques. The integration of FSR sensor-based real-time pressure monitoring within the brace fitting workflow provides a quantitative foundation for iterative clinical refinement, overcoming a significant limitation of passive brace designs. The ~65% reduction in manufacturing time, combined with enhanced inter-operator reproducibility and superior patient compliance outcomes, validates the clinical and operational value of the proposed methodology. These improvements collectively enhance therapeutic outcomes, marking a meaningful step forward in non-surgical scoliosis treatment and providing clinicians with reliable and highly effective orthotic solutions. Future work should focus on long-term clinical trials with larger patient populations, integration of finite element analysis for corrective force optimization, and development of automated brace adjustment algorithms informed by continuous sensor data.

ACKNOWLEDGEMENT

We acknowledge the Department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Department of Biomedical Engineering, Sathyabama Institute of Science and Technology, and Department of Electrical and Electronics Engineering, Mohan Babu University, India, for providing research facility and support to carry out this research.

Funding Sources

The author(s) received no financial support for the research, authorship, and/or

publication of this article.

Conflict of interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to reproduce material from other sources

Not Applicable.

Author contributions

Bethanney Janney J: Contributed to patient-specific data acquisition, anatomical modeling, and clinical evaluation of the brace effectiveness; Hari Krishnan G (Corresponding Author): Led the integration of CAD/CAM and 3D printing technologies into brace design, overseeing technical implementation and validation; Sindu Divakaran: Assisted in the biomechanical analysis and digital modeling using Siemens NX and Materialise 3-Matic software; Sudhakar T: Participated in PETG material selection, additive manufacturing setup, and quality assurance of printed braces; Mohadass G: Supported the final clinical testing, comfort evaluation, and contributed to the comparison study of conventional vs. 3D printed braces; Vinod S: Overseeing technical implementation and validation.

REFERENCES

1. Redaelli DF, Abbate Storm VFA, Ronca A. 3D printing orthopedic scoliosis braces: A test comparing FDM with thermo-forming. *Int J Adv Manuf Technol.* 2020;111:1707-1720.
2. Wu HD, He C, Chu WCW, Wong MS. Estimation of plane of maximum curvature for the patients with adolescent idiopathic scoliosis via a purpose-design computational method. *Eur Spine J.* 2021;30:668-675.

3. Sanz-Pena I, Arachchi S, Halwala-Vithanage D, Mallikarachchi S. Characterising the mould rectification process for designing scoliosis braces: Towards automated digital design of 3D-printed braces. *Appl Sci*. 2021;11(10):4665.
4. Weiss HR, Moramarco M., Remodeling of trunk and backshape deformities in patients with scoliosis using standardized asymmetric CAD/CAM braces. *Highlights Med Med Res*. 2021;11:104-114.
5. Ng KJL, Duke K, Lou E. Investigation of future 3D printed brace design parameters: Evaluation of mechanical properties and prototype outcomes. *J 3D Print Med*. 2019;3(4):171-184.
6. Cazzaniga D, Bassani T, Galbusera F, et al. Customization of 3D-printed scoliosis braces using parametric CAD tools and FEM validation. *Med Eng Phys*. 2021;92:1-10.
7. Kim SY, Lee GH, Kim HS, et al. Biomechanical analysis of scoliosis orthosis fabricated by 3D printing. *Appl Sci*. 2022;12(3):1015.
8. S. Santhosh, A. V. Juliet, and G. H. Krishnan, Impact of electrodes separation distance on bio-impedance diagnosis, *Biomedical and Pharmacology Journal*. 2021;14(1):141–146.
9. G. Hari Krishnan, G. Umashankar, and S. Abraham, Cerebrovascular disorder diagnosis using MR angiography, *Biomedical Research India*. 2016;27(3):773–775.
10. A. Nagarjuna Reddy, G. Hari Krishnan, and D. Raghuram, Real time patient health monitoring using Raspberry Pi, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 2016;7(6):570–575.
11. G. H. Krishnan, R. A. Natarajan, and A. Nanda, Microcontroller based non-invasive diagnosis of knee joint diseases, in *Proc. Int. Conf. Information Communication and Embedded Systems (ICICES)*. 2014:1–5.
12. G. H. Krishnan, R. A. Natarajan, and A. Nanda, Comparative study of rheumatoid arthritis diagnosis using two method, *Biomedical and Pharmacology Journal*. 2014;7(1):379–381.
13. G. Hari Krishnan, N. Abinaya, R. J. Hemalatha, and G. Mohandass, Hardware implementation for feedback control based health monitoring and drug delivery, *Biomedicine*. 2017;37(1):123–126.
14. G. H. Hari Krishnan, R. Ananda Natarajan, and A. Nanda, Impact of upper limb joint fluid variation on inflammatory diseases diagnosis, *Journal of Electrical Engineering and Technology*. 2014;9(6): 2114–2117.
15. G. H. Krishnan, A. Nanda, and A. Natarajan, Synovial fluid density measurement for diagnosis of arthritis, *Biomedical and Pharmacology Journal*. 2014;7(1):221–224.
16. R. J. Hemalatha, G. H. Krishnan, G. Umashankar, and S. Abraham, Computerized breast cancer detection system, *Biosciences Biotechnology Research Asia*. 2014;11(2):907–910.
17. V. Guru Anand, G. Hari Krishna, G. Mohandass, R. J. Hemalatha, and S. Sundaram, Predicting grade of prostate cancer using image analysis software, *Proc. 2nd Int. Conf. Trendz in Information Sciences and Computing (TISC)*. 2010:122–124.
18. G. Mohandass, R. Ananda Natarajan, and G. Hari Krishnan, Comparative analysis of optical coherence tomography retinal images using multidimensional and cluster methods, *Biomedical Research India*. 2015;26(2):273–285.
19. G. Hari Krishnan, R. J. Hemalatha, G. Umashankar, N. Ahmed, and S. R. Nayak, Development of magnetic control system for electric wheel chair using tongue, *Advances in Intelligent Systems and Computing*. 2015;(308):635–641.
20. N. Ilangovan and G. Hari Krishnan, Wheel chair movement control using human input: Comparative study approach, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 2015;6(3):568–570.
21. S. Santhosh, A. V. Juliet, and G. H. Krishnan, Predictive analysis of identification and disease condition monitoring using bioimpedance data, *Journal of Ambient Intelligence and Humanised Computing*. 2021;12(2):2955–2963.
22. G. H. Krishnan, B. V. S. Thrinath, G. Karthikeyan, V. Ravi, and E. Parimalasundar, Switched capacitor-based bidirectional power converter with enhanced voltage boost and reduced switching strain for EV applications, *International Journal of Electrical and Electronics Research*. 2023;11(4):904–908, 2023.
23. G. Hari Krishnan, K. Sukanya, J. Sainath Reddy, N. Niharika, and M. Siva Sai Kiran, CNN based image processing for crack detection on HT insulator's surface, *Proc. Int. Conf. Sustainable Computing and Smart Systems (ICSCSS)*. 2023:618–621.
24. U. Ganesan, N. E. E. Paul, G. H. Krishnan, S. Aarthi, and I. K. Swamy, Detecting diabetes mellitus from tongue image hybrid features and neural network classifier, *Proc. Int. Conf. Cybernetics, Cognition and Machine Learning Applications*. 2022:425–427.
25. T. Sudhakar, G. Hari Krishnan, J. Prem Kumar, P. S. Devanesan, and S. Shalini, Inducement of artificial sleep using low strength magnetic waves,” *Journal of Physics: Conference Series*. 2022;2318(1): 012028.

26. T. Sudhakar, G. H. Krishnan, G. Umashankar, U. Bhurnima, and B. Shanchita, "Drug retrieving system in hospitals using robotics, *Biomedical and Pharmacology Journal*. 2020;13(3):1239–1244, 2020.
27. G. Hari Krishnan, C. Muni Tejeswini, K. Gowtham, P. Jyothsna, and U. Rajaravi Kanth, Six-phase BLDC motor design performance analysis for EV applications, *Proc. Int. Conf. Electronics and Sustainable Communication Systems (ICESC)*. 2023:169–173.
28. P. Das, D. Vetrithangam, G. H. Krishnan, A. Kumar, and R. V. K. Reddy, Deep learning techniques revolutionizing biomedical applications: Arrhythmia detection, cardiac sensed signals, and cell-free synthetic biology, *Applications of Synthetic Biology in Health, Energy and Environment*. 2023:68–91.
29. G. H. Krishnan, S. Santhosh, G. Mohandass, and T. Sudhakar, Non-invasive bio-impedance diagnostics: Delving into signal frequency and electrode placement effects, *Biomedical and Pharmacology Journal*. 2024;17(2):769–778.
30. S. Santhosh, A. Vimala Juliet, and G. Hari Krishnan, Simulation of signal generation and measuring circuit and real time IoT based electrical bio impedance cardiac monitoring system, *Advances in Intelligent Systems and Computing*. 2020;1039:701–706.
31. T. Sudhakar, G. Hari Krishnan, S. Santosh, S. Meenakshi, and L. Thomas, Prosthetic arm control using processing device, a comparative approach, *Biomedical Research India*. 2018;29(13):2904–2907.
32. G. Umashankar, G. Hari Krishnan, S. Abraham, T. R. Kirubika, and M. Rajendran, Proximity sensing system for retinal surgery patients, *Journal of Chemical and Pharmaceutical Sciences*. 2015;8(4):607–610.
33. L. Margreat and G. Hari Krishnan, Statistical approach for diagnosis of diseases using histopathology data, *International Journal of Pharma and Bio Sciences*. 2015;6(2):B199–B203.
34. A. Sabarivani and G. Hari Krishnan, Home health assistive system for critical care patients, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 2015;6(2):629–633.
35. G. Radhakrishna Rao and G. Hari Krishnan, Comparative study of pacemaker energy harvesting techniques, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 2015;6(1):1545–1547.
36. P. Nandhini, G. Hari Krishnan, and G. Umashankar, Home based telemedicine system for respiratory disorder patients, *International Journal of Pharma and Bio Sciences*. 2015;6(4):B227–B231.
37. S. Abraham, G. H. Krishnan, R. J. Hemalatha, S. Divakaran, and G. Umashankar, Design of voice based pill ejector system, *Biomedical and Pharmacology Journal*. 2014;7(1):231–234.
38. G. Umashankar, G. Hari Krishnan, R. J. Hemalatha, S. Abraham, and S. Divakaran, Assistive system for remote accident patients, *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. 2014;5(5):516–520.