From Plaster to Pixels:

Revisiting the Sustainability of Rapid Manufacturing in Orthotics & Prosthetics (2011–2026)

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Abstract

In 2011, rapid manufacturing technologies such as Selective Laser Sintering (SLS) and early forms of 3D printing were emerging within Orthotics and Prosthetics (O&P) as potential alternatives to traditional fabrication methods. Early research suggested these technologies could improve efficiency, consistency, and long-term scalability. However, significant concerns existed regarding cost, material limitations, and clinical feasibility.

This paper revisits an original research proposal written in 2011 that questioned whether rapid manufacturing was truly sustainable within O&P. With fifteen years of technological advancement and clinical integration now available for analysis, this updated white paper examines how digital manufacturing has actually evolved within the profession.

The findings suggest that while rapid manufacturing did not replace traditional fabrication methods, it became part of a broader digital transformation that reshaped workflow design, communication, documentation, and clinical decision-making throughout O&P.

Rather than disruption through replacement, the profession experienced gradual integration.

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1. Introduction & Historical Context

When I first entered the O&P profession more than two decades ago, nearly every device in the laboratory was fabricated through traditional hands-on techniques. Workflows revolved around plaster casting, positive mold modification, vacuum forming, and composite lamination. The environment was highly manual and heavily dependent on technician skill and experience.

My own introduction to the profession began on the technical side of the lab. Like many who entered O&P during that era, I started with the foundational work that kept fabrication moving: emptying trash bins, pouring plaster molds, breaking apart casts, and assisting clinicians wherever needed. Over time, I gradually became more involved in fabrication itself, eventually pursuing formal technical education through the orthotic technician program at Century College before later attending the orthotic practitioner program at Northwestern University Prosthetics-Orthotics Center (NUPOC).

It was during my time at NUPOC that I was first exposed to additive manufacturing technologies. In the machine room sat a Stratasys 3D printer, representing one of the earliest examples many of us had seen of digital manufacturing potentially entering clinical O&P workflows.

That experience led to an important question:

> Could rapid manufacturing realistically become sustainable within Orthotics and Prosthetics when compared to traditional fabrication methods?

At the time, additive manufacturing generated significant interest within engineering and research communities. Early literature suggested that technologies such as Selective Laser Sintering (SLS) and emerging forms of 3D printing had the potential to improve fabrication consistency, reduce labor requirements, and enable more advanced device geometries.

However, many practical limitations were immediately apparent.

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2. The State of Technology in 2011

In 2011, rapid manufacturing technologies remained largely experimental within O&P.

Selective Laser Sintering systems offered the ability to manufacture complex geometries using layered powder materials such as nylon and polycarbonate. At the same time, early binder jet and extrusion-based systems were beginning to attract attention for possible orthotic and prosthetic applications.

The potential advantages appeared substantial:

- Digital reproducibility
- Reduced dependence on physical mold storage
- Increased geometric complexity
- Faster reproduction of existing designs
- Expanded design flexibility

Despite the optimism, significant barriers limited practical adoption:

- High equipment costs

- Limited clinically viable materials
- Long production times
- Inconsistent surface quality
- Significant post-processing requirements
- Limited durability data

Some early studies reported fabrication times exceeding 30 hours for printed ankle-foot orthoses, compared to only a few hours using traditional fabrication workflows.

At the same time, CAD/CAM systems were already gaining traction within portions of the profession, although they were primarily being used to carve foam positive molds rather than directly manufacture finished devices.

As a result, rapid manufacturing in 2011 was best understood as a promising but immature technology.

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3. Early Assumptions About Digital Manufacturing

During the early 2010s, many within O&P believed digital manufacturing would eventually replace large portions of traditional fabrication.

The logic seemed straightforward.

If patient anatomy could be captured digitally through scanning technology, and device designs could be developed using CAD software, it seemed reasonable to assume fabrication itself would eventually become fully digital.

Devices such as ankle-foot orthoses, cranial remolding orthoses, and prosthetic sockets were frequently discussed as candidates for fully additive manufacturing workflows.

These ideas were not without merit. The advantages of digital workflows were increasingly obvious:

- improved consistency
- digital design storage
- easier reproduction
- streamlined communication
- enhanced documentation

However, many of the early predictions underestimated the complexity of clinical workflows and the importance of hands-on clinical decision-making.

One of the lessons from the past fifteen years is that technological advancement alone rarely transforms clinical care.

Sustainable adoption occurs when new technologies successfully align with workflow design, practitioner behavior, communication systems, fabrication realities, and day-to-day patient care.

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4. What Actually Happened (2011–2026)

Over the past fifteen years, digital technologies have significantly influenced O&P, but not through direct replacement of traditional fabrication.

Instead, the profession experienced workflow integration.

3D scanning became widely adopted, allowing clinicians to quickly capture patient anatomy while improving reproducibility and long-term digital storage.

CAD-based design systems improved communication between clinics and fabrication facilities by replacing physical mold shipment with digital file transfer.

At the same time, traditional fabrication methods remained essential.

Thermoforming, lamination, and manual modification continue to play a major role throughout the profession because they remain efficient, reliable, and adaptable to clinical realities.

Looking back, one of the most important observations is that the most significant transformation did not occur at the fabrication stage.

The real transformation occurred within the surrounding systems that support patient care and device delivery:

- workflow design
- communication systems
- documentation
- reproducibility
- digital collaboration
- clinical decision support
- coordination between clinics and fabrication facilities

Additive manufacturing ultimately became one component within a broader digital ecosystem rather than a universal replacement for existing fabrication methods.

This distinction matters.

The profession did not experience technological replacement.

It experienced operational integration.

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5. Practical Lessons for Modern Clinics

One of the clearest lessons from the past fifteen years is that successful digital adoption rarely begins with purchasing a 3D printer.

The more valuable starting point is developing a strong understanding of digital workflow infrastructure.

This includes:

- 3D scanning
- CAD-based design
- digital file management
- communication systems
- workflow standardization

For many clinics, partnering with third-party manufacturing providers represents a practical and lower-risk entry point into additive manufacturing.

This approach allows clinicians to evaluate:

- workflow integration
- material performance
- device design concepts
- production consistency

without significant capital investment.

Clinics that successfully integrate digital technologies often discover that the greatest value is not necessarily fabrication itself, but rather the consistency, communication, and operational efficiency created throughout the broader workflow.

In many cases, digital integration improves not only fabrication planning, but also interdisciplinary communication, documentation quality, patient tracking, and long-term reproducibility.

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6. The Role of Digital Workflows in Cranial Orthotics

One area where digital technologies have had a particularly visible impact is cranial remolding orthoses.

Over the past decade, digital scanning and CAD-based design systems have significantly improved:

- anatomical data capture

- longitudinal monitoring
- design consistency
- communication between clinicians and fabrication teams

Even when final devices continue to rely on traditional thermoforming techniques, digital workflows have enhanced documentation, reproducibility, and treatment monitoring.

This highlights an important principle within O&P:

The value of digital integration is often found less in replacing fabrication and more in improving the systems surrounding clinical decision-making.

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7. Future Outlook

Looking forward, the next phase of transformation within O&P will likely be defined less by fabrication technology itself and more by how digital tools become integrated into larger clinical and operational systems.

One of the most significant developments will likely involve parametric and semi-automated design systems capable of generating baseline device designs using anatomical landmarks, biomechanical principles, and treatment objectives.

These systems may help reduce variability while improving consistency between clinicians and fabrication workflows.

Artificial intelligence-assisted design tools may also begin playing a larger role within O&P workflows.

By analyzing large datasets of anatomical scans, device geometries, treatment outcomes, and workflow patterns, future systems may assist clinicians in identifying design parameters, trim lines, pressure relief zones, and correction strategies based on similar patient presentations.

Importantly, these systems are unlikely to replace clinical judgment.

Instead, they may function as decision-support tools that help improve reproducibility, efficiency, and workflow consistency while preserving clinical intent.

Hybrid manufacturing approaches will also likely continue defining the profession.

Rather than replacing traditional fabrication, additive manufacturing will increasingly complement existing workflows by supporting:

- rapid prototyping
- complex geometries
- design iteration

- specialized manufacturing applications

At the same time, traditional fabrication knowledge will remain essential.

One of the profession's ongoing challenges will be ensuring clinicians are trained not only to operate digital tools, but also to understand how those tools influence workflow design, patient interaction, and clinical outcomes.

The future of O&P will not be defined by a single technology.

It will be defined by how effectively digital systems integrate into workflows that improve consistency, communication, scalability, and patient care.

The organizations that adapt most successfully will likely be those that understand digital transformation as a systems challenge rather than simply a fabrication upgrade.

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8. Conclusion

The original question posed in 2011 asked whether rapid manufacturing was sustainable within Orthotics and Prosthetics.

Fifteen years later, the answer appears more nuanced than many early predictions suggested.

Rapid manufacturing did not replace traditional fabrication methods.

Instead, it became part of a broader digital transformation that reshaped how clinicians design, document, communicate, and manufacture patient-specific devices.

The evolution of O&P manufacturing was not defined by sudden disruption.

It was defined by gradual integration.

After more than twenty-five years in the profession, it has been fascinating to watch these technologies evolve from experimental concepts into increasingly practical clinical tools.

The next phase of O&P innovation will likely depend not on whether digital technologies exist, but on how effectively clinicians, technicians, educators, and organizations integrate those technologies into systems that improve care delivery, operational consistency, and long-term clinical scalability.

The past fifteen years demonstrated that technology alone does not transform a profession. Sustainable progress occurs when tools, workflows, education, and clinical decision-making evolve together.

About the Author

Jose L. Gonzales Jr., CO, LO, has worked in the Orthotics & Prosthetics profession for more than twenty-five years with a clinical focus on pediatric orthotics and cranial remolding orthoses.

His work has increasingly focused on digital workflows, additive manufacturing, operational systems, and the evolving relationship between technology and clinical practice.

He is the founder of ForgeAxis, an emerging initiative focused on structured systems intelligence, workflow integration, and modern operational frameworks within healthcare and manufacturing.

Companion Publication

A companion article summarizing portions of this paper is scheduled for publication in the August 2026 issue of The O&P EDGE.

Additional ForgeAxis research publications and open-access resources are currently in development.

https://www.forgeaxis.co/edge-white-paper