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Sustainable material selection for immobilization devices: a comparative analysis of plaster casts and PLA

Seleção sustentável de materiais em dispositivos de imobilização: análise comparativa entre gesso hospitalar e PLA

Bárbara Tatiele Santos
Universidade Federal do Rio Grande do Sul
ORCID 0009-0007-4700-3144
barbara.santos.designer@gmail.com

Clariana Fischer Brendler
Universidade Federal do Rio Grande do Sul
ORCID 0000-0001-9309-2175
clafischer@hotmail.com

Jocelise Jacques de Jacques
Universidade Federal do Rio Grande do Sul
ORCID 0000-0003-2109-0677
jocelise.jacques@ufrgs.br

José Lucas Pereira Mendes
Universidade Federal do Rio Grande do Sul
joselucaspmendes@gmail.com

Abstract (In English, Times New Roman 14, bold, left-aligned)

This article analyzes, from the perspective of sustainable material selection, the comparison between plaster casts and polylactic acid (PLA) applied to immobilization devices. The study is characterized as qualitative, exploratory, and analytical, developed through an integrative literature review. The analysis was structured into five comparative categories: technical-functional performance, processability and manufacturing, ergonomics and user experience, implementation feasibility, and socio-environmental sustainability. The results indicate that plaster casts remain relevant due to their clinical consolidation and ease of application, whereas PLA, associated with additive manufacturing, presents potential for anatomical customization, improved comfort, and projectual reconfiguration. However, it was found that the association between PLA and sustainability cannot be assumed as inherent, as it depends on production, functional, and

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contextual factors. It is concluded that material selection for immobilization devices should be understood as a multicriteria decision, integrating performance, use, feasibility, and sustainability.
Key Words: sustainable material selection; sustainability; immobilization devices; polylactic acid (PLA)

Resumo

Este artigo analisa, sob a perspectiva da seleção sustentável de materiais, a comparação entre gesso hospitalar e ácido polilático (PLA) aplicados a dispositivos de imobilização. A pesquisa caracteriza-se como qualitativa, exploratória e analítica, desenvolvida por meio de revisão integrativa da literatura. A análise foi organizada em cinco categorias comparativas: desempenho técnico-funcional, processabilidade e fabricação, ergonomia e experiência de uso, viabilidade de implementação e sustentabilidade socioambiental. Os resultados indicam que o gesso hospitalar permanece relevante por sua consolidação clínica e facilidade de aplicação, enquanto o PLA, associado à manufatura aditiva, apresenta potencial para customização anatômica, conforto e reconfiguração projetual. Contudo, verificou-se que a associação entre PLA e sustentabilidade não pode ser assumida de forma automática, pois depende de fatores produtivos, funcionais e contextuais. Conclui-se que a seleção de materiais para dispositivos de imobilização deve ser compreendida como decisão multicritério, articulando desempenho, uso, viabilidade e sustentabilidade.
Palavras-chave: seleção de materiais; sustentabilidade; dispositivos de imobilização; PLA.

1 - INTRODUCTION

Sustainability in the healthcare sector has gained increasing prominence in contemporary discussions on innovation, resource management, and socio-environmental responsibility. Although healthcare systems are essential for maintaining life and collective well-being, their production and care chains involve intensive energy consumption, extensive material use, and significant waste generation, making this sector particularly sensitive to the incorporation of sustainable strategies. In this context, sustainability in healthcare cannot be reduced solely to hospital waste management; rather, it must be understood in a broader sense, encompassing decisions related to design, production, material selection, use, and disposal of devices employed in care practices (Leal Filho et al., 2024).

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Among the various artifacts used in healthcare, immobilization devices occupy a relevant position in orthopedic, trauma, and rehabilitation contexts. These devices are employed to stabilize body segments, control movement, and support the functional recovery process. Historically, plaster casts—and, more recently, other conventional immobilization systems—have become widely adopted due to their accessibility, clinical applicability, and low initial cost. However, the persistence of this traditional model does not eliminate its material, operational, and experiential limitations, particularly when considered in light of contemporary demands related to sustainability, personalization, and the qualification of user experience.

From a sustainability-oriented design perspective, material selection for immobilization devices should not be restricted to parameters of immediate clinical efficiency or short-term economic viability. Rather, it constitutes a complex decision involving the articulation of multiple criteria, such as raw material origin, processing energy intensity, waste generation, reuse potential, technical-functional adequacy, ergonomics, comfort, hygiene, maintenance, and adaptability to the context of use. This approach broadens the understanding of materiality in healthcare, shifting the focus from an exclusively corrective or functional logic to a more systemic and relational analysis, in which material, body, technology, environment, and care are understood in an integrated manner.

Within this framework, polylactic acid (PLA) has gained relevance as a material of interest for healthcare applications, particularly in association with additive manufacturing technologies. PLA is widely used in 3D printing processes and has been explored in personalized devices due to attributes such as processability, lightness, geometric customization, and compatibility with digital fabrication workflows. Recent systematic reviews on 3D-printed orthoses indicate that additive manufacturing has expanded the possibilities for personalized production, enabling improved anatomical fit, perceived comfort, clinical effectiveness, and user satisfaction across different rehabilitation contexts (Atallah et al., 2025).

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In the specific case of immobilization devices, the literature highlights relevant advantages of customized solutions produced through 3D printing compared to conventional systems, particularly regarding ventilation, hygiene, lightness, skin monitoring, and user experience. However, such advantages do not justify simplified generalizations regarding material superiority, as the performance of these devices depends on the context of use, the geometry of the artifact, the manufacturing process, and the selected material. Therefore, the discussion on materials for immobilization should not be guided solely by traditional criteria such as cost and availability, but also by dimensions related to usability, patient experience, and design adequacy.

Nevertheless, the incorporation of PLA as an alternative to plaster casts should not be approached in a linear or technically idealized manner. Although the material is often associated with renewable sources and narratives of reduced environmental impact, its sustainability assessment depends on concrete conditions related to life cycle, production pathways, processing, disposal infrastructure, and actual reuse possibilities. Life cycle assessment reviews of PLA-based products indicate that its environmental benefits are not absolute and should be analyzed according to contextual and systemic variables, rather than being treated as an intrinsic and universal property of the polymer (Fonseca et al., 2023).

Furthermore, in immobilization applications, material selection cannot disregard technical-functional criteria. Aspects such as mechanical strength, structural stability, moisture response, aging behavior, conformability, and suitability for prolonged use directly influence the material's viability in healthcare contexts. Recent studies on 3D-printed orthoses show that the mechanical performance of these devices varies significantly depending on the material used, infill density, and usage conditions, reinforcing the need for careful evaluation when considering PLA for support and immobilization applications (Vlăsceanu et al., 2024).

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Despite the advancement of discussions on sustainability, alternative materials, and digital fabrication in healthcare, there remains a relative dispersion in the literature regarding the comparative articulation of environmental, economic, social, and technical-functional criteria specifically applied to the selection between plaster casts and PLA in immobilization devices. While some studies focus on material properties, others emphasize clinical performance, personalization, or the productive advantages of 3D printing; however, integrative approaches that combine these dimensions into a systematized framework capable of supporting design and clinical decision-making remain less frequent.

In light of this gap, this article aims to comparatively analyze plaster casts and polylactic acid (PLA) in order to identify sustainable criteria for material selection in immobilization devices within the healthcare context. To this end, the study adopts a comparative approach guided by environmental, economic, social, and technical-functional dimensions, seeking to understand not only the potentials and limitations of each material, but also the conditions that influence their viability in contemporary healthcare scenarios.

By proposing this discussion, the article intends to contribute to the field of Design applied to healthcare by shifting the analysis from a logic centered exclusively on material substitution toward a broader perspective of sustainable material selection. In this sense, the comparison between plaster casts and PLA is mobilized not merely as a contrast between two distinct materialities, but as an opportunity to critically reflect on the criteria that should guide the development of more responsible, contextualized, and sustainability-oriented immobilization solutions.

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2 - THEORETICAL FRAMEWORK

The discussion on sustainable material selection for immobilization devices requires a theoretical approach capable of integrating dimensions that are often treated separately in the literature. On the one hand, there are debates on sustainability, material selection, and multicriteria decision-making within the field of Design; on the other, discussions on performance, usability, patient experience, and innovation in healthcare devices. When addressed in isolation, such approaches tend to limit the understanding of the problem, either by reducing materiality to purely technical parameters or by treating sustainability as an abstract attribute detached from the real conditions of use, production, and disposal.

In the context of immobilization devices, this fragmentation becomes particularly problematic, since material choice simultaneously affects mechanical stability, comfort, ventilation, hygiene, anatomical adaptability, production feasibility, and the environmental impacts associated with the artifact. Thus, the comparison between plaster casts and polylactic acid (PLA) cannot be conducted merely as a contrast between a conventional solution and a technologically innovative alternative; rather, it should be understood as a design problem in which different criteria of performance, sustainability, and use interact and, at times, come into tension.

Accordingly, this theoretical framework is structured into five complementary axes. First, the foundations of sustainability and material selection in Design for healthcare are discussed. Next, conventional immobilization devices and their projectual and experiential limitations are examined. Subsequently, the role of PLA and additive manufacturing in the development of personalized devices is analyzed. This is followed by a critical examination of the association between PLA and sustainability, avoiding simplified or deterministic interpretations. Finally, a

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theoretical synthesis is presented, aimed at delimiting the analytical criteria that support the comparison proposed in this study.

2.1 - Sustainability and material selection in Design for healthcare

Material selection constitutes a structuring stage in product development, as it simultaneously influences technical performance, manufacturing processes, costs, durability, user experience, and the environmental impacts associated with the artifact throughout its life cycle. In the field of Design, this selection should not be understood as a merely instrumental choice among available alternatives, but as a complex design decision situated at the intersection of functional requirements, production constraints, context of use, and sustainability criteria (Italia et al., 2023; Schoenung; Ogunseitan; Heine, 2025).

From this perspective, materials are no longer understood solely as the physical substrate of the product but as strategic elements in shaping performance, production feasibility, and the socio-environmental responsibility of the design. Methodologically, this implies recognizing that material selection must integrate multiple attributes simultaneously, such as strength, mass, durability, processability, cost, recyclability, embodied energy, associated emissions, and suitability to the context of use. Recent literature on sustainable material selection emphasizes precisely this multicriteria nature of material decision-making, particularly when the objective is not only to optimize performance but also to reduce environmental impacts and enhance the systemic coherence of the product (Aires; Ferreira, 2022; Italia et al., 2023).

In the contemporary context, material sustainability cannot be reduced to the renewable origin of raw materials or to the abstract possibility of recycling. Rather, sustainable evaluation requires a systemic approach capable of considering the material's trajectory throughout its life cycle, from

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extraction or production, through transformation, distribution, use, maintenance, and disposal. In this sense, sustainability-oriented design decisions require comparative tools capable of addressing trade-offs between technical properties, cost, circularity, energy consumption, and environmental impacts, avoiding simplified interpretations that treat a given material as inherently “green” (Schoenung; Ogunseitan; Heine, 2025; Fonseca et al., 2023).

This discussion becomes even more relevant when applied to the healthcare sector. Unlike many consumer products, devices used in care contexts must simultaneously meet requirements related to safety, functionality, hygiene, reliability, comfort, institutional feasibility, and user acceptability. Therefore, material selection in healthcare cannot be guided solely by environmental performance or cost reduction, but must articulate technical-functional, clinical, ergonomic, productive, and socio-environmental criteria. It is, therefore, a design decision situated within a high-demand environment, in which materiality directly affects not only the efficiency of the artifact but also the patient experience, care routines, and the concrete conditions of implementation (Leal Filho et al., 2024).

From this perspective, sustainability in healthcare devices should not be understood as an isolated attribute of the material, but as a relational quality emerging from the interaction between material, process, context of use, and the healthcare system. This formulation is particularly relevant for immobilization devices, in which material choice simultaneously affects mechanical stability, anatomical adaptability, thermal comfort, ventilation, hygiene, maintenance, and adherence to use. Thus, discussing sustainability in this field does not simply mean comparing “cleaner” and “more polluting” materials, but critically examining which criteria should guide material choice in situations where performance and care are inseparable.

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2.2 - Immobilization devices and the limits of conventional systems

Immobilization devices play a central role in orthopedic, trauma, and rehabilitation contexts, being used to restrict movement, stabilize body segments, and support processes of consolidation and functional recovery. Among historically consolidated solutions, plaster casts remain one of the most widely used, primarily due to their broad availability, low initial cost, relative ease of application, and clinically recognized effectiveness across different care settings.

However, the persistence of plaster as a widely adopted solution does not imply the absence of limitations. In material and experiential terms, conventional immobilization systems often present constraints related to weight, limited ventilation, moisture retention, hygiene difficulties, prolonged discomfort, restricted skin inspection, and reduced adaptability to users' anatomical specificities. These limitations are not secondary; they directly affect user experience, patients' daily routines, device tolerability, and, in some cases, adherence to treatment (Aydin; Dal Yilmaz, 2022; Phelps et al., 2025).

This dimension is particularly relevant because it shifts the analysis of immobilization from a strictly biomedical perspective to a broader field encompassing user experience and Design for healthcare. Recent qualitative studies indicate that patients' experiences with conventional immobilization devices involve not only stabilization and protection but also pain, functional limitation, loss of autonomy, difficulties in performing daily activities, uncertainty regarding recovery, and the need for continuous adaptation to the conditions imposed by the device (Aydin; Dal Yilmaz, 2022; Phelps et al., 2025).

From a Design perspective, these findings are significant because they demonstrate that the evaluation of an immobilization system cannot be reduced to its mechanical containment capacity.

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It is necessary to incorporate criteria related to usability, ergonomics, comfort, ventilation, maintenance, accessibility, and the overall quality of patient experience. In other words, the functional effectiveness of the device does not exhaust its design adequacy. A system may be clinically efficient and yet design-wise limited when observed through the lenses of experience, adaptability, and sustainability.

Additionally, conventional immobilization systems raise important questions from a sustainability standpoint. Although plaster may be economically advantageous in immediate terms, its application logic is generally associated with low customization, post-use disposal, limited formal flexibility, and reduced potential for fine adaptation to the user. In contexts that demand resource rationalization, greater anatomical adequacy, and improved integration between performance and care, these characteristics become particularly relevant when compared to digitally fabricated solutions.

However, this critique should not lead to a simplistic interpretation in which plaster casts are considered technically outdated or intrinsically inadequate. In many clinical contexts, their use remains functional, accessible, and institutionally consolidated. The central issue, therefore, is not to advocate for the automatic replacement of one system by another, but to understand to what extent conventional devices respond—or fail to respond—to contemporary demands for sustainability, personalization, comfort, and enhanced patient experience. This distinction is essential to avoid technodeterministic interpretations and to situate material comparison in terms of contextual adequacy rather than a simplified opposition between “traditional” and “innovative.”

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2.3 - PLA, additive manufacturing, and personalization in immobilization devices

Advances in additive manufacturing have significantly expanded the possibilities for the conception, production, and customization of healthcare devices. In the field of orthoses and body support solutions, 3D printing has been employed as an alternative capable of integrating digital modeling, anatomical adjustment, material rationalization, and on-demand fabrication. This transformation is particularly relevant for immobilization devices, as their effectiveness and acceptability depend largely on the relationship between form, body, stability, comfort, and context of use.

Within this scenario, polylactic acid (PLA) has become one of the most commonly used materials in additive manufacturing processes based on fused filament fabrication, mainly due to its wide availability, ease of processing, dimensional stability, and relative affordability. In design applications, PLA presents important operational advantages, including good printability, geometric repeatability, and compatibility with digital prototyping and production workflows. These characteristics explain its frequent presence in studies focused on the development of orthoses, supports, and body stabilization devices (Atallah et al., 2025; Vlăsceanu et al., 2024).

From a Design perspective, the main contribution of additive manufacturing lies not merely in replacing one production process with another, but in enabling a reconfiguration of the design logic itself. Instead of standardized solutions that are poorly responsive to bodily differences and constrained by conventional forming processes, digital fabrication allows greater formal freedom, geometric variation, localized ventilation, mass reduction, and improved anatomical accommodation. In immobilization devices, this means that materiality can be conceived not only

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in terms of strength and rigidity but also in relation to breathability, ergonomics, maintenance, skin inspection, and prolonged user experience.

Recent literature suggests that 3D-printed orthoses and devices may present positive outcomes in terms of comfort, user satisfaction, and clinical acceptability, particularly when compared to less adaptable conventional solutions. Systematic reviews indicate that the personalization enabled by additive manufacturing has contributed to improved fit, increased adherence to use, and better perceived outcomes across different types of orthotic devices, although methodological heterogeneity and material variability still require cautious interpretation (Atallah et al., 2025).

However, the incorporation of PLA in immobilization devices cannot be justified solely based on its biobased origin or technological appeal. Its suitability depends on an integrated evaluation of mechanical performance, behavior in use, dimensional stability, moisture response, comfort, durability, and appropriateness to the clinical context. Experimental studies on 3D-printed wrist orthoses show that PLA may present satisfactory performance under certain conditions but also reveal sensitivity to factors such as aging, moisture, infill density, and thermoforming processes (Vlăsceanu et al., 2024).

This indicates that the viability of PLA cannot be assumed as universal. Its use must be analyzed in relation to specific application requirements, since desirable attributes in terms of processability or lightness do not automatically translate into technical-functional superiority across all immobilization scenarios. This observation is central to avoiding the recurrent risk of techno-utopianism in the literature on digital fabrication in healthcare, where formal innovation and personalization are often equated with improved performance or sustainability.

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2.4 - Sustainability of PLA: potentials, limits, and the need for contextual evaluation

The association between PLA and sustainability has become recurrent in academic, industrial, and media discourses, particularly due to its origin from renewable resources and its frequent linkage to notions of biodegradability. However, specialized literature has demonstrated that these attributes, although relevant, are not sufficient in themselves to support the classification of the material as environmentally superior across all application contexts. The sustainability of PLA depends on a range of systemic variables, including production pathways, energy consumption, processing scale, manufacturing efficiency, conditions of use, reuse possibilities, and the effective infrastructure for disposal or post-use valorization (Fonseca et al., 2023).

From a life cycle assessment perspective, PLA may present advantages in certain impact categories when compared to fossil-based polymers, but these benefits are neither absolute nor uniform. Review studies indicate that environmental outcomes associated with PLA vary significantly depending on methodological assumptions, system boundaries, energy matrices, and end-of-life conditions. In many cases, attributing "sustainability" to the material results more from discursive simplifications than from effectively comparative and contextualized analyses (Fonseca et al., 2023).

This problematization is particularly relevant for healthcare applications, where materials cannot be evaluated solely based on abstract environmental potential but must be considered in relation to performance and safety requirements. In immobilization devices, for example, a material that appears environmentally advantageous under certain indicators may reveal significant limitations if it exhibits lower stability in use, reduced durability, or the need for more frequent replacement.

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In this sense, material sustainability should be understood as the result of a relational and multicriteria evaluation, rather than as an intrinsic or self-evident property of the polymer.

Furthermore, the association between sustainability and technological innovation must be approached with caution. The adoption of digitally fabricated solutions does not inherently imply lower environmental impact. Depending on the process, production volume, failure rates, energy consumption, material waste, and post-use destination, 3D printing technologies may either increase or reduce environmental impacts. Therefore, the potential of PLA in immobilization devices can only be adequately understood through comparative analysis that articulates environmental, economic, social, and technical-functional variables.

This formulation is central to the present study because it shifts the discussion from a simplified question—"which material is more sustainable?"—to a more analytically consistent inquiry: under which criteria and conditions does a given material prove more suitable for immobilization devices? It is precisely this shift that justifies the need for a comparative approach guided by sustainable material selection criteria.

2.5 - Theoretical synthesis and analytical delimitation of the study

The reviewed literature indicates that the comparison between plaster casts and PLA cannot be reduced to a dichotomy between conventional and innovative materials. Such an opposition, although frequent in discourses on healthcare innovation, is conceptually insufficient to support robust design decisions. What emerges from the literature is the need to understand material selection as a multicriteria decision situated at the intersection of sustainability, technical performance, user experience, production feasibility, and healthcare context.

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In this sense, plaster casts and PLA represent not only two distinct materialities but also two different regimes of production, use, and design implication. The former is associated with a widely consolidated, functional, and accessible logic, yet marked by limitations in personalization, comfort, and flexibility of use. The latter is linked to digital fabrication workflows, anatomical customization, and potential material rationalization, but also presents limitations related to performance, aging, disposal, and dependence on specific processing and infrastructural conditions.

Thus, the theoretical framework presented here supports the need for a comparative analysis that does not merely describe isolated material properties but considers the articulation between environmental, economic, social, and technical-functional dimensions. It is from this analytical matrix that it becomes possible to more consistently examine the criteria that may guide sustainable material selection for immobilization devices in the healthcare context.

3 - METHODOLOGY

Based on the theoretical framework presented, this study was developed with the aim of comparing, from the perspective of sustainability and design performance, the use of plaster casts and polylactic acid (PLA) in immobilization devices. To this end, a qualitative approach was adopted, with an exploratory and analytical character, based on an integrative literature review.

The review was conducted through a bibliographic survey in scientific databases relevant to the fields of Design, Healthcare, Engineering, and Sustainability, with emphasis on publications related to material selection, immobilization devices, orthoses, 3D printing, PLA, and sustainability. English-language descriptors combined with Boolean operators were used, such as

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"sustainable material selection," "PLA," "3D printing," "orthosis," "plaster cast," and "healthcare."

Studies were included if they addressed at least one of the following dimensions: (i) sustainable material selection; (ii) applications of PLA or additive manufacturing in healthcare devices; (iii) performance, comfort, user experience, or feasibility of immobilization devices; and (iv) environmental implications associated with the materials analyzed. Studies were excluded if they lacked direct relevance to the research problem, were duplicates, consisted of promotional documents, or did not present sufficient methodological consistency to support the comparative analysis.

After screening based on title, abstract, and full-text reading, the selected studies were organized and analyzed interpretatively, according to five comparative categories: technical-functional performance, processability and manufacturing, ergonomics and user experience, implementation feasibility, and socio-environmental sustainability. These categories were defined based on thematic recurrence identified in the literature and their relevance to material selection in immobilization devices.

As a limitation, it is acknowledged that the study is based on secondary evidence, not including laboratory testing or direct clinical evaluation of the materials. Therefore, the results should be understood as a comparative analytical synthesis aimed at discussing criteria for sustainable material selection within the context of Design for healthcare.

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4 - COMPARATIVE DISCUSSION BETWEEN PLASTER CASTS AND PLA

The comparison between plaster casts and polylactic acid (PLA) in immobilization devices reveals that material selection in this context cannot be reduced to a linear opposition between a conventional solution and a technologically advanced alternative. The analyzed literature indicates that both materials present potentials and limitations, whose relevance depends on the criteria adopted in the evaluation, the requirements of the healthcare context, and the concrete conditions of manufacturing, use, and disposal. Accordingly, the discussion is structured around five comparative dimensions: technical-functional performance, processability and manufacturing, ergonomics and user experience, implementation feasibility, and socio-environmental sustainability.

4.1 - Technical-functional performance

Regarding technical-functional performance, plaster casts remain relevant due to their well-established capacity for stabilization, rigidity, and consolidated application across diverse clinical contexts. Their persistence within healthcare systems does not result solely from institutional tradition but also from their practical effectiveness in short- and medium-term immobilization procedures. In this sense, plaster continues to be a functionally reliable material for anatomical containment and motion restriction, particularly in emergency settings or contexts with high care demand.

PLA, in turn, presents potentially satisfactory performance in orthotic and immobilization applications when employed in properly designed and manufactured devices. However, its performance depends not only on the raw material itself but on a set of variables related to artifact design, thickness, structural geometry, infill patterns, printing process, and conditions of use. This

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means that, unlike plaster—whose effectiveness is well established in conventional care practices—the performance of PLA is more strongly conditioned by design and production control (Vlăsceanu et al., 2024).

This distinction is significant because it demonstrates that PLA should not be evaluated merely as a “material substitute” for plaster, but as a component of a distinct technical system dependent on digital modeling, geometric parametrization, and controlled fabrication. In other words, while plaster operates primarily as a direct application solution, PLA functions as the material of a designed artifact. This difference substantially alters the logic of comparison and reinforces the need to approach it in terms of system adequacy rather than isolated material properties.

4.2 - Processability and manufacturing

The comparison becomes particularly expressive when observed from the perspective of processability and manufacturing. Plaster casts present as their main advantage the simplicity of clinical application, as they can be directly molded onto the body without requiring complex digital infrastructure or specialized production chains. This characteristic contributes to their widespread adoption in hospital and outpatient settings, especially in emergency situations, decentralized care, or contexts with limited technological availability.

However, this same simplicity is associated with important design limitations. Plaster tends to operate within a relatively standardized manual adaptation logic, with low precision in fine customization and limited capacity for controlled formal variation. Furthermore, once applied, it offers little flexibility for adjustment or reconfiguration without removal and reapplication.

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In contrast, PLA associated with additive manufacturing offers significant advantages in terms of customization, geometric repeatability, and formal control. The possibility of developing devices through digital modeling and 3D printing enables greater anatomical adequacy, the design of perforated structures, modulation of thickness, and incorporation of ergonomic and functional parameters from the design stage. From a Design perspective, this constitutes a substantial difference, as it shifts manufacturing from a predominantly adaptive logic to an effectively projectual one.

Nevertheless, this advantage is not without cost or complexity. The adoption of PLA depends on technological infrastructure, specialized technical knowledge, modeling time, appropriate parametrization, equipment availability, and process control. Thus, although PLA significantly expands customization possibilities, its implementation is not automatically simpler, faster, or more accessible in all healthcare contexts. Therefore, from a manufacturing perspective, PLA stands out more as a solution with greater design potential than as a universally more viable substitute.

4.3 - Ergonomics and user experience

The ergonomic and experiential dimension constitutes one of the areas in which PLA tends to present more consistent advantages over plaster casts. The reviewed literature indicates that devices produced through additive manufacturing may promote better anatomical adaptation, lower weight, increased ventilation, improved hygiene, and greater comfort during prolonged use, especially when compared to conventional immobilization solutions (Atallah et al., 2025; Phelps et al., 2025).

This advantage does not derive exclusively from PLA as a material, but from the possibility of articulating material, geometry, and personalization. In 3D-printed devices, the structure can be

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designed to respond not only to containment requirements but also to breathability, skin inspection, pressure reduction, and more precise anatomical accommodation. In terms of Design for healthcare, this represents a significant advancement, as it shifts the device from a strictly functional condition to one that is also experientially qualified.

In the case of plaster casts, although their immobilization effectiveness is widely recognized, their user experience tends to be more restrictive. Qualitative studies report discomfort, perceived heaviness, hygiene difficulties, heat retention, limitations in daily activities, and negative subjective impacts during the recovery period (Aydin; Dal Yilmaz, 2022). These factors should not be treated as peripheral, as they directly affect the relationship between patient and device, with implications for adherence, tolerability, and perceived quality of care.

Still, it is important to avoid idealizing PLA as an experientially superior solution in all circumstances. The ergonomic quality of a printed device depends strongly on design quality, anatomical fit, finishing, closure systems, and conditions of use. In other words, PLA expands the potential for improving user experience but does not, in itself, guarantee superior ergonomic performance. The advantage lies less in the raw material and more in the integration between materiality, form, and context of use.

4.4 - Implementation feasibility

Implementation feasibility constitutes a critical dimension in the comparison between materials, particularly when considering healthcare systems with varying levels of infrastructure, technical resources, and production capacity. In this respect, plaster casts present a significant advantage due to their widespread availability, low initial cost, and historical integration into care routines. They

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represent a consolidated solution, characterized by rapid application and institutional legitimacy, which supports their large-scale use.

PLA, on the other hand, despite its relevant potential for innovation in immobilization devices, faces implementation barriers related to the need for specific equipment, digital modeling expertise, fabrication time, availability of materials, and integration into existing clinical workflows. In many contexts, the adoption of customized 3D-printed devices still depends on laboratory infrastructure, institutional partnerships, or technical conditions that are not widely distributed within healthcare systems.

This implies that the design superiority of PLA in certain dimensions does not automatically translate into operational or institutional superiority. In contexts characterized by high demand, time constraints, or limited technological availability, plaster may remain the most viable solution, even if it is not the most comfortable or environmentally promising. Conversely, in scenarios with access to digital infrastructure, trained personnel, and demand for customization, PLA may represent a strategically advantageous alternative.

Thus, implementation feasibility reinforces a central aspect of this study: sustainable material selection in healthcare cannot be guided by abstract idealizations but must consider the real conditions of applicability and technological integration. A material that is potentially more promising from a design perspective may, in certain contexts, be less viable in practice.

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4.5 - Socio-environmental sustainability

Socio-environmental sustainability constitutes both the most relevant and the most susceptible dimension to oversimplification in this comparison. At first glance, PLA tends to be perceived as a more sustainable alternative due to its biobased origin, frequent association with biodegradability narratives, and linkage to potentially more controllable digital manufacturing processes. However, the literature demonstrates that these attributes are not sufficient to universally establish its environmental superiority (Fonseca et al., 2023).

Analytically, the sustainability of PLA depends on factors such as production pathways, energy matrices, printing efficiency, failure rates, support material requirements, device durability, reuse potential, and actual conditions of disposal or post-use valorization. In other words, the sustainable potential of PLA is conditional and context-dependent, and cannot be assumed solely based on its renewable origin. This observation is crucial to avoid techno-utopian discourses that automatically associate material innovation with sustainability.

Plaster casts, in turn, although less frequently associated with environmental innovation narratives, cannot be evaluated solely based on their image as conventional and disposable materials. Their analysis requires consideration of material consumption, application logistics, replacement frequency, post-use disposal, and integration into large-scale healthcare systems. Thus, the socio-environmental comparison between plaster and PLA cannot be resolved through a binary logic opposing an “old material” to an “ecological material,” but requires a more refined, life cycle-oriented and context-sensitive analysis.

In this sense, the main contribution of the reviewed literature is not to demonstrate that PLA is necessarily more sustainable than plaster, but to show that PLA expands the possibility of

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rethinking material sustainability in immobilization devices, provided that this discussion is conducted in a critical, systemic, and situated manner. The most consistent gain lies not only in the material itself but in the opening of new possibilities for design, customization, rationalization, and reconfiguration of the device.

4.6 - Comparative synthesis

The comparative analysis indicates that plaster casts and PLA respond to distinct rationalities of design, production, and use, and that their evaluation cannot be adequately conducted based on single or universal criteria. Plaster demonstrates greater institutional consolidation, simplicity of application, and broad operational viability, maintaining relevance across diverse clinical contexts. PLA, in turn, stands out primarily for its potential for customization, ergonomic qualification, and projectual reconfiguration of immobilization devices.

However, the findings also indicate that the adoption of PLA should not be understood as an automatic replacement for plaster, nor as an intrinsically more sustainable solution. Its suitability depends on available infrastructure, design quality, manufacturing conditions, functional adequacy, and context-sensitive impact assessment. Therefore, sustainable material selection for immobilization devices should be understood as a multicriteria decision, in which technical performance, user experience, implementation feasibility, and socio-environmental sustainability must be considered in an integrated manner.

From this perspective, the main contribution of this study lies in demonstrating that discussions on materials in healthcare devices must move beyond both the naturalization of conventional solutions and the uncritical idealization of emerging alternatives. Rather than seeking a universal answer to

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“the best material,” the analysis highlights the need to construct more rigorous, situated, and design-oriented selection criteria.

5 - FINAL CONSIDERATIONS

This study aimed to analyze, from the perspective of sustainable material selection, the comparison between plaster casts and polylactic acid (PLA) applied to immobilization devices. Based on an integrative literature review and the organization of the analysis into comparative categories, it was found that the choice between these materials cannot be supported by isolated criteria or by simplified narratives of innovation or sustainability.

The results indicate that plaster casts remain a widely viable solution due to their clinical consolidation, ease of application, and institutional integration, particularly in contexts characterized by high care demand and limited infrastructure. On the other hand, PLA, associated with additive manufacturing, presents significant potential for anatomical customization, ergonomic improvement, and the design reconfiguration of immobilization devices, especially in scenarios that allow greater control over design and fabrication processes.

However, the analysis also demonstrated that the association between PLA and sustainability cannot be assumed as self-evident. Its suitability depends on factors related to production processes, performance in use, implementation feasibility, and the actual conditions of disposal or reuse. In this sense, the main contribution of this article lies in proposing a multicriteria, critical, and context-sensitive interpretation of material selection for immobilization devices, shifting the debate from a simplistic opposition between “traditional material” and “innovative material” toward a discussion grounded in design, functional, experiential, and socio-environmental criteria.

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As a limitation, it should be noted that the study is based on secondary evidence, not including laboratory testing, clinical trials, or empirical evaluation of prototypes in real use contexts. Therefore, the results should be understood as a comparative analytical synthesis rather than as conclusive experimental validation of the superiority of one material over another.

Finally, future research is encouraged to advance through experimental studies, life cycle assessments, applied ergonomic evaluations, and investigations involving both users and healthcare professionals, in order to deepen the understanding of the technical, environmental, and clinical viability of materials applied to immobilization devices. Such developments may contribute to establishing more robust decision-making parameters in the field of Design for healthcare, particularly with regard to the development of solutions that are more materially appropriate, sustainable, and user-centered.

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