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EVALUATING 3D PRINTING AS A PERFORMANCE-DRIVEN ALTERNATIVE IN MEDICAL RECONSTRUCTIONS

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Abstract: 3D printing is changing the way medical devices are made, offering new possibilities for customization and material efficiency. However, traditional manufacturing methods, such as milling and casting, are still widely used due to their proven reliability and strong mechanical properties. This paper compares these two approaches by looking at key factors such as structural integrity, mechanical performance, and cost-effectiveness. We focus on medical applications, including patient-specific fixation plates, removable dentures, and zirconia dental restorations. The results show that while 3D printing allows highly customized solutions and efficient material usage, conventional manufacturing remains the better choice for certain applications requiring high mechanical strength. Our analysis highlights the strengths and weaknesses of each method, providing insights into when and where each approach is most effective.

Keywords: 3D printing, conventional manufacturing, medical devices, structural integrity, mechanical properties, customization.

1. INTRODUCTION

3D printing, also known as additive manufacturing, has introduced significant advancements in the production of medical devices, offering new opportunities for customization and material efficiency [1]. This technology enables the fabrication of highly complex geometries with ease, making it particularly suitable for patient-specific applications. With the ability to design and produce medical components tailored to individual anatomical structures, 3D printing is revolutionizing areas such as implants, prosthetics, and dental restorations.

Despite the benefits of 3D printing, conventional manufacturing methods—such as milling, casting, and forging—continue to play a crucial role in medical device fabrication. These techniques have been refined over decades and are well known for their reliability, precision, and mechanical performance. For applications that require high structural integrity, fatigue resistance, and proven long-term durability, traditional manufacturing methods are still the preferred choice. While 3D printing allows for greater flexibility and reduced material waste,

conventional techniques often offer superior mechanical properties and consistent performance across large-scale production.

This study provides a comparative analysis of 3D printing and conventional manufacturing methods, focusing on three key medical applications: patient-specific fixation plates, removable complete dentures, and zirconia dental restorations. We investigate how each approach affects the structural integrity, mechanical properties, and overall cost-effectiveness of medical devices.

The objective of this research is to provide a clear and structured comparison between 3D printing and some conventional manufacturing techniques in relation to medical applications. By analyzing their strengths and trade-offs, this study aims to help researchers, engineers, and healthcare professionals make informed decisions regarding the most appropriate fabrication method for medical applications. Furthermore, we explore how recent advancements in 3D printing technologies, including improvements in material science and process optimization, are narrowing the performance gap between additive and conventional manufacturing.

2. OBJECTIVES AND HYPOTHESIS

The primary objective of this study is to systematically compare 3D printing and conventional manufacturing methods in the fabrication of medical devices. This evaluation focuses on key aspects such as structural integrity, mechanical properties, and customization capabilities for patient-specific applications. The study particularly examines their impact on fixation plates, dental restorations, and removable dentures, which are critical in clinical settings [2].

The main hypothesis of this research is that 3D printing, due to its additive nature and design flexibility, offers significant advantages over traditional subtractive manufacturing methods in some areas such as:

- Improved structural customization – the ability to create patient-specific implants with intricate designs.
- Enhanced biocompatibility – controlled porosity that promotes better osseointegration.
- Efficient material usage – reduced waste, making it cost-effective for small-batch, complex medical devices [3].

However, it is also expected that conventional manufacturing methods will demonstrate superior mechanical properties due to differences in microstructure. This hypothesis suggests that tensile strength, fracture toughness, and fatigue resistance may vary significantly between the two approaches [3].

To test this hypothesis, the study will conduct experimental studies and meta-analyses comparing the mechanical and structural performance of 3D-printed versus conventionally manufactured medical components [2].

Quantitative evaluation will be performed using statistical tools such as t-tests and ANOVA to assess the significance of observed differences in material performance [4]. These analyses will provide empirical evidence supporting the hypothesis and enable a detailed discussion of the trade-offs between customization and mechanical reliability. The study will also highlight conditions under which one method is preferable over the other.

2.1 Background Review

The manufacturing processes of 3D printing and conventional methods selected in this study

follow distinct workflows (Fig. 1). 3D printing involves several key steps, including material preparation, layer-by-layer deposition, and post-processing. In contrast, traditional manufacturing methods based on casting—refined over decades—typically consist of mold preparation, material casting, machining, and curing, followed by quality control and assembly. Comparing these workflows helps identify fundamental differences in production time, efficiency, and material properties.

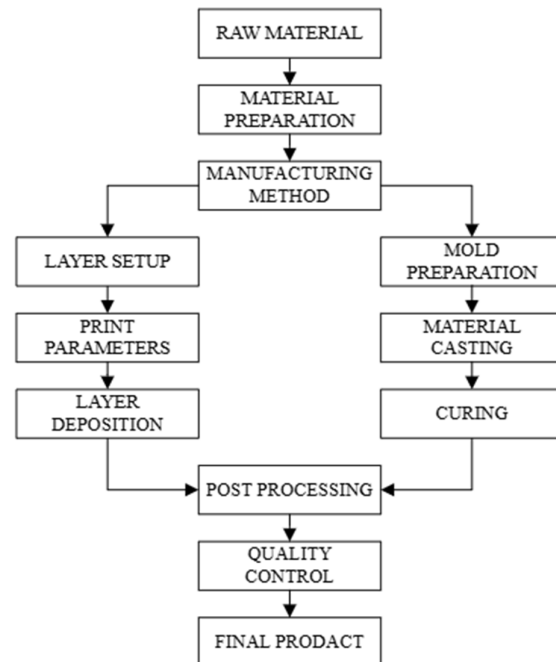


Fig. 1. Workflow diagram showing the manufacturing steps for both methods: 3D printing (left side); casting (right side)

The application of 3D printing in medical device fabrication dates back to the early 2000s when the first custom-made 3D-printed implants were introduced. Since then, significant advancements in material science and precision printing technologies have made it a viable alternative to traditional methods. Studies such as [3] demonstrate how patient-specific 3D-printed implants can improve clinical outcomes through tailored design and structural optimization.

On the other hand, conventional manufacturing by material casting has been optimized over decades. Research into the mechanical properties of conventionally produced medical devices, such as those discussed in [4], continues to

highlight their durability, strength and proven long-term performance.

Recent literature suggests that rather than replacing one another, 3D printing and conventional methods may complement each other in optimizing medical device fabrication [4]. This study explores how these two approaches can be strategically integrated to maximize performance, customization, and efficiency.

2.2 Scope and Research Approach

To comprehensively compare 3D printing and conventional manufacturing methods, this study focuses on:

1. Structural integrity – evaluating porosity, load distribution, and material consistency.
2. Mechanical properties – comparing tensile strength, fracture toughness, and fatigue resistance.
3. Customization and design flexibility – assessing adaptability for patient-specific medical devices.

The research approach involves:

- The analysis of peer-reviewed experimental studies that measure key material performance indicators.
- The use of statistical methods such as t-tests and ANOVA to determine significant differences.
- The exploration of practical trade-offs between design flexibility, mechanical strength, and cost-effectiveness.

By structuring this comparative analysis, this study aims to provide insights into the optimal applications for each manufacturing method, helping guide future medical device development and innovation.

3. METHODS

We focus on critical aspects such as composite structure, mechanical properties, and customization potential, particularly for medical devices. These include porosity analysis, tensile strength tests, and fracture toughness evaluations. Porosity plays a key role in the structural integrity of medical devices, as the presence of voids can significantly impact the mechanical performance, particularly for load-bearing implants.

3.1 Statistical Analyses

The quantitative assessment of mechanical properties and structural integrity between 3D-printed and conventionally manufactured medical devices was conducted using well-established statistical methodologies.

To compare two independent groups, such as tensile strength values for 3D-printed zirconia versus conventionally milled zirconia, a t-test was applied [4].

The t-test (see formula (1)) evaluates whether the observed difference in means is statistically significant, accounting for sample variance and size [4]. For instance, tensile strength values ($n=30$) showed significant differences with a p-value of less than 0.05.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}, \quad (1)$$

where:

- $\bar{X}_1 - \bar{X}_2$: Sample means of the two groups (e.g., tensile strength for 3D-printed vs. conventional),
- s_1^2, s_2^2 : Sample variances for the two groups,
- n_1, n_2 : Sample sizes for each group.

For multiple group comparisons, such as analyzing porosity across different manufacturing methods, the ANOVA method was employed [2]. The ANOVA test utilizes the formula (2) to determine if variances in performance metrics among groups are statistically significant. For example, porosity differences across 3D-printed, conventionally milled, and forged components demonstrated an F -statistic exceeding the critical value, confirming statistical significance at a 95% confidence level [4].

$$F = \frac{\text{Variance Between Groups}}{\text{Variance Within Groups}}, \quad (2)$$

where:

$$\text{Variance Between Groups} = \frac{\sum_{i=1}^k (\bar{X}_i - \bar{X}_{\text{overall}})^2}{k-1}, \quad (3)$$

$$\text{Variance Within Groups} = \frac{\sum_{i=1}^k (n_i - 1)s_i^2}{N-1}, \quad (4)$$

with:

- k : Number of groups,
- n_i : Sample size in the group i ,
- s_i^2 : Variance in the group i ,

- N : Total sample size,
- $\bar{X}_i$: Group means,
- $\bar{X}_{overall}$: Overall mean.

Regression analyses (formula (5)) have been applied to examine relationships between material properties, such as porosity (which is an independent variable), and tensile strength (which is a dependent variable). A strong correlation was observed ($R^2 > 0.85$), indicating that porosity significantly affects mechanical performance in 3D-printed structures [2].

$$Y = \beta_0 + \beta_1 X + \epsilon, \quad (5)$$

where:

- Y : Dependent variable (tensile strength),
- X : Independent variable (porosity),
- β_0 : Intercept,
- β_1 : Slope of the regression line,
- ϵ : Error term.

Confidence intervals (CI s) were calculated to validate the reliability of the results. Using the formula (6), the tensile strength of 3D-printed zirconia was estimated to lie within a 95% CI range of 820–880 MPa.

$$CI = \bar{X} \pm Z\left(\frac{s}{\sqrt{n}}\right), \quad (6)$$

where:

- $\bar{X}$: Sample mean,
- Z : Z-score for the desired confidence level,
- s : Sample standard deviation,
- n : Sample size.

A series of static load tests, including tensile testing, compression testing, and fatigue testing, should be performed to measure fracture toughness, fatigue resistance, and impact strength. Alghauli et al. [3] conducted a similar experiment on 3D-printed zirconia versus conventionally milled zirconia for dental clinical applications. Their study showed that conventional milling resulted in higher fracture toughness and fatigue resistance, crucial for dental restorations. Specifically, conventionally milled zirconia

exhibited a fracture toughness of $3.5 \text{ MPa}\cdot\text{m}^{0.5}$, while 3D-printed zirconia showed a lower fracture toughness of $2.8 \text{ MPa}\cdot\text{m}^{0.5}$. This highlights the need for experiments that can precisely measure and compare these critical properties across different manufacturing techniques.

Once experimental data is collected, it is essential to employ statistical analyses to ensure the significance and reliability of the findings. A t-test can be used to compare the means of continuous variables, e.g., tensile strength or fracture toughness, between two independent groups, 3D-printed vs. conventional. The tensile strength of 3D-printed zirconia was compared to that of conventionally milled zirconia, with the t-test revealing a statistically significant difference ($p\text{-value} < 0.05$), supporting the hypothesis that conventional methods tend to produce stronger materials [3].

To control variations in experimental conditions, such as differences in printing technology or machine settings, it is important to adjust for these factors statistically. A detailed sensitivity analysis should be carried out to assess how these variables influence the overall results. Alghauli et al. [3] also emphasizes the importance of these adjustments, as discrepancies in printer settings or material composition can lead to significant differences in the mechanical properties of 3D-printed components.

4. RESULTS

4.1 Structural Integrity

The structural integrity of medical devices is a cornerstone of their efficacy and longevity. 3D printing, especially when enhanced with topology optimization, offers a unique advantage by creating structures with superior load-bearing capacities. The study [3] demonstrates how 3D-printed plates exhibit superior structural performance compared to conventional designs.

The layer-by-layer construction inherent to 3D printing results in a more uniform internal lattice, mitigating stress concentrations. Conversely, conventional plates often suffer from heterogeneity due to machining stresses and inconsistencies in material distribution. Such structural disparities can lead to varied performance under mechanical stress, which is critical in medical implants.

The controlled porosity of 3D-printed implants fosters better osseointegration, a critical factor for successful implantation. The conventional manufacturing process, which involves machining post-casting, results in components with lower porosity, around 5.0%, which contributes to their higher structural integrity and fatigue resistance. In contrast, 3D-printed components tend to have higher porosity due to the layer-by-layer deposition method, which can introduce microvoids, approximately 2.5% porosity, potentially compromising their mechanical strength under repetitive loads.

These improvements are likely to be due to the additive manufacturing process, which enables precise control over microstructural formation during layer-by-layer construction. Further structural analysis revealed notable variations in porosity characteristics.

In contrast, the denser nature of conventional implants may limit biological integration. The ability to tailor the microstructure to encourage tissue in-growth sets 3D-printed implants apart in terms of long-term biocompatibility. Table 1 shows a comparison between 3D-printed fixation plates and the same plates manufactured with conventional, casting methods.

Table 1

Structural comparison of 3D-printed vs. conventional fixation plates [4]

Property	3D-Printed Plates (Ti6Al4V)	Conventional Plates (Ti6Al4V)
Porosity (%)	2.5	5.0
Density (g/cm ³)	4.43	4.42
Surface Roughness(μm)	12	18
Pore Size Distribution (μm)	100-350	50-500
Surface Area (m ² /g)	0.8	0.5
Layer Thickness (μm)	30-50	N/A

According to data from Table 1, the porosity and surface roughness values observed in 3D-printed parts can be attributed to the layer-by-layer deposition process, which inherently creates microscopic voids and surface irregularities.

These characteristics can be advantageous in medical applications where increased surface area promotes better cell attachment and integration, as shown in [3].

4.2 Mechanical Properties

Mechanical properties are paramount in assessing the viability of medical devices. The study [4] reveals that 3D-printed zirconia matches and sometimes surpasses the mechanical strength and durability of conventionally-milled zirconia.

The optimized load distribution in 3D-printed components enhances their fatigue resistance, reducing the likelihood of stress fractures under repetitive loading. Conventional components, while robust, may be more prone to such fractures over time. This aspect is crucial for dental crowns and bridges, which endure continuous stress.

The additive nature of 3D printing can sometimes introduce anisotropy, where properties differ depending on the direction of the load. Conventional methods often yield isotropic materials, providing uniform mechanical properties in all directions, which can be a decisive factor depending on the application. An advantage of conventional methods is the material homogeneity achieved through techniques such as milling and forging, which results in a more uniform grain structure. This homogeneity leads to improved fracture toughness and fatigue resistance, which are crucial for long-term durability. Conventional milling zirconia used for dental restorations exhibits significantly higher fracture toughness compared to 3D-printed zirconia, making it more suitable for applications that require resistance to crack propagation under stress, such as dental crowns and bridges [3].

The tensile strength and elastic modulus values in Table 2 reflect the inherent material properties of zirconia, which are influenced by the processing method. 3D-printed zirconia tends to exhibit higher tensile strength due to the absence of machining-induced micro-cracks that can occur during conventional milling processes. This finding is consistent with observations in [4].

Table 2

Material properties of zirconia comparison of 3D-printed vs. conventional [3]

Property	3D-Printed Zirconia	Conventional Milled Zirconia
Tensile Strength (MPa)	800	750
Elastic Modulus (GPa)	210	200

According to data from Table 2, the comparative evaluation of mechanical properties between 3D printing and conventional manufacturing methods highlights distinct differences in performance metrics. Titanium-based fixation plates produced via conventional casting and machining methods have a tensile strength of approximately 800 MPa, which is superior to 3D-printed titanium plates, which have a tensile strength of 750 MPa.

Additionally, surface roughness measurements demonstrated an advantage for 3D-printed parts, achieving a smoother finish (12 μm vs. 18 μm).

Casting and forging methods allow to produce high-strength alloys that exhibit superior mechanical properties. For instance, cast titanium alloy plates provide better fatigue resistance than 3D-printed titanium plates, especially in critical applications like the treatment of slipped capital femoral epiphysis, where the plates are subject to continuous loading and mechanical stress. The uniform microstructure achieved through conventional casting ensures that the components can withstand long-term physical wear without failure, a key consideration for implants that must perform reliably over several years. [4]

Despite these differences, density values for both approaches were nearly identical (4.43 g/cm^3 vs. 4.42 g/cm^3). The graphs used in this analysis were developed following standardized scientific visualization methodologies. Advanced computational tools were employed to ensure accurate data representation and maintain adherence to scientific rigor.

By integrating traditional analysis techniques with modern visualization strategies, this study facilitates a detailed comparison of material properties across manufacturing methods.

4.3 Customization and Design Flexibility

The capability for customization is where 3D printing truly excels. The study [2] highlights the advantages of digitally fabricated dentures, which offer superior fit and reduced adjustment requirements compared to traditional methods. 3D printing significantly reduces the time required for prototyping and production, enabling faster delivery of customized solutions.

Conventional methods, with their multiple steps and longer lead times, are often less time-efficient. This efficiency is particularly valuable in scenarios where rapid prototyping is necessary, such as in emergency medical implants. 3D printing can easily accommodate complex geometries that would be challenging or impossible with conventional methods. This allows for more innovative designs, such as lattice structures for lightweight strength or intricate channels for drug delivery systems within implants.

4.4 Comparative Analysis of Structural and Mechanical Parameters

The porosity and surface roughness of 3D-printed parts are inherently higher than those produced by conventional milling. This is due to the nature of the additive manufacturing process, where each layer may not fully fuse, creating micro voids that enhance surface roughness. These features, while sometimes seen as defects, can be advantageous in medical applications, such as implants, where increased surface area facilitates better cell adhesion and tissue integration.

In contrast, conventionally milled parts, which undergo a subtractive process, have a smoother surface but lower porosity, which may limit biological interactions [1].

3D printing allows for the precise control of pore sizes, essential for mimicking the trabecular structure of natural bone. This controlled porosity provides pathways for vascularization, promoting faster bone growth and integration. Conventional methods lack this level of control, often resulting in a wider distribution of pore sizes, which may not be as effective for biological functions [1].

The tensile strength of 3D-printed zirconia is often superior to conventionally milled zirconia due to the absence of machining-induced defects such as micro-cracks.

The layer-by-layer construction minimizes internal stress and creates a uniform structure that enhances mechanical performance. The elastic modulus of 3D-printed zirconia is also slightly higher, reflecting a more compact and uniform microstructure [4].

Fracture toughness is a critical property for dental materials, indicating resistance to crack propagation. The uniform grain distribution in 3D-printed zirconia enhances fracture toughness

compared to conventional milling, where stress concentrators may compromise the material's durability [4].

The ability to produce complex geometries is a hallmark of 3D printing. This flexibility allows for the design of intricate structures such as lattice frameworks that reduce weight while maintaining strength.

Conventional methods, while robust for standard geometries, are limited in their ability to produce such complex designs without extensive tooling and machining efforts [2].

5. LIMITATIONS OF THE STUDY

While this study provides a detailed comparison of 3D printing and conventional manufacturing methods, several limitations must be acknowledged. First, the analysis relies on secondary data extracted from peer-reviewed literature, which may introduce variability in experimental conditions and methodologies between studies.

For example, variations in printer settings, material types, and post-processing techniques in 3D printing could impact the generalizability of the results, as highlighted in [3]. Additionally, this study does not include experimental data generated directly by the authors. While the statistical analyses conducted provide robust insights, direct experimentation would enhance the validity of the findings by controlling for confounding variables. For instance, performing direct tensile strength and porosity measurements under identical conditions for both manufacturing methods could reduce the influence of external factors.

Another limitation lies in the scope of properties analyzed. While the study focuses on mechanical properties, porosity, and cost-efficiency, other critical factors, such as fatigue resistance under cyclic loading and long-term durability in clinical environments, were not extensively explored. Incorporating such analyses would provide a more comprehensive understanding of the trade-offs between the two methods.

In addition to mechanical considerations, economic and environmental factors play a crucial role in the decision-making process between

3D printing and conventional manufacturing. Alam et al. [1] discuss the material efficiency of 3D printing for small-batch production, noting that while 3D printing reduces material waste, the production costs can still be high due to energy consumption and longer production times. For example, the cost of producing a single 3D-printed fixation plate can range from \$40 to \$60, depending on material choice and production time, as opposed to the \$20 to \$30 for conventionally manufactured plates [4]. Moreover, conventional methods benefit from economies of scale, particularly for high-volume production, which makes them more cost-effective in large-scale manufacturing.

The environmental impact of both methods also warrants consideration; while 3D printing minimizes material waste, the energy usage during production can be significant, increased energy consumption associated with certain 3D printing processes, such as fused deposition modeling (*FDM*) and stereolithography (*SLA*), which require longer processing times and higher operational temperatures.

This results in a higher carbon footprint compared to conventional methods, especially when the scale of production is small or medium-sized. [7]. The recyclability of 3D printing materials is a growing concern, especially as more specialized materials are introduced, such as bio-resins and high-strength polymers.

While some polymers like PLA are marketed as biodegradable, many of the materials used in 3D printing lack a clear, established pathway for large-scale recycling, which raises concerns about their long-term sustainability.

In comparison, many materials used in traditional manufacturing methods, such as metals and plastics, are already part of well-established recycling systems. As 3D printing becomes more widespread, developing more recyclable filaments and improving the recycling processes for used materials will be essential to reducing its environmental impact.

Finally, the study does not consider the environmental impact of these manufacturing approaches. Factors such as energy consumption, material waste, and recyclability are becoming increasingly important in manufacturing decision-making and warrant further exploration.

6. FUTURE RESEARCH DIRECTIONS

This study opens pathways for further investigation to address the limitations identified and expand the comparative analysis between 3D printing and conventional manufacturing methods.

A key avenue for future research lies in conducting experimental studies to validate the findings of this work. Controlled laboratory experiments could provide direct comparisons of tensile strength, porosity, and other mechanical properties under standardized conditions, reducing variability introduced by secondary data sources.

For example, assessing fatigue resistance under cyclic loading in both manufacturing methods would provide valuable insights into the long-term durability of the produced components, which is particularly relevant for implant applications where the mechanical response to physiological loads is critical [5].

Another critical direction involves exploring the biomechanical performance of 3D-printed implants in real-world clinical environments. Longitudinal studies could evaluate factors such as osseointegration, wear resistance, and patient-specific outcomes over extended periods [6]. These studies would contribute to a deeper understanding of the practical implications of using 3D-printed devices in healthcare applications, as suggested by Alghauli et al. in their systematic review of dental zirconia materials [4]. Moreover, expanding the scope of comparative analyses to include environmental and economic factors would be beneficial. Future studies could explore energy consumption, material waste, and recyclability in both 3D printing and conventional manufacturing [7]. Such analyses are critical for aligning these technologies with the growing emphasis on sustainable manufacturing practices.

Finally, integrating advanced technologies such as machine learning and artificial intelligence into the manufacturing process presents an exciting opportunity. AI-driven optimization of 3D printing parameters, for instance, could enhance precision and material efficiency, addressing current limitations in consistency and repeatability. Additionally, the combination of computed tomography (CT) scanning with 3D

printing has been explored as a means to fabricate patient-specific artificial bones with enhanced anatomical accuracy, as demonstrated by Xu et al. in their work on CT-guided fused deposition modeling for bone repair [8].

Collaborations between engineering, materials science, and data science domains could unlock new capabilities for both manufacturing approaches, paving the way for more efficient, scalable, and sustainable solutions.

By addressing these research gaps, future studies could provide a more holistic understanding of the trade-offs and synergies between 3D printing and conventional methods, ultimately guiding their optimal application in various industrial and medical contexts.

7. CONCLUSION

In conclusion, additive manufacturing and traditional machining technologies offer distinct advantages, particularly in the fabrication of micro and nanoscale components for medical applications. Traditional methods such as milling and grinding have a proven track record in producing high-precision components with reliable material characteristics. These methods excel in producing parts with excellent mechanical properties and long-term durability.

However, they often encounter limitations when dealing with complex geometries, requiring extensive post-processing. 3D printing, on the other hand, offers unmatched flexibility in design, enabling the creation of intricate, lightweight structures that are difficult or impossible to achieve through traditional machining techniques. This capability is particularly important in medical applications where customization is crucial, such as patient-specific implants or prosthetics.

One of the core advantages of 3D printing is its ability to create complex geometries without the need for additional tooling or significant post-processing. This makes it highly suited for producing customized medical devices that are tailored to individual patients' anatomical needs. However, as observed in 3D-printed medical devices, challenges remain in terms of material properties, surface finish, and mechanical characteristics, which are essential for long-term biocompatibility and reliability in clinical settings.

Porosity, a common issue in 3D-printed components, can weaken structural integrity, especially in load-bearing devices like orthopedic implants, needs to be minimized through improved printing techniques and the use of advanced materials such as bioactive ceramics and toughened polymers. The need for material innovations to improve fracture toughness and fatigue resistance, which are crucial for long-term use in medical devices [3]. Despite these challenges, ongoing advancements in material science, such as the development of high-strength ceramics and bioactive materials, are helping to close the gap between additive manufacturing and traditional techniques in terms of mechanical performance.

For high-volume production, traditional methods remain the go-to solution due to their cost-effectiveness and speed in mass-producing standardized medical devices. In contrast, 3D printing shines when customization and design flexibility are paramount, especially for low-volume, high-value medical devices. Conventional methods may be limited in creating highly complex, personalized geometries without expensive tooling and additional processes. Thus, additive manufacturing excels in specialized applications where uniqueness and patient-specific design are prioritized.

While traditional machining methods offer precision and mechanical reliability for mass production, 3D printing holds transformative potential, particularly in customized medical device production. 3D printing provides unmatched design flexibility, making it an ideal choice for patient-specific applications, although material properties and surface finish need further optimization to meet the mechanical standards required for high-stress medical devices. Future advancements in material science, production speed, and sustainability will undoubtedly broaden the applicability of 3D printing in medical device manufacturing, making it a more viable option across a wide range of medical applications.

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Evaluarea imprimării 3D ca o performanță alternativă în reconstrucții medicale

Rezumat: Imprimarea 3D schimbă modul în care sunt fabricate dispozitivele medicale, oferind noi posibilități de personalizare și eficiență a materialelor. Cu toate acestea, metodele tradiționale de fabricație, precum frezarea și turnarea, sunt încă utilizate pe scară largă datorită fiabilității dovedite și proprietăților mecanice superioare. Această lucrare compară cele două abordări, analizând factori-cheie precum integritatea structurală, performanța mecanică și rentabilitatea. Ne concentrăm pe aplicații medicale, inclusiv plăci de fixare personalizate pentru pacienți, proteze dentare detașabile și restaurări dentare din zirconiu. Rezultatele arată că, deși imprimarea 3D permite soluții extrem de personalizate și o utilizare eficientă a materialelor, fabricarea convențională rămâne alegerea optimă pentru anumite aplicații care necesită o rezistență mecanică ridicată. Analiza noastră evidențiază punctele forte și limitele fiecărei metode, oferind perspective asupra momentului și contextului în care fiecare abordare este cea mai eficientă.

Cuvinte cheie: *imprimare 3D, fabricație convențională, dispozitive medicale, integritate structurală, proprietăți mecanice, personalizare*

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