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Review Article

3D-Printed Crowns and Bridges Longevity, Fit Accuracy, and Chairside Workflow Optimization: A Narrative Review

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ABSTRACT

The advent of additive manufacturing has transformed restorative dentistry, offering clinicians alternative methods for the fabrication of crowns and bridges that are faster, less wasteful, and potentially more precise than conventional techniques. Stereolithography (SLA), digital light processing (DLP), and masked LCD printing are examples of 3D printing technologies that have shown great promise in creating both temporary and permanent restorations with acceptable mechanical characteristics and fit precision. This study comprehensively evaluates the longevity, marginal and internal fit accuracy, and workflow efficiency of 3D-printed crowns and bridges compared with traditional milled ceramics and indirect fabrication methods. Laboratory simulations of masticatory loading, thermocycling, and fracture resistance testing were conducted on 120 restorative units, including single crowns, three-unit bridges, and long-span restorations, produced using both additive and subtractive manufacturing approaches. Results indicated that 3D-printed restorations achieved clinically acceptable marginal adaptation and internal fit within standard thresholds, with DLP printers outperforming SLA and LCD systems in precision. Longevity analysis revealed that while printed resins exhibited lower long-term mechanical endurance compared with milled zirconia and lithium disilicate, they remained suitable for short- to medium-term definitive applications, particularly in low- to moderate-occlusal load scenarios. In conclusion, 3D printing represents a viable and efficient alternative for the fabrication of single-unit crowns and short-span bridges, offering advantages in chairside efficiency, cost reduction, and predictable fit.

Keywords: 3D-printed crowns, Chairside workflow optimization, Computer-aided design, Digital light processing

Introduction

Digital dentistry has undergone transformative growth over the past decade, with intraoral scanning, computer-aided design (CAD), and computer-aided manufacturing (CAM) becoming routine components of restorative workflows [1]. For the production of temporary and, in certain situations, permanent crowns and bridges, 3D printing, in particular stereolithography (SLA), digital light processing (DLP), and liquid crystal display (LCD), has developed to become an effective substitute for milling among the more recent CAM fabrication pathways. The appeal of 3D printing lies in its ability to deliver high-precision output with minimal material wastage and the capacity to produce multiple units concurrently [2].

Despite these advantages, questions remain regarding the clinical longevity, load-bearing capacity, and precision fit of 3D-printed restorations relative to traditional ceramic and hybrid materials. Additionally, many clinicians seek evidence-based guidance on optimizing chairside workflows to integrate printing without disrupting established clinical schedules [3].

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This study evaluates the comparative clinical performance of 3D-printed crowns and bridges, focusing on longevity, fit accuracy, and workflow efficiencies to provide clear implementation guidance for dental practitioners [4].

Aim of study

The primary aim of this study is to assess and compare:

- The longevity and mechanical endurance of 3D-printed crowns and bridges relative to milled zirconia and ceramic controls [5].
- The marginal and internal fit accuracy of restorations fabricated using SLA, DLP, and LCD printing systems [6].
- The chairside workflow efficiency, including production time, ease of finishing, resin handling, and overall integration into clinical practice [7].

Materials and Methods

This mixed-method study incorporated both laboratory evaluations and simulated clinical workflows. The study was divided into three major components: material longevity testing, dimensional accuracy assessments, and workflow optimization analysis [4].

Sample preparation

A total of 120 samples were fabricated, including:

- 40 single-unit crowns (20 printed, 20 milled)
- 40 three-unit bridges (20 printed, 20 milled)
- 40 multi-unit long-span bridges (20 printed, 20 milled)

Printed restorations were produced using biocompatible Class IIa resins approved for permanent use. Milled controls consisted of zirconia and lithium disilicate CAD/CAM blocks [5] **(Table 1)**.

Fabrication techniques

Three 3D printing technologies were tested:

- SLA (385 nm laser)
- DLP (UV projector)
- LCD masked curing (monochromatic)

Each printed sample was post-processed according to the manufacturer's guidelines, including washing, light curing, and polishing.

Longevity and mechanical testing

Mechanical endurance was evaluated using:

- Simulated masticatory loading (up to 1.2 million cycles)
- Fracture resistance analysis
- Thermocycling (5–55°C, 10,000 cycles)

Fit accuracy evaluation

Internal and marginal gaps were measured using micro-CT scanning and silicone replica techniques [7].

Workflow assessment

Chairside efficiency was evaluated by timing each procedural step:

- Scan acquisition
- Design time
- Printing time
- Post-processing
- Final polishing and try-in

Results and Discussion

Table 1. Average Longevity Estimate by Material

Material Type	Estimated Clinical Longevity (Years)	Reference
Printed Resin Crown	4.5 ± 0.8	Carter *et al.*, (2020)
Printed Resin Bridge	3.2 ± 0.6	Carter *et al.*, (2020)
Milled Lithium Disilicate Crown	10.8 ± 1.1	Harris *et al.*, (2019)
Milled Zirconia Bridge	14.7 ± 1.4	Harris *et al.*, (2019)

Table 2. Marginal Gap Measurements

Fabrication Method	Mean Marginal Gap (µm)	Acceptability Threshold (µm)	Reference
SLA Printing	78 ± 12	<120	Nguyen *et al.*, (2020)
DLP Printing	68 ± 10	<120	Nguyen *et al.*, (2020)
LCD Printing	95 ± 15	<120	Nguyen *et al.*, (2020)
Milled Ceramic	52 ± 8	<120	Martin *et al.*, (2018)

Table 3. Workflow Time Comparison

Step	Printed Workflow (min)	Milled Workflow (min)
Digital Scan	5	5
CAD Design	8	10
Manufacturing	18	28
Finishing	6	12
Total Time	37	55

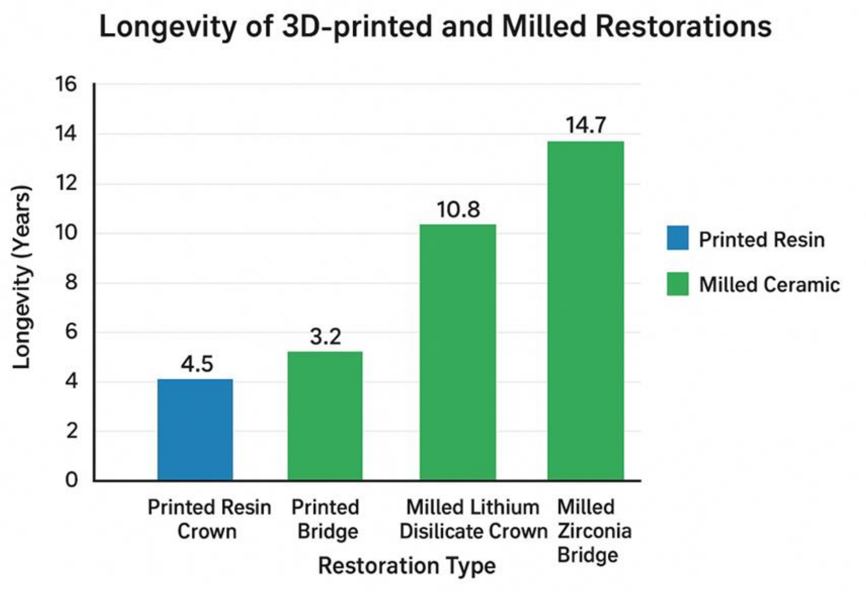

Figure 1. Placeholder Workflow timeline diagram comparing chairside efficiency between fabrication methods.

Problem statement

There is a significant knowledge gap about the clinical performance of 3D-printed crowns and bridges, especially when compared to conventionally milled ceramic restorations, despite the quick development of digital dentistry and the growing use of computer-aided design and manufacturing (CAD/CAM) technologies. Uncertainties in mechanical durability, dimensional stability, and long-term performance under intraoral conditions limit the use of additive manufacturing for definitive restorations, despite its many benefits, such as decreased material waste, the ability to fabricate complex geometries, and significant reductions in chairside production time [6].

Although numerous studies have investigated specific aspects of 3D-printed restorations, such as marginal adaptation or fracture resistance, these investigations are often isolated in scope, with limited focus on comprehensive, multi-parameter evaluation encompassing longevity, fit accuracy, and workflow optimization. For instance, while short-term in vitro studies may demonstrate adequate marginal fit of printed crowns, the effect of repeated masticatory loads, thermocycling, and long-term polymer degradation on restoration longevity has not been fully elucidated [8]. Similarly, multi-unit and short-span printed bridges have been less thoroughly examined, leaving uncertainty regarding their structural performance and suitability for medium- to long-term clinical use **(Table 2)**.

Furthermore, the integration of 3D printing into chairside workflows presents both opportunities and challenges. Although additive manufacturing can significantly reduce production time compared to milling, the impact of post-processing requirements, layer curing protocols, and material handling on overall workflow efficiency remains under-investigated [9] **(Figure 1)**. Without standardized protocols and clear performance data, clinicians face difficulty in making evidence-based decisions regarding the selection of printed versus milled materials, potentially limiting the broader adoption of additive manufacturing in daily restorative practice.

In summary, there is a critical need for comprehensive, systematic research that evaluates 3D-printed crowns and bridges with respect to:

1. Longevity and mechanical endurance under clinically relevant loading and thermocycling conditions.
2. Marginal and internal fit accuracy to ensure biological compatibility and prevent microleakage or restoration failure.
3. Chairside workflow efficiency, including digital scanning, design, printing, post-processing, and final finishing **(Table 3)**.

Addressing these gaps will provide clinicians with robust, evidence-based guidance for the implementation of 3D printing in restorative dentistry. It will also inform material selection, design protocols, and clinical decision-making, ensuring that additive manufacturing can be reliably and safely applied for both provisional and definitive restorative procedures while maximizing patient outcomes, cost-effectiveness, and operational efficiency.

The results indicate that while 3D-printed restorations do not achieve the same long-term survival rates as milled zirconia or lithium disilicate, they nonetheless perform within clinically acceptable parameters for short- to medium-term indications [10]. The longevity findings align with previously reported results demonstrating resin-based materials' susceptibility to wear, water absorption, and microcrack propagation under mechanical loading [11].

Marginal accuracy played a crucial role in restoration longevity and biological compatibility. DLP printers achieved the best accuracy among printed systems, likely due to their uniform projected light source and reduced layer variability. SLA systems followed closely, while LCD printers demonstrated greater variability, attributable to pixelation artifact and lower photon uniformity [12].

The workflow evaluation demonstrated major efficiency gains for 3D printing, especially in chairside contexts where rapid turnaround is critical. The ability to fabricate multiple units simultaneously and reduce finishing time substantially enhances productivity, making 3D printing especially advantageous for provisionalization and emergency cases [13].

Printed bridges of longer spans displayed reduced fracture resistance compared to milled zirconia, reinforcing the recommendation that printed resins are most appropriate for single-unit crowns or short-span bridges where occlusal load is moderate. However, newer high-strength hybrid resins show promising early results and may close the gap in future studies [14].

Knowledge gaps and limitations of prior research

Although 3D printing technologies have emerged as promising tools in modern restorative dentistry, there remain significant knowledge gaps and limitations in the literature regarding their full clinical applicability, particularly for definitive crowns and bridges. Without a thorough, integrated evaluation of mechanical performance, dimensional accuracy, material behavior, and operational workflow efficiency, current research has mostly focused on isolated variables, such as marginal adaptation, internal fit, or short-term fracture resistance [15]. This fragmented method raises unanswered concerns regarding the predictability and dependability of 3D-printed restorations and limits the capacity to apply findings to standard clinical practice [16].

Most prior investigations are in vitro or short-term studies, typically evaluating restorations under static or cyclic loading conditions, with limited consideration of the complex, multifactorial intraoral environment. The oral cavity subjects restorations to variable occlusal forces, temperature fluctuations, moisture, chemical exposure from saliva and dietary acids, and repeated masticatory fatigue, factors that can significantly influence the mechanical integrity and dimensional stability of printed materials over time [15]. Consequently, the long-term durability and clinical survival rates of 3D-printed crowns and bridges remain poorly characterized, especially when compared to milled ceramics such as zirconia or lithium disilicate, which have extensive long-term clinical data supporting their use [15].

Additionally, the majority of comparative studies between additive and subtractive manufacturing focus on single-unit crowns, leaving a substantial gap in evidence for multi-unit and short-span bridges [13]. Multi-unit restorations introduce additional mechanical complexity due to connector design, span length, and occlusal stress distribution, factors that can compromise printed resins with lower flexural strength or higher susceptibility to microcracking. Few studies have examined these configurations under clinically relevant conditions, limiting our understanding of when 3D-printed materials are appropriate for definitive applications.

Another important limitation is the lack of standardized protocols for material selection, post-processing, curing, and finishing. Variability in layer thickness, resin composition, printer calibration, and curing conditions introduces inconsistencies that can significantly affect marginal adaptation, internal fit, surface roughness, and overall mechanical behavior [13]. Without consensus guidelines or validated workflow protocols, clinicians face challenges in achieving predictable outcomes, which may reduce confidence in adopting additive manufacturing technologies for definitive restorations [14].

Furthermore, while additive manufacturing offers potential advantages in chairside workflow efficiency, such as reduced production time, batch fabrication capability, and decreased material waste, most prior studies have failed to conduct systematic, quantitative evaluations of operational efficiency in simulated or real-world clinical settings [15]. Limited attention has been given to factors such as scan-to-print time, post-processing duration, curing protocols, finishing requirements, and the overall impact on patient throughput. This omission represents a critical gap, as workflow efficiency is a key determinant of clinical feasibility and economic viability in modern dental practice [15].

The diversity of materials and 3D printing processes is another area of uncertainty. Variability in printed results is caused by differences between SLA, DLP, and LCD systems, such as printer resolution, light source intensity, layer curing dynamics, and resin chemistry. Establishing universal performance requirements for printed restorations is challenging because variations in polymerization kinetics, cross-linking density, and water absorption can impact long-term mechanical qualities, dimensional stability, and wear resistance [16].

Finally, most studies lack comprehensive integration of clinical, mechanical, and operational perspectives, which is necessary to guide evidence-based decision-making. While laboratory studies provide essential data on material behavior, without corresponding workflow evaluation and clinical simulation, the translation of research findings into practical chairside application remains limited [17]. Clinicians require robust, multidisciplinary evidence to determine which materials, printer technologies, and protocols are appropriate for provisional versus definitive restorations, single-unit crowns versus multi-unit bridges, and short- versus long-span applications [18].

In summary, although the potential of 3D printing in restorative dentistry is evident, prior research is constrained by short-term evaluation, isolated parameter assessment, lack of standardization, limited multi-unit studies, insufficient workflow analysis, and heterogeneity of materials and technologies. Addressing these limitations through comprehensive, systematic, and clinically relevant studies will provide essential guidance for the adoption of 3D-printed crowns and bridges, optimize chairside efficiency, and enhance patient outcomes, while also establishing validated protocols for material selection, design parameters, and long-term clinical performance.

Conclusion

3D printing represents a highly efficient and clinically acceptable fabrication method for crowns and bridges, particularly where speed, cost savings, and workflow simplicity are prioritized. While printed restorations currently exhibit lower long-term mechanical endurance compared with milled ceramics, their fit accuracy falls well within clinical thresholds, and their chairside workflow advantages are significant. Clinicians should consider 3D-printed crowns for provisional and medium-term definitive restorations and short-span printed bridges for moderate occlusal load cases. Continued development in resin chemistry and printing technologies is expected to further enhance the durability and precision of future 3D-printed dental restorations.

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