

# Rapid Prototyping in Fixed Partial Denture (FPD) Prosthodontics — A Review

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**Abstract-** Rapid prototyping (RP) and additive manufacturing (AM; commonly “3D printing”) have transformed dental laboratory workflows, offering new approaches for the design and fabrication of fixed partial dentures (FPDs). RP technologies—stereolithography (SLA), digital light processing (DLP), selective laser sintering/melting (SLS/SLM), material jetting and binder-jetting—enable layer-by-layer fabrication of models, patterns, frameworks and definitive restorations. This review summarizes RP technologies and materials relevant to FPD prosthodontics, evaluates accuracy and fit data, discusses clinical workflows and limitations, and outlines future directions including directly printed ceramics and hybrid production routes. Evidence suggests that RP-produced single-unit and short-span FPDs can achieve clinically acceptable marginal and internal fits comparable to conventional and milled restorations in many settings, while larger-span frameworks and long-term mechanical performance remain active areas of research. Practical considerations for clinicians and technicians are emphasized to harness RP safely and effectively in FPD practice.

**Keywords:** rapid prototyping, 3D printing, additive manufacturing, fixed partial denture, prosthodontics, stereolithography, selective laser sintering, zirconia, CAD/CAM

## I. INTRODUCTION

Digital dentistry has advanced rapidly over the last two decades. The integration of intraoral scanning, computer-aided design (CAD), and computer-aided manufacturing (CAM) has allowed a shift from subtractive (milling) to additive (layered) production for many dental indications. Rapid prototyping (RP) — the umbrella term historically used to describe the automated creation of physical objects from virtual CAD files — now largely overlaps with additive manufacturing (AM) and 3D printing terminology in dental research and practice. RP provides highly flexible fabrication routes for FPDs (crowns, short-span bridges, implant superstructures and frameworks), model production, and pattern fabrication for casting and pressing workflows. The aim of this review is to synthesize current evidence on RP techniques and materials as applied to FPD prosthodontics, with emphasis on accuracy, materials performance, clinical workflow, advantages, limitations and future directions.<sup>1,2</sup>

## II. METHODS OF LITERATURE IDENTIFICATION

A targeted literature search was performed across PubMed/PMC, Scopus and major open-access journals up to Sept 30, 2025, using keywords: “rapid prototyping”, “3D printing”, “additive manufacturing”, “fixed partial denture”, “crown”,

“bridge”, “stereolithography”, “selective laser sintering”, “zirconia 3D printing”, and combinations. Priority was given to recent systematic reviews, in-vitro accuracy studies, materials reviews and clinical reports. Seminal technology overviews and consensus statements were also included to provide technological context.<sup>3,4</sup>

RP technologies used in FPD prosthodontics

RP/AM techniques relevant to FPD production can be grouped by the mechanism used to build layers:

Vat polymerization: SLA & DLP

Stereolithography (SLA) and digital light processing (DLP) cure photopolymer resins layer-by-layer by light exposure. SLA typically uses a laser to trace each layer while DLP exposes whole layers using a projector. These methods are widely used to produce highly detailed dental models, resin provisionals, splints and casting patterns for metal frameworks. SLA/DLP printers offer excellent surface detail and are relatively low-cost for dental labs and clinics. SLA/DLP-printed resin crowns and frameworks (after appropriate post-processing) are increasingly used for provisional and, in some cases, definitive restorations when biocompatible, long-term resins are employed.<sup>1,2,4</sup>

Material jetting (PolyJet)

Material jetting deposits droplets of photopolymer that are instantly cured — enabling multi-material and multi-color prints with fine resolution. It has been used for highly detailed models, try-ins and complex prototypes where accurate fit and esthetics for try-in are needed.<sup>5</sup>

Powder-bed fusion: SLS/SLM

Selective laser sintering (SLS) and selective laser melting (SLM) fuse powder particles (polymers or metals) with a laser. Metal SLM/SLS is used to produce cobalt-chromium or titanium frameworks for RPD and implant frameworks; it has been applied to metal frameworks for FPDs and to fabrication of implant bars. Powder-bed fusion offers the advantage of direct metal fabrication without casting, often improving reproducibility and reducing manual steps.<sup>5,8</sup>

Binder jetting and hybrid routes

Binder jetting deposits an adhesive (binder) into a powder bed to form shapes which can then be infiltrated or sintered; it has been used to create casting patterns or metal parts after post-processing. Hybrid workflows—3D printing patterns that are then cast—remain common for some clinician-lab workflows (e.g., printing wax/resin patterns -> invest -> cast).<sup>6,7</sup>

Direct ceramic printing (emerging)

Direct additive manufacturing of ceramics — especially zirconia — is an active area. Approaches include stereolithography-based ceramic slurry printing with subsequent sintering and binder-assisted printing. Early reports demonstrate promising aesthetics and geometrical fidelity, though clinical long-term data are still limited.<sup>3,6</sup>

Materials for RP FPDs

Photopolymer resins for SLA/DLP and material jetting: used for models, temporary crowns, and pattern fabrication. Biocompatible resins for definitive restorations are emerging but differ in mechanical performance from ceramics and metals. Resin composites printable by vat polymerization for long-term temporaries. Metals (Co-Cr, Ti) used in powder-bed fusion for direct fabrication of frameworks and implant bars.

Zirconia and glass-ceramics — direct AM of zirconia is increasingly reported; milled zirconia remains the standard for high-strength definitive FPDs. Recent 3D-printed zirconia studies report improving accuracy and aesthetics but sintering shrinkage control and mechanical properties remain under evaluation.<sup>2,6,9</sup>

Applications in FPD

Diagnostic models, occlusal records and try-in

SLA/DLP prints of diagnostic casts and mock-ups facilitate try-in and patient communication. High-resolution resin patterns may be printed for investment and casting of metal frameworks, bypassing manual waxing steps.<sup>10</sup>

Definitive restorations — single crowns and short-span FPDs

Resin-based printed crowns and hybrid printed-ceramic crowns are used especially for provisional and short-term definitive crowns. For single-unit crowns and short-span bridges, some studies report marginal and internal fit comparable to milled restorations when optimized printing and post-processing are applied.<sup>11,13,6</sup>

#### Metal frameworks and implant superstructures

SLM/SLS can directly produce Co-Cr frameworks and titanium implant bars with accurate fit and good strength, increasingly replacing casting in high-volume labs.<sup>5,12,27</sup>

#### Long-span prostheses and full-arch work

While AM is advancing for long-span frameworks and implant-supported bars, conventional multi-stage workflows and hybrid approaches remain common due to mechanical and fit concerns for long unsupported spans.<sup>13</sup>

#### Accuracy, fit and clinical performance

Accuracy (trueness and precision) and fit (marginal, internal) are central to prosthodontic success. Recent in-vitro and clinical studies provide these insights:

Single crowns and short-span FPDs: Multiple comparative studies and reviews report that resin-based 3D printed single crowns and short-span bridges (SLA/DLP) can achieve clinically acceptable marginal gaps (often under 120  $\mu\text{m}$  in many reports) comparable to CAD/CAM milled crowns when printer resolution, resin properties and post-curing are controlled. Systematic reviews also show improving trends over the past decade as printers and materials mature.<sup>1,13</sup> Metal frameworks: Powder-bed fusion (SLM/SLS) frameworks for removable and fixed prostheses often show accuracy comparable or superior to conventional cast frameworks, with reduced human variability in many labs. However, printing orientation, support design and post-processing (heat treatment, polishing) influence fit significantly.<sup>5,8,14</sup>

Zirconia: Directly printed zirconia is promising; comparisons with milled zirconia show potential advantages in contouring and color matching in some studies, but mechanical and long-term fatigue data are

still evolving. Controlling sintering shrinkage and porosity is critical.<sup>3,6,16</sup>

Load-bearing and fatigue behavior: For definitive FPDs, long-term mechanical behavior under cyclic loading remains an important determinant. Many resin-based printed materials are suitable for provisionals; for definitive high-load posterior FPDs, ceramic or metal restorations currently remain preferred for proven long-term performance.<sup>16</sup>

#### Advantages of RP in FPD workflows

Design freedom & complexity: Additive layering allows geometries difficult to mill or cast, including undercut and lattice structures for bars and frameworks. Reduced manual steps: Printing patterns for casting reduces labor-intensive waxing and human variability. Customization & speed: On-demand production of models, provisionals and small definitive restorations can shorten turnaround times.<sup>17</sup>

Material efficiency: Additive processes can reduce material waste compared to subtractive milling. Digital traceability & reproducibility: Digital files enable easy reproduction and quality control.<sup>17,18</sup>

### III.LIMITATIONS AND CHALLENGES

Material properties: Printed polymers often have lower mechanical strength and different wear and aging characteristics compared to ceramics and metals; long-term clinical data remain limited for many printable materials.<sup>3</sup>

Post-processing criticality: Post-curing, cleaning, sintering and heat treatments are essential steps that significantly affect final properties and dimensional stability. Inadequate post-processing leads to poor fit or compromised mechanical behavior.<sup>8</sup>

Dimensional changes & shrinkage: Ceramic printing involves sintering shrinkage that must be accurately compensated in design and software workflows. Surface finish & polishing: Additively produced surfaces may require additional finishing or polishing, especially for metal frameworks and occlusal contacts. Regulatory & material biocompatibility: Certification and medical-grade material availability vary by region — clinicians must use certified materials for intraoral long-term use.<sup>7</sup>

Equipment & training costs: Investment in reliable printers, post-processing equipment and staff training is necessary for predictable results.<sup>19</sup>

Clinical workflow considerations and best practices

Scanner and data quality: Begin with accurate intraoral or laboratory scans. Data integrity is foundational—errors propagate through printing. Printer selection by indication: Use SLA/DLP for models and provisional crowns; use SLM for metal frameworks and titanium implant bars; consider direct ceramic approaches only where validated clinically for the indication.<sup>14</sup>

Orientation and support planning: Print orientation and support placement affect surface quality and dimensional accuracy—optimize orientation to minimize critical-surface supports and layer stepping on margins. Calibration and validation: Routine calibration, test prints and validation against master models improve consistency.<sup>12</sup>

Material traceability and post-processing: Maintain manufacturer-recommended post-processing (wash, post-cure, sintering schedules). Document batch and lot for traceability.<sup>16</sup>

Try-in & adjustments: Use printed try-in models or provisional restorations to verify occlusion, contacts and esthetics before definitive processing. Collaboration with dental lab: Close clinician-technician communication remains key: design approvals, scan verification and clear instructions reduce remakes.<sup>20</sup>

Emerging trends & future directions

Directly printed high-strength ceramics: Continued improvements in zirconia AM (slurry/photopolymer-based ceramic printing with controlled sintering) may allow direct production of definitive zirconia FPDs with predictable properties.<sup>3,18</sup>

Multi-material printing and gradient materials: Combining materials in a single build (e.g., graded enamel-dentin analogs, soft-hard interfaces) may improve esthetics and functional matching. AI-assisted design and error prediction: Machine learning models trained on print errors and fit outcomes may predict and compensate for distortion, improving first-pass accuracy.<sup>7,12</sup>

On-demand chairside manufacturing: As chairside desktop printers and biocompatible resins/cements mature, same-day provisional and short-span definitive FPDs may become routine. Standardization and long-term clinical trials: Broad clinical adoption will follow large-scale, long-term randomized trials comparing AM restorations to milled and cast alternatives.<sup>20</sup>

#### IV. CONCLUSION

Rapid prototyping and additive manufacturing are established and growing tools in FPD prosthodontics. For diagnostic models, provisionals and many single-unit and short-span restorations, RP offers clinically acceptable accuracy, faster workflows and design flexibility. Powder-bed fusion enables direct metal framework fabrication with reproducible fit, while direct ceramic printing is an advancing field with significant future promise. Clinicians and laboratories should select technology and material according to indication, adhere to validated post-processing protocols, and monitor emerging evidence on long-term mechanical and biological outcomes. Continued innovation, standardization, and clinical trials are necessary to fully integrate RP-produced definitive FPDs into mainstream prosthodontic practice.

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