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Review Article

The Impact of Layer Thickness on Key Parameters Affecting 3D-Printed Dental Materials: A Systematic Review

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Abstract

Background: Three-dimensional (3D) printing has transformed restorative, and prosthetic dentistry, providing new possibilities for the fabrication of dental materials. Nevertheless, the influence of printing layer thickness on the final properties of dental resins remains insufficiently clarified.

Study Design (Methods): A systematic review was conducted through a comprehensive electronic search of PubMed, Scopus, and Web of Science up to June 2025. Eligible *in-vitro* studies investigated the effect of 3D printing layer thickness on the mechanical properties, dimensional accuracy, surface roughness, and bond integrity of dental resins. Thirty-seven studies met the inclusion criteria, and were analyzed narratively due to heterogeneity in study designs, materials, and testing methods.

Results: Printing layer thickness demonstrated a significant effect on dental resin performance. Thinner layers (25-50 µm) were generally associated with enhanced flexural strength, hardness, surface smoothness, and color stability. However, in some composite-based materials, thicker layers yielded superior mechanical properties. Dimensional accuracy, and marginal fit varied across studies, with some reporting optimal results at 50 µm, and others at 100 µm.

Conclusion: Layer thickness represents a critical parameter influencing the performance of 3D-printed dental resins. Optimal outcomes depend on a balance between layer thickness, build angle, and post-curing protocols. Further standardized investigations, including clinical studies, are essential to establish evidence-based guidelines for layer thickness selection in dental additive manufacturing.

Keywords: 3D Printing; Additive Manufacturing; Dental Biomaterials; Layer Thickness

Introduction

Three-Dimensional (3D) printing has seen remarkable progress in recent years, becoming more accurate, and reliable, which has made it an increasingly attractive tool in the medical field. In dentistry, additive manufacturing enables the rapid fabrication of customized devices, ranging from surgical guides, and orthodontic appliances to provisional, and definitive restorations. Compared with conventional subtractive techniques, 3D printing offers advantages such as reduced material waste, enhanced design flexibility, and the ability to reproduce complex geometries with high precision. These developments have accelerated its integration into both clinical, and laboratory workflows. Its versatility has opened new doors in healthcare, with applications ranging from medicine, and dentistry to orthopedics, tissue engineering, and the creation of medical devices [1-3]. At the heart of this technology is the ability to transform digital designs into physical objects-starting with a 3D model in Standard Tessellation Language (STL) format, which is then built layer by layer by bonding, joining,, or curing small amounts of material [4].

In dentistry, several 3D printing technologies have become widely used, with Stereolithography (SLA), and Digital Light Processing (DLP) standing out as the most common [5]. Other methods include Fused Deposition Modeling (FDM), Powder Bed Fusion (PBF), laser powder forming, and inkjet printing, each differing mainly in the materials they use, and how they build layers to form a 3D object [6,7].

SLA, one of the earliest 3D printing techniques introduced in 1986, works through a photopolymerization process. It uses a photosensitive liquid resin cured layer-by-layer with Ultraviolet (UV) light, or a laser to gradually build a solid structure on a platform. Each cured layer bonds to the previous one, creating a strong, cohesive object [5].

DLP shares many similarities with SLA but replaces the laser with a digital light projector to cure the resin [8]. This change offers significant benefits: DLP can cure an entire layer at once, affectedly speeding up the printing process. It also tends to be more cost-effective since it uses less material compared to SLA, and other 3D printing techniques [5]. Currently, DLP is widely adopted in dental applications, such as producing precise models from digital impressions, surgical guides, castable restorations, splints, and even temporary crowns. Given its combination of speed, accuracy, and cost-efficiency, DLP's role in dentistry is expected to continue growing rapidly [5]. The efficiency of 3D printing is influenced by several factors, including layer thickness, laser intensity, and speed, build angle, the design of support structures, and the specific printing technology used (Table 1) [9-14].

Several studies have assessed the influence of layer thickness on the properties of 3D-printed dental materials [15-25]. Models printed using SLA, and DLP technologies at various layer heights have been shown to remain within clinical accuracy limits [15,16]. Layers of 100 μm exhibited less deviation than finer ones [15,16], improved flexural, and tensile strength, better degree of conversion, and color stability, and shorter printing time [5,19-21]. Hence, layers of 50 μm were found to have superior mechanical properties, and marginal fit [5,22,23]. Beyond mechanical performance, advances in 3D printing have also targeted esthetic outcomes, with new strategies such as integrated color rendering mechanisms using adaptive colored layer sequencing, which improve color reproduction quality by considering both global, and local model characteristics [17]. Additionally, 50 μm layers were determined to reduce surface roughness, contact angle, and microbial adhesion compared to 100 μm in high-viscosity DLP denture bases [25]. Çakmak, et al., revealed that milled interim crowns had better margin quality than printed ones, especially at 20 μm, and 100 μm [24]. Collectively, these findings underscore the importance of selecting an appropriate layer thickness to optimize the mechanical, esthetic, and biological outcomes of dental 3D printing. As previously highlighted, several key factors significantly influence the reliability of 3D-printed materials in dentistry. These include the accuracy of the print, the material's mechanical strength, the speed of printing, the chosen layer thickness, and the specifics of the curing process [9,12,26-29]. Selecting the appropriate 3D printing material ultimately depends on the intended dental application. For instance, materials used in dental restorations should exhibit strength, resistance to degradation, biocompatibility, and esthetics [30].

Given the diversity of findings across different studies, and printing protocols, there is a pressing need to synthesize the current evidence to clarify how layer thickness variations affect the performance of 3D-printed dental materials [15-25]. Therefore, this systematic review aims to assess the impact of different 3D printing layer thicknesses on key material properties including mechanical strength, dimensional accuracy, surface roughness, and bond integrity in *in-vitro* studies involving dental resins.

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations, and therefore, was exempt.

Material and Methods

Study Design

This systematic review, and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews, and Meta-Analyses (PRISMA) guidelines, and the Cochrane Handbook for Systematic Reviews of Interventions [21]. The study protocol was registered in the Open Science Framework (OSF) under the identifier DOI: 10.17605/OSF.IO/GW68P.

The research question was formulated using the PICOT framework:

Population (P): 3D-printed dental materials.

Intervention (I): Use of different layer thicknesses during the 3D printing process.

Comparison (C): Standard, or alternative layer thicknesses.

Outcome (O): Mechanical properties.

Time/Study Design (T): *In-vitro* studies.

The research question guiding this study was: "How does the variation in layer thickness during the 3D printing process influence the properties of 3D-printed dental materials in *in-vitro* studies?".

Search Strategy

A comprehensive electronic search was used to identify relevant *in-vitro* studies using major scientific databases (e.g., PubMed, Scopus, Web of Science). The search included studies published up to June 3, 2025.

Search	Keywords
# 1	3D printing, or 3D-printing, or 3D-printed dental resin, or additive manufacturing, or additive manufacturing technologies, or 3D printing manufacturing, or 3D printing resin, or 3D print resin, or 3D-printed materials, or 3-dimensional printing
# 2	Thickness, or layer thickness, or print layer thickness
# 3	tensile test, or microtensile strength, or microtensile bond strength, or micro-tensile strength, or shear bond strength, or microshear bond strength, or compression test, or flexural strength, or elastic modulus, or hardness, or mechanical tests, or mechanical properties, or degree of conversion, or polymerization, or wear resistance, or color stability, or dimensional stability, or trueness, or accuracy, or marginal fit, or margin quality, or surface roughness, or surface properties, or contact angle, or cell adhesion, or bond, or bonding, or dental bonding, or bonding efficacy, or bond strength, or bonding performance, or bonding effectiveness, or bond performance, or bonding properties, or adhesive properties
# 4	# 1, and # 2, and # 3

Table 1: Search strategy used.

Study Selection

Two independent reviewers (RB, and CECS) assessed titles, and abstracts based on these inclusion criteria: (1) *In-vitro* studies reporting the effect of layer thickness variation on the properties of 3D-printed dental materials; (2) Evaluated at least one outcome parameter; (3) Included a comparison between at least two different layer thicknesses; (4) Included quantitative data with mean, and standard deviation values; (5) Published in English, Spanish,, or Portuguese. Studies were excluded if they were case reports, case series, pilot studies, reviews,, or did not meet the specified inclusion criteria. Full-text articles were retrieved for studies that met the inclusion criteria, or if eligibility was unclear. Any discrepancies between reviewers were addressed through discussion, or consultation with a third reviewer (LH).

Data Extraction

Data extraction was performed using a standardized form, including: Study, and year, Materials tested, Printer used, Layer thickness tested, Properties evaluated, and Main results.

Quality Assessment

The risk of bias in the selected studies was evaluated using the Quality Assessment Tool for *In-Vitro* Studies (ROBDEMat) [22], which addresses four main domains: D1 - planning, and allocation, D2 - sample/specimen preparation, D3 - outcome assessment, and D4 - data analysis, and reporting.

Domain D1 includes three criteria: the use of an appropriate control, or reference group, randomization of specimens, and justification of the sample size.

Domains D2, D3, and D4 each involve two criteria. Specifically, D2 focuses on standardization of methodology, and experimental conditions; D3 considers reproducibility, and the presence of operator blinding; while D4 examines the adequacy of statistical analyses, and the clarity of outcome reporting.

Each criterion was scored as "sufficiently reported," "insufficiently reported," "not reported,", or "not applicable." Two reviewers (RB, and NN) conducted the assessment independently, and disagreements were resolved by discussion or, if necessary, with the input of a third reviewer (MLS) until consensus was achieved [22].

Results

Search Strategy

A comprehensive search across all databases initially identified 7,366 records. Following the removal of duplicates, 5,625 unique publications were retained for preliminary screening. After evaluating titles, and abstracts, 5,571 studies were excluded for not meeting the inclusion criteria. This left 54 articles for full-text assessment. Of these, 17 were excluded because the full-text cannot be retrieved. A detailed overview of the selection process is illustrated in the PRISMA flowchart (Fig. 1).

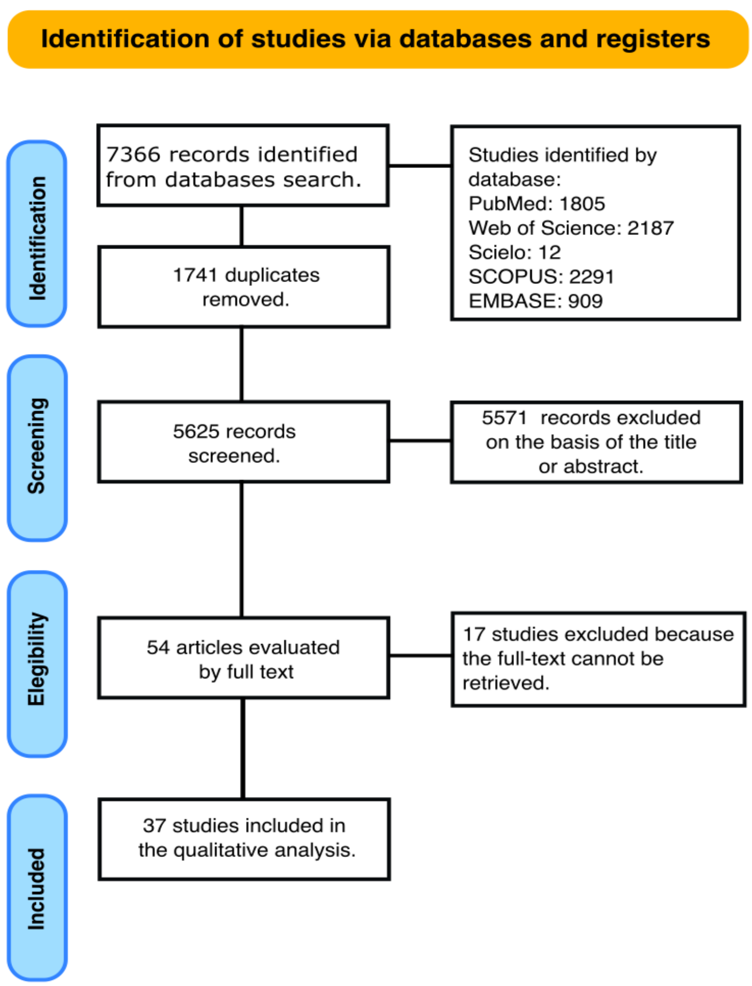

Figure 1: PRISMA flowchart.

Main Findings
This systematic review synthesized data from various *in-vitro* studies investigating the effect of layer thickness on the properties of 3D-printed dental materials [5,20,31-65]. The included studies evaluated a range of materials, including denture base resins, interim crown/FPD resins, PLA, ABS, PETG, and stainless steel. Diverse 3D printers, such as Asiga, NextDent, Formlabs, SISMA, Zaxe, and Flashforge, were utilized across the studies.

Although these studies were performed *in-vitro*, their findings carry important clinical implications. Variations in printing layer thickness were shown to influence mechanical strength, dimensional accuracy, and surface quality, which are critical for the long-term success of dental restorations. For example, in interim crowns, and fixed partial dentures, optimal layer thickness can improve marginal fit, and resistance to fracture, while in denture bases, it may enhance adaptation, and patient comfort. Similarly, in orthodontic, or surgical applications, accuracy related to layer thickness directly impacts treatment precision. These outcomes highlight the translational value of *in-vitro* results to clinical scenarios, where material properties strongly determine restoration performance, esthetics, and patient satisfaction.

The assessed layer thicknesses varied significantly, ranging from 20 μm to 2 mm, with common thicknesses including 25, 50, and 100 μm. The properties evaluated were extensive, covering mechanical strength (e.g., flexural, tensile, compressive strength, hardness, fracture resistance, wear resistance), dimensional accuracy (trueness, precision, marginal/internal gap), surface characteristics (roughness, wettability), optical properties (color stability, translucency, scattering, absorption), and degree of conversion.

Key findings demonstrated that layer thickness plays a crucial role in determining the properties of 3D-printed dental materials. Thinner layers (25-50 μm) were frequently associated with greater flexural strength, and hardness in denture base resins. In contrast, certain materials exhibited superior mechanical performance at thicker settings, such as 0.64 mm for CF/PLA composites, and 0.7 mm for shape memory resin flexural strength. Surface roughness typically decreased with thinner layers, contributing to smoother finishes. Dimensional accuracy, and marginal fit yielded mixed results: while some studies identified 50 μm as optimal for adaptation, others reported that 100 μm enhanced trueness, and precision. Optical outcomes, including color stability, and translucency, were also influenced by layer thickness, often showing improvement with thinner layers. Furthermore, the degree of conversion was affected not only by the printing layer thickness but also by the post-curing protocol employed. Overall, the studies highlight the critical role of layer thickness, often alongside other printing parameters like build angle, in determining the final performance of 3D-printed dental materials (Table 2).

Study, and Year	**Materials Tested**	**Printer Used**	**Layer Thicness Tested**	**Properties Evaluated**	**Main Results**
AlRumaih, 2024 [31]	Denture Base Resins	Asiga (Asiga, Alexandria, New South Wales, Australia) NextDent 5100 (NextDent by 3D Systems, Soesterberg, Netherlands) Form 3+ (Formlabs Inc., Somerville, Massachusetts, USA)	25 μm, 50 μm, and 100 μm	Flexural strength, Hardness	- 25 μm, and 50 μm showed significantly higher flexural strength than 100 μm in all resins. - 25 μm, and 50 μm significantly increase d hardness in NextDent, and FormLabs. - For ASIGA, only 25 μm had significantly higher hardness than 50 μm, and 100 μm.
Alshamrani, 2022 [5]	A2 EVERES TEMPORARY (SISMA, Italy)	EVERES ZERO *(SISMA, Schio, Vicenza, Italy)*	25 μm, 50 μm, 100 μm	Flexural strength (3-point bending), Vickers	- 100 μm showed the highest flexural strength (up to 94.60

				microhardness (VHN), Degree of Conversion (DC%)	MPa with dry storage). - Highest VHN observed in 100 µm + heat curing for 5 min (VHN = 17.95). - Highest degree of conversion observed at 50 µm (42.84%). - Both layer thickness, and post-printing conditions significantly affected mechanical properties.
Ayrilmis, 2018 [32]	Wood flour/Polylactic Acid (PLA) filament (1.75 mm diameter)	Zaxe 3D (*Zaxe 3D Printer Company, Istanbul, Turkey)*	0.05 mm, 0.1 mm, 0.2 mm, 0.3 mm	Surface roughness (Ra, Rz, Ry), Wettability (contact angle)	- Surface roughness decreased with decreasing layer thickness (i.e., smoother surfaces at 0.05 mm). - Wettability increased (higher contact angle) with increasing layer thickness. - Printing layer thickness significantly influences both surface texture, and wetting behavior.
Vinoth Babu, 2022 [33]	Carbon fiber/polylactic acid (CF/PLA) composite	Fused Deposition Modeling (FDM) 3D printer (model/manufacturer not specified)	0.08 mm, 0.25 mm, 0.64 mm	Tensile strength, Flexural strength, Interlaminar shear strength (ILSS), Surface roughness	- Best mechanical properties observed at 0.64 mm layer thickness, and 60% infill density with rectilinear, and hexagonal patterns. - Thinner layers caused poor fiber-matrix bonding leading to fiber pull-out failure. - Slicing parameters strongly affect mechanical performance, and failure mode.
Bakardzhie	PLA, Acrylonitrile	Flashforge Creator	0.1 mm, 0.5	Surface roughness,	Layer thickness had

v, 2024 [34]	Butadiene Styrene (ABS), Polyethylene Terephthalate Glycol-modified (PETG) filaments (1.75 mm diameter)	Pro 2 *(Flashforge Ltd., Jinhua, Zhejiang, China)*	mm, 0.3 mm, 0.02 mm, 0.58 mm,	print quality	the greatest impact on surface roughness, and print quality; extrusion temperature, and printing speed had smaller effects.
Çakmak, 2024 [35]	Interim fixed partial dentures (FPDs) resin	NextDent C&B MFH (*NextDent by 3D Systems, Soesterberg, Netherlands)*	20 µm, 50 µm, 100 µm	Trueness (RMS deviation at external, intaglio, marginal, occlusal surfaces)	- 100 µm layer thickness showed highest deviations (lowest trueness) overall, and on most surfaces. - No significant difference in marginal trueness among groups. - Subtractive manufacturing (milled FPDs by Upcera) showed highest trueness compared to all additive groups.
Çakmak, 2021 [36]	3D-printed interim crowns made of composite resin based on acrylic esters with inorganic microfillers; milled crowns fabricated from polymethylmethacrylate (PMMA) discs.	MoonRay S100 (SprintRay Inc., Los Angeles, California, USA)	20 µm, 50 µm, 100 µm	Trueness (RMS deviations), Margin quality (stereomicroscope grading)	- Layer thickness affected trueness, and margin quality of 3D-printed crowns. - Milled crowns showed higher trueness on intaglio, and occlusal surfaces than 100 µm printed crowns. - Milled crowns had the highest margin quality overall. - 20 µm, and 100 µm printed crowns showed lowest margin quality, varying by margin location.
Corbani, 2020 [37]	Nanocomposite resin crowns (3D-printed, and milled composite)	DFAB (DWS, Thiene, Italy)	0.5 mm, 1.0 mm, 1.5 mm	Fracture resistance, failure pattern	- 3D-printed crowns showed significantly higher fracture resistance than milled crowns at all thicknesses.

					- Both groups had higher fracture resistance with increased thickness. - Highest fracture loads at 1.5 mm thickness. - More irreparable fractures observed at 1.5 mm thickness.
Cremonin, 2025 [38]	Thermoformed Aligners 3D-Printed Aligners	Nexa3D Xip printer (Nexa3D, Ventura, CA, USA)	0.65-0.95 mm (3D-printed); uniform (thermoformed)	Retention force (Tensile test)	3D-printed aligners with high margins, and gradients had higher retention; scalloped thermoformed aligners had the lowest retention.
de Gois Moreira, 2025 [39]	Resin for provisional restorations	Form 2 (Formlabs Inc., Somerville, Massachusetts, USA)	25 µm, 50 µm, 100 µm	Flexural strength (σ), flexural modulus (E), precision, surface topography (micro-CT, profilometry, scanning electron microscopy (SEM))	25 µm layer thickness with 90°, and 45° build angles showed highest flexural strength, and precision. 0°/25 µm group showed highest shrinkage. 30°/25 µm group had highest surface roughness. 60° angle groups had lowest porosity.
Diken Türksayar, 2024 [40]	V-Print Splint resin (3D-printed occlusal splints)	SolFlex 350 (W2P Engineering GmbH, Vienna, Austria)	50 µm, 75 µm, 100 µm	Wear resistance (volume loss via 2-body wear test); SEM evaluation	Polishing significantly reduced wear (p = 0.003). Layer thickness had no significant effect (p = 0.105). D50-polished had lowest wear. 100 µm thickness may be preferred for faster printing.
Espinar, 2023 [41]	DFT- Detax Freeprint Temp (DETAX GmbH, Ettlingen, Germany), FT- Formlabs Temporary CB (Formlabs Inc., Somerville, MA, USA) FP- Formlabs	Asiga Max UV1 (Asiga HQ, Alexandria, NSK, Australia), 3D Form 3B+2 (Formlabs Inc.,35 Medford, Somerville, MA	0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm	Scattering (S), Absorption (K), Albedo (a), Transmittance (T%), Reflectivity Index (RI), Infinite Optical Thickness (X∞) using	Optical properties were wavelength-dependent, and varied significantly with thickness, and printing angle (0° vs 90°). S, and K increased with

	Permanent Crown (Formlabs Inc., Somerville, MA, USA), GCT- GC TempPrint (GC Corporation, Tokyo, Japan)	02143, USA)		Kubelka-Munk model	thickness; T%, and X∞ decreased. Orientation influenced RI, S, K, and X∞ values at certain thicknesses. These variations impact the biomimetic potential of 3D-printed resins, and should be considered for clinical use.
Zoltan Farkas, 2023 [42]	NextDent C&B Micro-Filled Hybrid (NextDent B.V., Netherlands, Soesterberg)	ANYCUBIC Photon Mono x (Anycubic,China, Shenzhen)	0.05 mm, and 0.1 mm	Tensile strength, Compression strength	Brittle behavior was observed in all tensile specimens. Highest tensile strength occurred with 0.05 mm layer thickness. Both layer direction (0°, 45°, 90°), and thickness influenced mechanical properties, allowing optimization for clinical application.
Farzadi, 2014 [43]	Calcium sulfate-based powder	3DP machine (Z450, Z Corporation, USA)	0.0875, 0.1, 0.1125 and 0.125 mm	Compressive strength, Toughness, Young's modulus, Dimensional accuracy (via SEM & μCT)	Best mechanical, and structural performance was observed with 0.1125 mm, and 0.125 mm layer thickness. X-axis orientation gave highest dimensional accuracy, and best match with CAD model for pore size, porosity, and pore interconnectivit.
Fouda, 2025 [44]	Formlabs denture base resin (FormLabs, Somerville, MA, USA), V-print dentbase (VOCO, Cuxhaven, Germany), Conventionally pressable resin material PalaXpress, (Kulzer, Hanau, Germany)	Form 3 (Formlabs Inc., Somerville, Massachusetts, USA), P30 (Straumann, Rapid Shape, Heimsheim, Germany)	50 μm, 100 μm (only for Formlabs denture base resin), 50 μm (for V-print dentbase)	Flexural strength, Surface roughness (Ra, Rz), Hardness (HM, HV2), before, and after thermocycling	Build angle, and thermocycling significantly affected flexural strength. Layer thickness had no significant effect for FL. ISO 20795-1 (≥65 MPa) was exceeded by PP (70.5 MPa), FL at 90° (69.3 MPa), and VC at 0°

					(69.0 MPa). Proper build angle selection is key for strength, and clinical performance.
Gad, 2024 [45]	Asiga DentaBASE (Asiga, Erfurt, Germany) with 0%, 0.25%, 0.5% SiO_2NPs, and NextDent Denture 3D+ (NextDent B.V., Soesterberg, The Netherlands)with 0%, 0.25%, 0.5% SiO_2NPs	Asiga MAX UV (Alexandria, New South Wales, Australia) NextDent 5100 (Nexa3D, Ventura, CA, USA)	50 µm, 75 µm, 100 µm	Flexural strength (3-point bending), SEM fracture analysis	Flexural strength was highest at 50 µm, and 75 µm, lowest at 100 µm for both resins. SiO_2NP addition significantly improved strength at 50, and 75 µm, but had no significant effect at 100 µm. Best values: Asiga 0.25%/50 µm (97.32 MPa), NextDent 0.5%/50 µm (97.54 MPa). SEM showed more lamellae/irregularities with thinner layers, and added nanoparticles.
García-Gil, 2025 [46]	SLA resin for maxillary hollow master casts	Form 2 (Formlabs, Somerville, MA, USA)	50 µm, and shell thickness (2 mm, and 4 mm)	Accuracy (trueness, and precision), RMS error of printed casts vs STL reference	No significant effect of print orientation (0°, 10°, 20°), or shell thickness on accuracy of SLA casts.
Grymak, 2023 [47]	DentaCAST (Asiga, Australia), SuperCAST (Asiga, Australia), and NextDent (3D Systems, Netherlands)	Asiga 4 K 3D printer (Sydney, Australia)	50 µm, 75 µm, 100 µm	Accuracy (RMSE), dimensional discrepancies, print failures	Optimal accuracy at 45° build angle, and middle plate position. Clinically acceptable RMSE: SuperCAST 50 µm (98 ±35 µm), NextDent 75 µm (143 ±14 µm), DentaCAST 100 µm (115 ±19 µm). Higher discrepancies at 0°. Layer thickness most significant factor for accuracy.
Hasanzade, 2023 [48]	Interim crowns	Digident Plus (Digident Co., Ltd., South Korea, Seoul)	25 µm, 50 µm, 100 µm	Marginal gap, Internal gap (axial, occlusal)	50 µm layer thickness yielded best marginal, and internal fit. 100 µm had significantly higher marginal, and

					occlusal gaps; 25 μm had larger axial gap than 50 μm.
Iyibilgin, 2025 [49]	316L stainless steel filament	Printer (Zaxe, Istanbul, Türkiye)	100 μm, 200 μm, 300 μm, 400 μm	Tensile strength, Hardness, Density, Phase analysis	Tensile strength, and hardness increased with decreasing layer thickness; highest tensile strength (432 MPa), and hardness (213 Hv) at 100 μm layer thickness.
Khalil, 2025 [50]	Shape memory resin for direct aligners	NBEE printer (Uniz, California, USA)	0.5 mm, and 0.7 mm	Flexural strength (3-point bending)	No significant difference in flexural strength among printing orientations (vertical, horizontal, 30°, 45°). 0.7 mm thickness showed significantly higher strength.
Kul, 2025 [51]	3D-printed acrylic denture base resin	Not specified	2 mm, and 3 mm	Flexural strength, and colour stability (ΔE00)	Highest flexural strength (95 MPa) was achieved with 3 mm specimens cured at 80 °C for 60 min. However, 2 mm specimens showed better colour stability (ΔE00 = 2.59).
Li, 2023 [52]	3D-printed denture base polymer	Solflex 350 plus (W2P Engineering GmbH, Vienna, Austria)	25 μm, 50 μm, 100 μm	Surface roughness (Sa) via SEM & Sa metrics; Candida albicans adhesion	Surface roughness significantly impacted by both layer thickness, and build angle (Sa: $F(4,45)=90.77$, $p<0.0001$). Candida adhesion significantly affected by layer thickness ($F(2,99)=6.96$, $p=0.0015$), but not by build angle. Thinner layers improved both surface smoothness, and reduced microbial adhesion.
Liu, 2021 [53]	PLA custom trays	Lingtong II (SHINOTECH, Shenzhen, China,)	0.1 mm, 0.2 mm, 0.3 mm, 0.4 mm,	Tensile bond strength, flexural strength, tensile strength,	Bond strength increased with thickness up to 0.4 mm, then

			0.5 mm	dimensional accuracy, print time, SEM analysis of fracture surfaces	decreased. Flexural, and tensile strengths declined as thickness increased. Dimensional accuracy stable (0.1-0.4 mm), but worsened at 0.5 mm. Print time decreased significantly with thicker layers. Fracture SEM suggested weaker layer bonding at extremes of thickness.
Mahajan, 2025 [54]	Interim crowns for maxillary left central incisor, D-Tech crown, and bridge resin	Asiga 3D printer (Asiga, Alexandria, New South Wales, Australia)	50, 75, 100 μm	Color stability, surface roughness (Ra)	100 μm showed greatest color stability; 50 μm showed least. Surface roughness increased with layer thickness.
Mushtaq, 2023 [55]	ABS	CR5-3D printer (Creality, Shenzhen, china)	0.05-0.4 mm	Flexural strength, tensile strength, surface roughness, print time, energy consumption	Layer thickness influenced surface roughness, and print time; infill density affected mechanical properties. Optimal settings: LT=0.27 mm, ID=84%, PS=51.1 mm/s, FS=58.01 MPa, TS=35.8 MPa, Ra=8.01 μm, print time=58 min, energy=0.21 kWh.
Park, 2023 [56]	Thermoformed: Polyethylene terephthalate glycol, Copolyester-elastomer (TM); 3D-printed: TC-85 resin cleaned with alcohol (PA), and centrifuge (PC)	Asiga MAX (Asiga, Alexandria, Australia) SprintRay Pro 95 (SprintRay, Los Angeles, CA)	~614 μm (alcohol-cleaned), ~688 μm (centrifuge-cleaned)	Thickness, Gap Width (micro-CT), Translucency (spectrophotometry)	PC group had higher translucency than PA; thickness decreased after thermoforming, increased in 3D prints; TM had smallest gap; cleaning affects properties.
Reymus, 2019 [20]	NextDent C&B resin for temporary restorations (NextDent B.V., Netherlands, Soesterberg)	D20 II (Rapid Shape, Heimsheim, Germany)	25 μm, 50 μm, 100 μm	Degree of Conversion (DC), ΔDC, effect of post-curing methods	Post-curing method highly influenced DC; Otoflash G171 (OF) gave highest DC, and ΔDC; 50,

					and 100 μm layers showed higher ΔDC than 25 μm.
Sasany, 2024 [57]	VarseoSmile Crown Plus (Bego; Bremen, Germany), Crowntec (Saremco Dental; Aschau, Germany), GC Temp PRINT (GC Dental; Tokyo, Japan), NextDent C&B MFH (NextDent; Soesterberg, Netherlands)	MAX UV (Asiga, Alexandria, Australia)	25 μm, 50 μm, 100 μm	25 μm, 50 μm, 100 μm	25-, and 50-μm thicknesses showed color properties closer to target shade; 100-μm thickness showed lower translucency, and higher surface roughness.
Shergill, 2023 [58]	PLA, ABS, Polyethylene Terephthalate Glycol	Ultimaker 2+ printer (Ultimaker, Utrecht, The Netherlands)	0.12, 0.16, 0.20, 0.28 mm	Mechanical properties (tensile strength)	Increasing layer thickness decreased mechanical properties in ABS, and PLA, with PLA showing more significant effects. PETG showed less significant changes. Differences attributed to layer adhesion, and structural defects from the additive process.
Sousa, 2021 [59]	Poly(lactic acid) recycled (rPLA), Poly(methyl methacrylate) (PMMA), High impact polystyrene (HIPS), Thermoplastic polyurethane (TPU), Ethylene-vinyl acetate (EVA, control) for protective mouthguards	3D Robo R2 printer (San Diego, California, USA)	2 mm, 4 mm	Chemical, thermal, surface, mechanical (impact strength, energy absorption)	Impact strength decreased with thickness increase except TPU; TPU showed highest deformation capacity, and similar energy absorption to EVA; other polymers had higher energy absorption than EVA.
Wu, 2025 [60]	Direct 3D-printed clear aligner resin	Uniz NBEE printer (Uniz, CA, USA)	50 μm, 100 μm	Mechanical properties (tensile stress, strain, modulus), color stability, surface roughness	50 μm layer + 90° orientation showed best color stability in artificial saliva. Coffee staining affected all. Mechanical properties, and surface roughness

					improved with build orientation order: 90° > 60° > 45°. Significant differences ($p < .05$).
Yang, 2022 [61]	Three-unit resin prostheses	Zenith U (Dentis, Daegu, Korea)	50 μm, 100 μm	Marginal fit (marginal gap, and absolute marginal discrepancy)	Build orientation significantly affected marginal fit; 45° better than 60°. Layer thickness had no significant effect. Marginal fit affected by pontic area.
Yilmaz, 2022 [62]	Removable dies (resin)	MAX UV (Asiga, Alexandria, Australia)	50 μm, 100 μm, 50-100 μm combined	Trueness (RMS), Fit of removable dies on cast	50-100 μm group had higher overall RMS than 100 μm. 100 μm had highest crown RMS; 50 μm had highest root RMS. 50 μm group showed best crown trueness on cast. Differences clinically small; 100 μm recommended for efficiency.
Yilmaz, 2024 [63]	3D-CB, 3D-TH, 3D-CT (additive); G-CAM, VE (subtractive)	MAX UV (Asiga, Alexandria, Australia)	1 mm, 1.5 mm, 2 mm	Color change (ΔE_{00}), Relative Translucency Parameter (RTP)	3D-TH showed the highest ΔE_{00}, G-CAM the lowest. Color change increased with AM vs. SM. Translucency (RTP) decreased with increased thickness, and coffee thermocycling. 3D-TH had most unacceptable changes, while G-CAM was more color stable, and translucent.
You, 2021 [64]	Trial dentures (resin)	Zenith U (Dentis, Daegu, Korea)	50 μm, and 100 μm	Trueness, and precision (RMS values of intaglio, and cameo surfaces)	100 μm layer thickness yielded significantly better trueness, and precision for cameo surfaces. No significant difference in intaglio surface precision. 100 μm recommended.

Zhang, 2019 [65]	3D printed dental models (from scanned digital dental models)	EvoDent (UnionTech, Shanghai, China); EncaDent (Encashape, WuXi, China); Vida HD (EnvisionTEC, Dearborn, MI, USA); Form 2 (Formlabs, Somerville, MA, USA)	20, 25, 30, 50, 100 μm (depending on printer)	Printing accuracy (3D comparison with STL)	50 μm was optimal for DLP. DLP had better accuracy, and speed at 100 μm than SLA. EvoDent 50 μm showed highest accuracy. Form 2 at 100 μm showed lowest accuracy.

Table 2: Characteristics of the studies included in the review.

Risk of Bias

The risk of bias assessment revealed that most studies exhibited unclear, or high risk in planning, and allocation due to insufficient reporting, while outcome assessment, and data reporting domains demonstrated a consistently high risk of bias, highlighting concerns regarding the validity, and reliability of the reported results (Table 3).

Study	D1. Bias in planning, and allocation			D2. Bias in sample/ specimen preparation		D3. Bias in outcome assessment		D4. Bias in data treatment, and outcome reporting	
	1.1	1.2	1.3	2.1	2.2	3.1	3.2	4.1	4.2
Study, and Year									
AlRumaih, 2024 [31]	NR	NR	R	R	R	R	NR	R	R
Alshamrani, 2022 [5]	R	NR	NR	R	R	R	NR	R	R
Ayrilmis, 2018 [32]	NR	R	NR	R	R	R	NR	R	R
Vinoth Babu, 2022 [33]	NR	NR	NR	R	R	R	NR	IR	R
Bakardzhiev, 2024 [34]	NR	NR	NR	R	R	IR	NR	IR	R
Çakmak, 2024 [35]	R	NR	IR	R	R	R	NR	R	R
Çakmak, 2021 [36]	R	R	IR	R	R	R	R	R	R
Corbani, 2020 [37]	NR	R	NR	R	R	R	NR	R	R
Cremonin, 2025 [38]	NR	NR	R	R	R	R	NR	R	R
de Gois Moreira, 2025 [39]	NR	R	R	R	R	R	NR	R	R
Diken Türksayar, 2024 [40]	NR	NR	R	R	R	R	NR	R	R
Espinar, 2023 [41]	NR	NR	NR	R	R	R	NR	R	R
Zoltan Farkas, 2023 [42]	NR	NR	NR	R	R	R	NR	IR	R
Farzadi, 2014 [43]	NR	NR	NR	R	R	R	NR	R	R
Fouda, 2025 [44]	R	NR	NR	R	R	R	NR	NR	R
Gad, 2024 [45]	NR	NR	R	R	R	R	NR	R	R
García-Gil, 2025 [46]	NR	NR	NR	R	R	R	NR	R	R
Grymak, 2023 [47]	R	R	R	R	R	R	NR	R	R
Hasanzade, 2023 [48]	NR	NR	NR	R	R	R	R	R	R
Iyibilgin, 2025 [49]	NR	NR	NR	R	R	R	NR	R	R
Khalil, 2025 [50]	NR	R	NR	R	R	R	NR	R	R
Kul, 2025 [51]	NR	NR	R	R	R	R	NR	R	R
Li, 2023 [52]	R	R	R	R	R	R	NR	R	R
Liu, 2021 [53]	R	NR	NR	R	R	R	NR	R	R
Mahajan, 2025 [54]	R	NR	R	R	R	R	NR	R	R

Mushtaq, 2023 [55]	NR	NR	NR	R	R	R	NR	R	R
Park, 2023 [56]	NR	NR	NR	R	R	R	NR	R	R
Reymus, 2019 [20]	NR	NR	NR	R	R	R	NR	R	R
Sasany, 2024 [57]	NR	NR	R	R	R	R	NR	R	R
Shergill, 2023 [58]	NR	NR	NR	R	R	R	NR	R	R
Sousa, 2021 [59]	R	NR	NR	R	R	R	NR	R	R
Wu, 2025 [60]	NR	NR	NR	R	R	R	NR	R	R
Yang, 2022 [61]	NR	NR	NR	R	R	R	NR	R	R
Yilmaz, 2022 [62]	NR	NR	NR	R	R	R	NR	R	R
Yilmaz, 2024 [63]	NR	NR	NR	R	R	R	NR	R	R
You, 2021 [64]	NR	NR	NR	R	R	R	NR	R	R
Zhang, 2019 [65]	NR	R	IR	R	R	R	NR	IR	R

Table 3: Quality analysis of studies included in the systematic review, separated by their risk of bias in different domains. R - sufficiently reported/adequate; NR - not reported; IR - insufficiently reported;, and NA - not applicable.

Bias sources within each domain: 1.1 - use of control group; 1.2 - sample randomization; 1.3 - justification of sample size; 2.1 - standardization of materials/samples; 2.2 - uniformity of experimental conditions; 3.1 - consistency in testing procedures/outcomes; 3.2 - blinding of the operator; 4.1 - statistical evaluation; 4.2 - reporting of results.

Discussion

3D printing software allows control over the thickness of each printed layer, commonly referred to as layer height, or print resolution. This layer thickness significantly affects both the number of layers required to build the object, and the total printing time. Typically, layer heights can vary from about 20 to 175 micrometers (µm), or more. Smaller layer heights result in more layers, which can enhance the level of detail, and create smoother surfaces. However, this also means longer print durations. It is important to balance these benefits against potential drawbacks: with each additional layer, there is an increased chance of curing errors that may lead to distortions, or even print failures. Therefore, optimizing layer thickness is crucial to achieving a balance between print quality, and efficiency [5,14].

The present systematic review underscores the significant influence of printing layer thickness on the performance characteristics of 3D-printed dental materials. As additive manufacturing becomes increasingly integral to prosthetic dentistry, understanding how layer thickness affects mechanical strength, dimensional accuracy, surface properties, optical characteristics, and polymerization is crucial to optimizing clinical outcomes [15-25].

Dimensional Accuracy, and Marginal Fit

Dimensional accuracy, and marginal adaptation are critical factors for the clinical success of fixed prostheses, as they influence fit, longevity, and biological compatibility. Research shows that the optimal layer thickness for these properties varies across studies. While some investigations indicate that thinner layers (~50 µm) improve trueness, and marginal fit by enabling finer details, and smoother surface transitions, other studies report that 100 µm layers can achieve comparable, or even superior outcomes, depending on the printer resolution, and resin type [13,16,23,24]. This inconsistency is likely due to differences in printer calibration, resin viscosity, build orientation, and post-processing protocols [11,13]. For instance, build angle interacts with layer thickness to influence polymerization shrinkage, and dimensional distortion, factors critical for precise fit [27]. Additionally, thicker layers may reduce cumulative errors by decreasing the number of layers, consequently, the interlayer bonding interfaces that can cause distortion. Song, et al., found that increased layer thickness shortened printing time but sometimes at the cost of surface detail, highlighting the trade-offs involved [19].

Degree of Conversion, and Post-Processing

The degree of conversion (DC) of resin monomers to polymers directly impacts mechanical durability, and biocompatibility. Reymus, et al., demonstrated that thinner layers generally achieve higher DC due to better light penetration, and reduced attenuation in each layer, improving polymer network formation [20]. However, post-curing protocols light intensity, time, and temperature-also critically influence DC, sometimes overriding the effects of layer thickness [5,20]. Clinicians should, therefore, carefully calibrate post-processing to complement printing parameters for optimal material performance.

Mechanical Properties

A consistent finding across multiple studies is that thinner layers, generally between 25, and 50 μm, tend to enhance the mechanical strength of dental resins [18,21-23]. Increased flexural strength, and hardness at these finer layer settings are commonly reported for denture base resins, and interim crowns [5,18]. The improved mechanical properties can be attributed to more effective layer-to-layer bonding, and a higher degree of polymer conversion, which decreases internal porosity, and micro-defects that serve as stress concentrators [20]. This effect aligns with foundational additive manufacturing principles where thinner layers yield more homogenous, and tightly bound printed structures [2].

However, this relationship is not consistently linear. Certain composite materials, including CF/PLA, and shape memory resins, exhibit optimal mechanical properties at relatively thicker layers (approximately 0.6-0.7 mm), indicating that material composition, and resin chemistry influence how layer thickness affects strength [22,19]. These observations suggest that mechanical performance is determined by the interplay between layer thickness, resin formulation, and the specific 3D printing technology used. Hence, material-specific optimization protocols are needed rather than a one-size-fits-all approach.

Surface Roughness, and Microbial Adhesion

Surface quality affects esthetic outcomes, and biological responses such as plaque accumulation, and secondary caries risk [21]. Thinner layers produce smoother surfaces due to the finer step increments in each printed layer, reducing microscopic ridges, and valleys where bacteria can adhere [25,9]. Moreover, surface roughness influences patient comfort, and staining susceptibility, making it a crucial parameter in material selection, and printing settings [39,54,58].

Optical Properties, and Esthetics

Esthetics remains a central consideration in prosthetic dentistry, with optical properties such as translucency, color stability, and surface gloss playing key roles. The review findings suggest that thinner printing layers enhance optical uniformity by minimizing light scattering, and creating smoother surfaces, resulting in more natural-looking restorations [21]. These effects are particularly important for anterior restorations, where seamless integration with the surrounding dentition is critical. Nevertheless, post-curing protocols, and resin pigmentation also impact final esthetic outcomes, interacting with layer thickness in complex ways [26].

Limitations

This review has several limitations. The included studies were highly heterogeneous in printer types, materials, layer thicknesses, testing protocols, and post-processing methods, limiting generalizability. Moreover, the predominance of *in-vitro* studies restricts direct clinical translation, as factors such as saliva, masticatory forces, and thermal cycling were not fully simulated. Finally, publication bias may exist, as studies with significant findings tend to be reported more frequently. Future clinical studies, and standardized testing protocols are needed to validate the laboratory findings, and optimize printing parameters for clinical use.

Future Directions

Given the rapidly evolving nature of 3D printing technology, and materials, further standardized research is essential to develop comprehensive guidelines. Future studies should employ consistent testing methodologies, including standardized specimen designs, post-processing protocols, and clinically relevant aging simulations. Additionally, in vivo studies evaluating the long-term clinical performance of 3D-printed restorations fabricated with varying layer thicknesses are necessary to translate *in-vitro* findings into practice.

Trade-offs and Clinical Implications

Despite the advantages of thinner layers in accuracy, strength, and esthetics, thicker layers offer practical benefits including faster print times, and reduced material consumption, which are important in busy dental laboratories, and clinics [2,3]. These trade-offs must be balanced according to the clinical situation, with provisional restorations potentially favoring speed over optimal detail, while definitive prostheses may prioritize mechanical, and esthetic excellence. Furthermore, layer thickness does not act in isolation, but is interdependent with build orientation, printer type (SLA, DLP, LCD), resin composition, and environmental factors. This complexity demands an integrated approach to protocol development, incorporating manufacture specifications, and empirical data to tailor printing parameters for each application [27].

Conclusion

Layer thickness critically affects the mechanical, dimensional, and surface properties of 3D-printed dental materials. Thinner layers generally improve surface smoothness, and certain mechanical properties, while thicker layers may reduce printing time, and occasionally enhance strength depending on the material. Optimal outcomes require balancing layer thickness with other printing parameters, such as build angle, and post-curing. Although *in-vitro* evidence is promising, further clinical studies are needed to validate these findings, and establish standardized guidelines for layer thickness selection.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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