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Clinical and Laboratory Performance of 3D-Printed Removable Dentures Compared with Conventionally Fabricated Dentures: A Systematic Review

Ibrahim Salah Aimutairi

Dental Technician, Islamic University of Madinah, Madinah, Saudi Arabia, 11RT0012986

ABSTRACT: Background: Additive manufacturing (AM), also known as 3D printing, has gained popularity in the fabrication of removable complete dentures, but the performance of printed dentures versus conventionally processed complete dentures in the form of heat-polymerized PMMA dentures is yet to be established.

Methods: This study intends to compile clinical and laboratory data, published in between 2020 and 2025, for 3D printed denture and denture-base resins versus conventional. The search identified 33 records, and 12 eligible studies (six clinical, six laboratory) were included and extracted in a ready-to-analyze form.

Results: were divided into patient-reported, functional, and biological end points; mechanical, surface, and biological properties; and residual monomer. Heterogeneity across studies in study design, comparators, and outcome measures precluded meta-analysis; therefore, a narrative synthesis was performed. In clinical studies, 3D-printed dentures were comparable with conventional complete dentures regarding all domains of patient satisfaction and oral health-related quality of life in five of six studies. One study preferred conventional complete dentures in all domains of satisfaction (phonetics, cleaning, stability, comfort, general satisfaction). One pilot study noted that printed dentures provided more comfort; while a single crossover study detected decreased microbial adherence on printed dentures. In laboratory studies, printed denture-base resins had lower flexural strength than heat-polymerized PMMA in four of five studies (e.g., 69.15 MPa versus 86.63 MPa; $P<0.005$), as well as lower impact strength (2.44 kJ/m^{2}versus 6.32 kJ/m^2) and hardness. Printed dentures had a smoother surface and lower residual methyl methacrylate concentrations than milled dentures.

Conclusions: Within the limitations of these two current studies, recent data shows that 3D-printed removable dentures can offer short-term patient-reported outcomes similar to conventional dentures, but with inferior denture-base resin mechanical properties in vitro. More long-term randomized trials with consistent outcomes, printer parameters, resin properties, post-curing parameters and including fracture and repair endpoints are needed to explore these findings further

1. INTRODUCTION

Complete removable dentures are still the treatment of choice for the edentulous patient and heat-polymerized PMMA (compression- or injection-molded) has been considered the gold standard material for many decades (Alotaibi, 2025). However, conventional fabrication requires multiple clinical and laboratory steps, is technique-sensitive and suffers from polymerization shrinkage and porosity. The emergence of digital workflows seeking to minimize treatment time and standardize procedures, along with a review of clinical and laboratory protocols, shows that digital complete dentures may reduce clinical

time but some patients still experienced loss of retention or needed remakes. Satisfaction and oral health-related quality of life of conventional, milled, and printed complete dentures seem similar (Thu et al., 2023).

Production of removable prosthesis Digital manufacturing options for removable prostheses include subtractive manufacturing in which the denture base is milled from a block of industrially – prepolymerized PMMA material, as well as additive manufacturing in which the prosthesis is built up in layers of light-curing resin (photopolymerizable methacrylate) using stereo lithography or digital light processing methods; followed by wash-up and post-curing (Anadioti et al., 2020). Multiple dentures can be fabricated simultaneously during one print job without much material wastage making this suitable for chair side and dental laboratory processes. However, 3D-printing resins have different chemical composition as compared to heat-polymerized PMMA, and the printing process itself influences mechanical properties of the resin, as well as print setting parameters such as build orientation, layer thickness, and post-curing protocols (Fouda et al., 2025; Perea-Lowery et al., 2021).

Previous systematic reviews have generally combined the use of milled and printed dentures in the general term "digital" or "CAD/CAM" dentures. This has compromised the distinction between the two technology types. Since the systematic reviews that have specifically looked at printed dentures have been limited to one outcome only (patient satisfaction (Alotaibi, 2025)), denture repair (Seow et al., 2023) or the in vitro mechanical properties of denture bases (Lourinho et al., 2022), an appraisal attempting to compare the laboratory and clinical evidence related to 3D printed RPDs with that of a traditional comparator is required. The review is therefore designed to answer the following PICO question: In removable dentures, how does the clinical and laboratory performance of 3D printed prostheses compare with conventionally fabricated prostheses?

2. MATERIALS AND METHODS

2.1 Protocol and reporting

The review was structured according to the PRISMA 2020 statement (Page et al., 2021) and the Cochrane handbook (Higgins et al., 2022). As the design, comparators, and the outcomes were not homogeneous between the included studies, this is a narrative result reported following the SWiM (Synthesis without Meta-Analysis) guideline (Campbell et al., 2020).

2.2 Criteria for Eligibility

Eligibility criteria were based on the PICO model (Table 1). Clinical trials had to compare 3D-printed removable dentures with conventionally processed removable dentures for patient use; laboratory trials should compare printed denture-base resins or 3D-printed dentures with heat-polymerized PMMA, and if applicable, with milled dentures. The review included only English language articles from January 2020 to December 2025.

Table 1. PICO-based eligibility criteria

Element	Criteria
Population	Clinical: edentulous or partially edentulous adults receiving removable dentures. Laboratory: denture-base resin specimens or complete denture bases/prostheses.
Intervention	Removable dentures or denture-base resins manufactured by 3D printing (stereolithography, digital light processing or equivalent).
Comparator	Conventionally fabricated dentures (heat-polymerized or injection-molded PMMA). Milled CAD-CAM comparators were retained as secondary comparators and are flagged.
Outcomes	Clinical: patient satisfaction, oral health-related quality of life (OHRQoL), chewing efficiency, comfort, microbial colonization. Laboratory: flexural strength, impact strength, hardness, surface roughness, fracture toughness, residual monomer.
Study design	Randomized or crossover clinical trials, clinical pilot trials, and in vitro comparative studies with a defined sample size.

Element	Criteria
Exclusions	Narrative or systematic reviews (used for background only), registry entries or theses without peer-reviewed results, case reports, studies without a conventional or milled comparator, and publications before 2020.

PICO, population, intervention, comparator, outcome.

2.3 Sources of Information and Selection

Records were located by subject-specific searches of publishers sites, Pub Med records, and trial registries with search terms combining "3D printed denture," "complete denture," "additive manufacturing," "digital denture," "denture base resin," "patient satisfaction," and "flexural strength." Records were screened initially on title and abstract, then on full text (or full abstract) according to the criteria of Table 1. The flow of records is shown in Figure 1.

2.4 Data Extraction and Quality Considerations

For each study, the following data were extracted: first author and year, design, sample size, interventions and comparators, outcome measures, and results (see Table 2). Quantitative data were extracted only if they could be verified from the abstract and/or full text. Data that could not be verified were indicated as not extracted. Internal validity (quality) of studies were assessed qualitatively based on factors such as the randomization and allocation procedure, blinding, washout periods for cross-over studies, sample size, registration for clinical studies, specimen number, standardized testing (ie, ISO 20795-1), thermo cycling, and statistical testing for laboratory studies.

2.5 Synthesis

Direction of effect for each outcome was categorized as favouring convention, favouring 3D printing, no difference or mixed/unclear according to the authors' statistical comparisons, and is shown in the evidence map (Figure 3). Due to the heterogeneity of study design, printers, resin types and outcome scales, data could not be combined.

3. RESULTS

3.1 Study Selection

The targeted searches yielded 33 records, 3 duplicates were removed, leaving 30 records screened. Six records were excluded for not meeting the inclusion criteria of being published within 2020-2025, having found in a registry or thesis and protocols, or being off-topic with respect to denture type. The remaining 24 reports were assessed for eligibility, with 12 being excluded: five systematic or narrative reviews cited as background, three registry records or theses citing non-peer-reviewed results, two with inapplicable comparators or outcomes, and two with non extractable results. Twelve studies were included in the review, six clinical and six laboratory studies (Figure 1). Two thirds of the included studies were published in 2022 or later (Figure 2).

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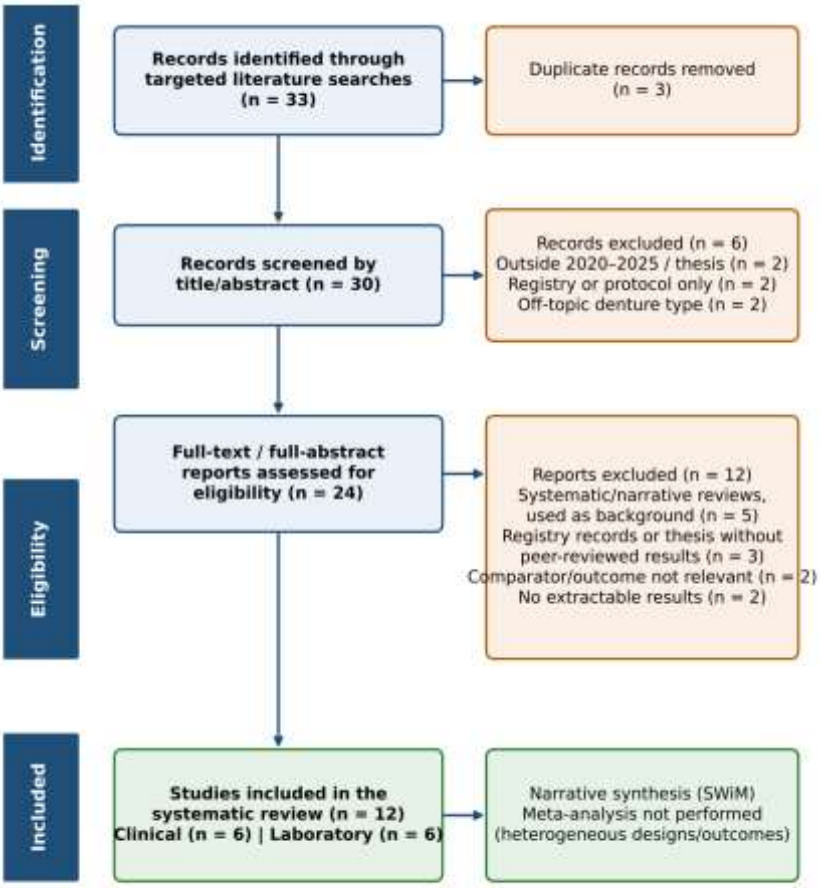

Figure 1. PRISMA 2020 flow diagram of study selection. Counts reflect the targeted search conducted for this draft and should be replaced with the authors' own database log.

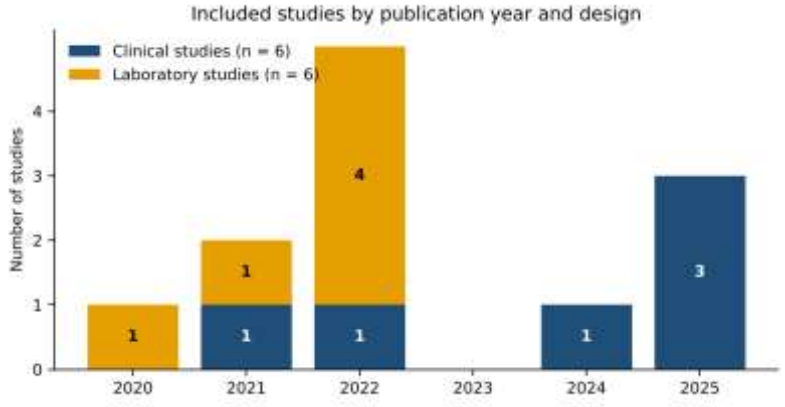

Figure 2. Included studies by publication year and design.

3.2 Characteristics of Included Studies

All six clinical studies were randomized crossover trials or crossover pilot trials, where the same prosthesis user wore conventional dentures and digitally generated dentures (Ohara et al., 2022; Srinivasan et al., 2021; Iwaki et al., 2024; Emera et al., 2025; Bors et al., 2025; Elsarrif et al., 2025). The duration of the crossover period was between 6 weeks and 6 months. One of the crossover trials was a comparison of printed dentures versus milled dentures (for which the conventional dentures were

not used as comparison); this trial is presented separately (Srinivasan et al., 2021). The other six laboratory studies measured standardized denture-base specimens or dentures, with respect to flexural strength, impact resistance, hardness, surface properties and chemical properties (Prpić et al., 2020; Perea-Lowery et al., 2021; Di Fiore et al., 2022; Gad et al., 2022; Fouda et al., 2022; Srinivasan et al., 2022). The full data-extraction sheet can be seen in Table 2.

Table 2. Data extraction sheet of the 12 included studies

Study	Design	Sample / specimens	Intervention vs comparator	Main findings
Ohara et al. (2022)	Crossover RCT (clinical)	Edentulous patients; 15 at final preference stage; three prosthodontists; Nov 2017–May 2020	3D-printed digital dentures vs conventional dentures (CDs)	VAS and OHIP-EDENT-J outcomes; CDs superior for phonetics, ease of cleaning, stability, comfort and general satisfaction; 12 patients preferred CDs, 3 chose digital dentures
Srinivasan et al. (2021)	Double-blind crossover RCT	Edentulous patients; 6-week crossover (n not extracted)	Milled vs 3D-printed CAD-CAM dentures (secondary comparator)	No differences in denture satisfaction, OHIP-EDENT, final choice, clinician quality rating, chewing efficiency or bite force; printed dentures inferior for time-related outcomes
Iwaki et al. (2024)	Crossover RCT (non-inferiority)	Edentulous patients, maxillary and mandibular (n not extracted)	CAD-3D-printed vs conventional complete dentures	OHIP-EDENT-J total and subdomains and VAS satisfaction not significantly different; printed dentures non-inferior
Emera et al. (2025)	Randomized two-period crossover	20 patients (12 M, 8 F), aged 55–75; sample size calculated at 17 and raised to 20	3D-printed dimethacrylate resin vs conventional CDs	No significant difference in OHIP-EDENT at T0, T3, T6; chewing efficiency measured by two-color gum; both improved OHRQoL vs baseline
Bors et al. (2025)	Randomized crossover pilot	40 maxillary edentulous patients; 6 months per denture; 2023–2024	Digital (DLP-printed) vs heat-cured PMMA maxillary CDs	Overall satisfaction comparable; digital dentures showed notable improvement in comfort; 10-item questionnaire at 6 and 12 months
Elsarrif et al. (2025)	Crossover RCT	11 edentulous patients; 3 months per denture; 2-week washout	3D-printed CAD-CAM vs conventional dentures	Significantly lower microbial counts on printed dentures over 3 months; satisfaction slightly higher with printed dentures, not significant
Prpić et al. (2020)	In vitro	160 specimens; 3 heat-polymerized, 3 CAD/CAM, 1 printed, 1 polyamide material	3D-printed (NextDent Base) vs heat-polymerized, CAD/CAM, polyamide	Printed material had the lowest flexural strength; CAD/CAM and polyamide highest; significant differences in hardness among materials

Study	Design	Sample / specimens	Intervention vs comparator	Main findings
Perea-Lowery et al. (2021)	In vitro	64 bar specimens for flexural tests (n = 16/group); dry and 30-day water storage	Imprimo LC Denture (two post-curing units) vs Paladon 65 and Palapress	Heat-cured resin highest flexural strength and modulus; printed resin lowest fracture toughness and work of fracture; post-curing unit affected flexural strength
Di Fiore et al. (2022)	In vitro	n = 6/group for 3-point bending (65 × 10 × 3.3 mm)	Heat-polymerized (CV) vs milled (CAD) vs 3D-printed (3D) PMMA	UFS 80.79 ± 7.64 (CV), 110.23 ± 5.03 (CAD), 87.34 ± 6.39 MPa (3D); similar roughness after polishing and similar microbial adhesion at 16 h
Gad et al. (2022)	In vitro	120 specimens (n = 10 per test and condition); 10,000 thermocycles	NextDent 3D-printed vs Major.Base.20 heat-polymerized	Printed resin lower flexural strength, impact strength and hardness but smoother ($P < 0.001$); thermocycling reduced printed flexural strength to 63.93 MPa
Fouda et al. (2022)	In vitro	120 specimens, 6 groups (n = 20/material)	3 printed resins (Asiga, FormLabs, NextDent) vs 2 milled and heat-polymerized	Milled resins highest flexural properties and hardness; printed lowest but flexural strength and modulus above clinically acceptable values
Srinivasan et al. (2022)	In vitro	32 dentures: milled n = 8; printed n = 24 in three rinsing protocols	3D-printed vs CNC-milled dentures (secondary comparator)	Methyl methacrylate release lower in printed than milled dentures (HPLC, 1–24 h); extended wash and standard wash plus coating did not differ

RCT, randomized controlled trial; VAS, visual analogue scale; OHIP-EDENT, Oral Health Impact Profile for edentulous patients; UFS, ultimate flexural strength; DLP, digital light processing; HPLC, high-performance liquid chromatography.

3.3 Clinical outcomes

Patient satisfaction and OHRQoL were the most commonly reported primary outcomes in the reviewed studies. In the Japanese crossover trial by Iwaki et al. (2024), no statistically significant differences in the total score of OHIP-EDENT-J and all seven subdomains were observed between 3D-printed and conventional dentures. Satisfaction in the 100-mm visual analogue scale was not significantly different, further reinforcing the non-inferiority claim. Similar findings were reported by Emera et al. (2025), with no statistically significant difference in OHIP-EDENT at baseline, 3 months, or 6 months, which demonstrates that both types of dentures improved OHRQoL relative to the pre-treatment state. Bors et al. (2025) showed that 40 maxillary edentulous patients reported comparable overall satisfaction, with comfort significantly higher with the use of digital dentures. Elsarrif et al. (2025) also found slightly higher but non-statistically different satisfaction with printed dentures.

By comparison, the study by Ohara et al. (2022) was the only one to clearly show a preference for conventional dentures, with improved ratings for phonetics, ease of cleaning, stability, comfort and overall satisfaction with conventional dentures, although 20% of the participants (n=3/15) chose to use the printed denture instead, which the authors interpreted as practically equivalent. This concurs with a systematic review of five trials in which, out of seven domains, one study showed a preference for conventional dentures in five domains, while the others showed no significant difference, except for esthetic appearance and pronunciation (Alotaibi, 2025).

Biological and functional results were reported less frequently. Elsarrif et al. (2025) found printed dentures showed statistically significantly lower microbial counts after 3 months of use. Emera et al. (2025) determined chewing efficiency by a two-color

gum mixing test, and clinical performance was concluded to be similar between the types of dentures. A double-blinded study comparing milled and printed dentures found no statistically significant differences in satisfaction, OHIP-EDENT, chewing efficiency, or bite force, but the printed dentures showed a greater number of unfavorable scores in the time-related outcomes (Srinivasan et al., 2021). The direction of effect is summarized in Table 3 and Figure 3.

Table 3. Direction of effect for clinical outcomes (3D-printed relative to conventional dentures)

Outcome	Favors conventional	No difference	Favors 3D-printed	Studies
Overall patient satisfaction	1	5	0	Ohara 2022 (conventional); Srinivasan 2021*, Iwaki 2024, Emera 2025, Bors 2025, Elsarrif 2025 (no difference)
OHRQoL (OHIP-EDENT)	0 (1 mixed)	3	0	Iwaki 2024, Emera 2025, Srinivasan 2021*; mixed: Ohara 2022
Chewing efficiency / function	0	2	0	Emera 2025, Srinivasan 2021*
Comfort domain	1	0	1	Ohara 2022 (conventional); Bors 2025 (printed)
Microbial colonization	0	0	1	Elsarrif 2025

*Comparator was milled CAD-CAM dentures. OHRQoL, oral health-related quality of life.

3.4 Laboratory Results

The most common measured property within the laboratory studies in this review was flexural strength. Four of the five studies that compared a printed resin to a heat-polymerized or other conventional material, found the printed material to have a lower flexural strength (Prpić et al., 2020; Perea-Lowery et al., 2021; Gad et al., 2022; Fouda et al., 2022). Gad et al. (2022), found the heat-polymerized resin had a flexural strength of 86.63 ± 1.0 MPa compared with the printed resin at 69.15 ± 0.88 MPa. After 10,000 thermal cycles the strength decreased to 63.93 ± 1.54 MPa, which is below the 65 MPa value commonly required of denture-base polymers for conventional heat-polymerized acrylic resin (ISO 20795-1, 2013, p. 71) (Figure 4 and Figure 6). Conversely, Di Fiore et al. (2022), found the flexural strength of the printed PMMA at 87.34 ± 6.39 MPa compared to 80.79 ± 7.64 MPa in the heat-polymerized control group. The milled group had a higher flexural strength at 110.23 ± 5.03 MPa (Figure 7). Fouda et al. (2022), reported that the milled group had the highest strength and the printed group had the lowest, but both were within clinically acceptable ranges for flexural strength and modulus.

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Figure 3. Evidence map of the direction of effect for clinical (A) and laboratory (B) outcomes in the 12 included studies.

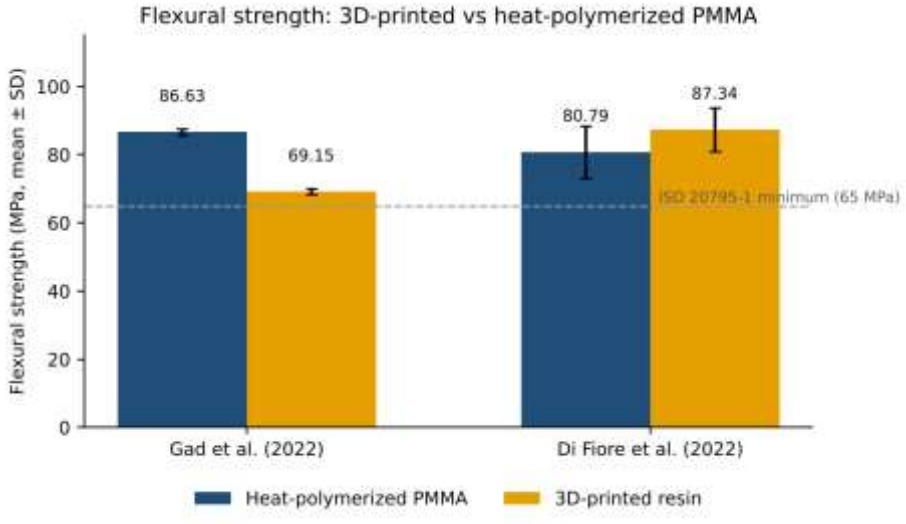

Figure 4. Flexural strength of 3D-printed and heat-polymerized resins in two laboratory studies (mean ± SD; dashed line indicates the 65 MPa minimum in ISO 20795-1).

Similar trends are found in other mechanical properties. Gad et al. (2022) found that the impact strength (2.44 ± 0.31 versus 6.32 ± 0.50 kJ/m^2) and Vickers hardness (34.62 ± 2.1 versus 41.63 ± 2.03 VHN; $P < 0.001$) are much lower in the printed resin, whereas the printed resin has a lower surface roughness (0.12 ± 0.02 versus 0.18 ± 0.01 μm, see Figure 5). Perea-Lowery et al. (2021) found that the printed resin had the lowest fracture toughness and work of fracture of the three materials they

tested, and that the flexural strength of the printed resin probably depends on the post-curing unit used. This agrees with the review by Lourinho et al. (2022) of the in vitro properties of printed and heat-polymerized PMMA.

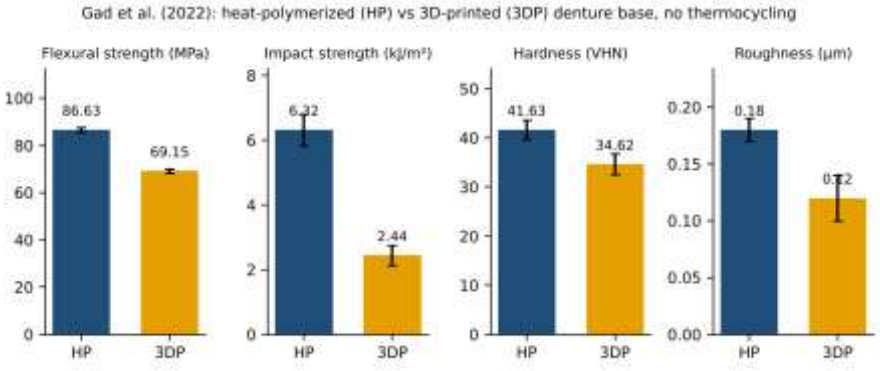

Figure 5. Mechanical and surface properties of heat-polymerized (HP) and 3D-printed (3DP) denture base resins (Gad et al., 2022; mean ± SD).

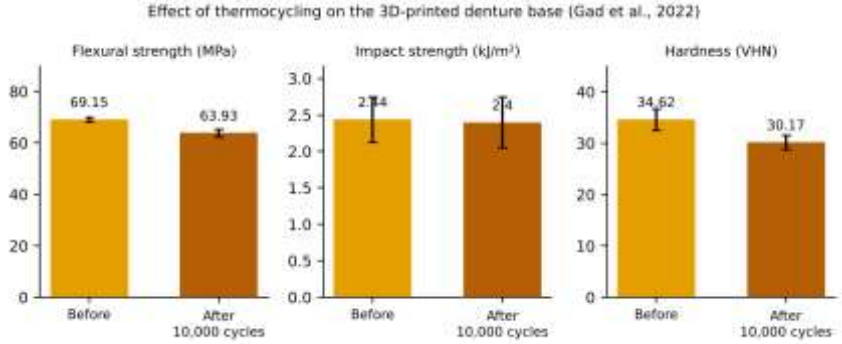

Figure 6. Effect of thermocycling on the 3D-printed resin (Gad et al., 2022; mean ± SD).

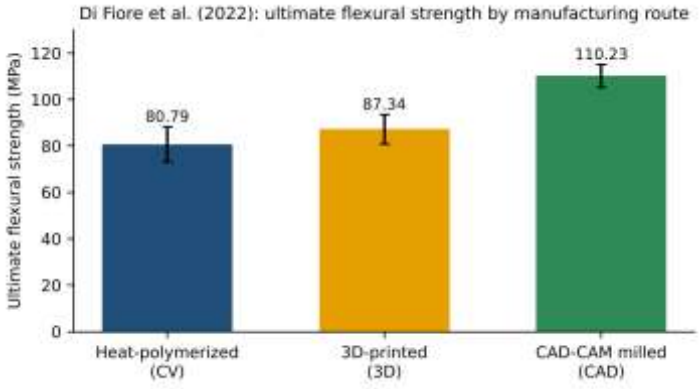

Figure 7. Ultimate flexural strength by manufacturing route (Di Fiore et al., 2022; mean ± SD).

Surface And Chemical Properties

The surface and chemical characteristics of the material may be advantageous to printing in some aspects. Smoother surfaces were observed on printed specimens (Gad et al., 2022), which may mean that printing improves the surface finish. However, polishing did not alter the surface roughness in printed or milled specimens (Di Fiore et al., 2022), and as such polishing techniques may produce similar outcomes regardless of method of fabrication. Similarly, a study of 32 CAD-CAM dentures found the release of methyl methacrylate was lower from printed than from milled dentures, and the longer wash cycle was no more effective than a normal wash with an extra coating (Srinivasan et al., 2022). Interestingly, no included study tested

conventional heat-polymerised dentures for residual monomer under the same protocol, making this finding in comparison to milled only. The quantitative laboratory findings are tabulated in Table 4.

Table 4. Quantitative laboratory results for printed versus conventional (or milled) materials

Study / property	Heat-polymerized or milled comparator	3D-printed	Unit	Statistical comment
Gad 2022: flexural strength	86.63 ± 1.0	69.15 ± 0.88	MPa	$P < 0.001$
Gad 2022: flexural strength after thermocycling	—	63.93 ± 1.54	MPa	Reduced vs untreated
Gad 2022: impact strength	6.32 ± 0.50	2.44 ± 0.31	kJ/m²	$P < 0.001$
Gad 2022: hardness	41.63 ± 2.03	34.62 ± 2.1	VHN	$P < 0.001$
Gad 2022: surface roughness	0.18 ± 0.01	0.12 ± 0.02	μm	$P < 0.001$
Di Fiore 2022: UFS (heat-polymerized)	80.79 ± 7.64	87.34 ± 6.39	MPa	Kruskal–Wallis, n = 6
Di Fiore 2022: UFS (milled CAD)	110.23 ± 5.03	87.34 ± 6.39	MPa	Milled highest

UFS, ultimate flexural strength. Values are mean ± SD as reported by the authors.

3.5 Methodological features of the included studies

Methodological details were highly variable. Among clinical studies, two trials were registered prospectively; UMIN000028047 – Ohara et al. 2022 and NCT05845099 – the Ain Shams crossover trial reported by Elsarrif et al. 2025. One trial was explicitly identified as double-blinded (Srinivasan et al. 2021) and another documented an a priori calculation of sample-size, inflated to account for attrition (Emera et al. 2025). Washout was only explicitly identified in a single trial, which used a 2 week washout period (Elsarrif et al. 2025). Laboratory studies varied in specimen number per group from n=6 to n=24, with ISO 20795-1 cited as the standard by Gad et al. 2022. Only two studies mentioned thermocycling (Gad et al. 2022) or water storage (Perea-Lowery et al. 2021) to age specimens, among six laboratory studies. These methodological differences (summarized in Table 5) are arguably the primary reason why confidence in the effect estimate is rated as low to moderate.

Table 5. Methodological features reported by the included studies

Study	Randomization / allocation	Blinding or registration	Other design features
Ohara et al. (2022)	Randomized crossover (CD-DD vs DD-CD sequence)	Registered: UMIN000028047	Three prosthodontics; Nov 2017–May 2020
Srinivasan et al. (2021)	Randomized crossover	Double-blind (clinicians and participants)	6-week period before crossover

Study	Randomization / allocation	Blinding or registration	Other design features
Iwaki et al. (2024)	Randomized crossover	Not extracted	Non-inferiority design on OHIP-EDENT-J
Emera et al. (2025)	Randomized two-period crossover	Not extracted	Sample size 17 raised to 20; Wilcoxon and paired t-tests
Bors et al. (2025)	Randomized crossover pilot	Not extracted	6 months per denture; DLP printer
Elsarrif et al. (2025)	Randomized crossover	Registered: NCT05845099	3 months per denture; 2-week washout
Prpić et al. (2020)	—	—	160 specimens; 3-point flexure and Brinell hardness
Perea-Lowery et al. (2021)	—	—	n = 16/group; dry and 30-day water storage
Di Fiore et al. (2022)	—	—	n = 6/group; Kruskal–Wallis with post hoc tests
Gad et al. (2022)	—	—	ISO 20795-1; n = 10; 10,000 thermocycles; ANOVA with Tukey HSD
Fouda et al. (2022)	—	—	n = 20 per material (10 flexural, 10 hardness)
Srinivasan et al. (2022)	—	—	HPLC at 1, 2, 4, 8 and 24 h; 32 dentures

3.6 Summary of findings

Table 6. Summary of findings by outcome domain

Outcome domain	Studies	Synthesis	Confidence
Patient satisfaction and OHRQoL	6	Comparable in 5 of 6 trials; conventional preferred in 1; comfort better with printing in 1 pilot	Moderate–low: small crossover samples, short follow-up
Function and biofilm	3	Chewing efficiency comparable; lower microbial counts on printed dentures in one trial (n = 11)	Low: few trials, single small study for biofilm
Flexural strength	5	Lower for printed resin in 4 of 5 studies; one study with higher printed value than heat-polymerized but below milled	Moderate: consistent direction, in vitro only
Impact strength and hardness	2	Lower for printed resin in both studies reporting them	Low–moderate

Outcome domain	Studies	Synthesis	Confidence
Surface roughness	2	Smoother or similar for printed resin	Low
Residual monomer	1	Lower for printed than milled dentures	Low: no conventional comparator

4. DISCUSSION

4.1 Principal findings

Two somewhat opposing conclusions were obtained by this review of 12 studies. In clinical studies, 3D-printed removable dentures are relatively equal to conventional dentures in terms of patient satisfaction and OHRQoL over follow-up periods of weeks to months, despite isolated differences at the level of individual domains in either direction. Laboratory-wise, the strength of printed denture-base resins does not appear to match that of heat-polymerized resins and most distinctly of milled poly(methyl methacrylate), since these are characterized by significantly decreased flexural strength, impact strength and hardness. The clash may be explained due to the differences in the type of outcomes: patient-reported outcomes will accumulate the patients' overall views during a relatively short follow-up period, while laboratory-based strength tests reveal a safety margin that may only manifest in the long-term with occurrence of fracture, repair or other failure modes.

4.2.Comparison with Previous Reviews

The patient report findings of this review are in agreement with that of Alotaibi (2025) who concluded that printed complete dentures are similar to conventional dentures for patient's satisfaction but with concern for aesthetics and speech. This review aligns with the patient report findings of Thu et al. (2023), which found no difference in patient satisfaction and OHRQoL between conventional, milled and printed dentures, although retention loss, patients' satisfaction and need for remakes still occur. The laboratory findings concur with those of Lourinho et al. (2022) and in the repair review by Seow et al. (2023) which highlighted that fracture of the denture base in the midline as being a common complication and that repair techniques for printed dentures require more study. Overall, this review provides a comparison of the clinical and laboratory evidence, the direction of effect for flexural strength appears similar in four out of five laboratory studies.

4.3.Clinical Implications

For clinicians, this is consistent with the literature thus far, which suggests that printed dentures are an acceptable option for edentulous patients, particularly when digital workflows speed up the process or allow for copies of dentures to be printed. Clinicians should remain vigilant of denture base thickness, material choice, and post-curing protocols, given that flexural strength is affected by both post-curing unit and thermal cycling (Perea-Lowery et al., 2021; Gad et al., 2022). Additionally, build orientation and aging are expected to affect flexural values for printed resins (Fouda et al., 2025). According to the domain-level results described by Ohara et al. (2022), further follow-up with respect to phonetics, stability, and comfort in patients with printed dentures is justified. While advantages of lower microbial adherence and less monomer release are possible, these promises are only corroborated by a few small studies.

4.4.Strengths and Limitations

Strengths and limitations of this review strengths include the examination of printed dentures in general, the limited inclusion to recent papers, the consideration of clinical and laboratory evidence, and the inclusion of quantifiable numeric values. Limitations include narrow searches, which might have missed some relevant papers; small clinical samples and short follow-up periods (although several of the trials included crossover designs with potential for carry-over), the heterogeneity in printer, resin, layer thickness, post-curing, and denture design that makes findings unlikely to be generalizable to current commercial systems and to prevent data pooling, the use of standardized specimens (not replicating intraoral loading), and inconsistent aging protocols, formal risk-of-bias assessment was not conducted, and publication bias could not be assessed.

4.5.Implications for research

Future trials should use parallel or well-washed crossover designs with longer follow-up of at least 12 months and recording of fractured, repaired, remade and adjusted frequencies. Use of standardized patient questionnaires should be adopted. Reports of laboratory testing should include details such as printer used, lot of resin, layer thickness, build angle, washing and post-curing

conditions, include ageing protocols and compare results with heat-polymerized and milled controls. Protocols registered with comprehensive outcome data may allow for meta-analyses in future.

5. CONCLUSIONS

In the limitations of the evidence available, 3D-printed removable dentures provide similar patient-reported outcomes to conventionally fabricated dentures short-term, with some variations depending on the domain; however, printed denture-base resins provide decreased flexural strength, impact strength, and hardness in vitro. As such, printed dentures may be an acceptable clinical alternative, but the need for long-term clinical data for fracture, repair, and longevity must be considered before they can be regarded as equivalent to conventional or milled dentures.

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