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Denture Base Resins for Removable Complete Dentures: Material Properties and Clinical Evaluation—A Narrative Review

Neada Hysenaj[1,2*], Belisa Kaleci[1,2], Eni Jani[1], Xhanina Lulaj[1], Desara Zazaj[1], Vergjini Mulo[2]

[1]University Dental Clinic, Tirana, Albania
[2]Faculty of Dental Medicine, University of Medicine, Tirana, Albania
*Corresponding author: Neada Hysenaj; e-mail: neada.hysenaj@umed.edu.al; ORCID: 0000-0001-7785-4563

ABSTRACT: This narrative review aimed to synthesize two complementary bodies of evidence on resin materials used for definitive removable complete dentures: (1) laboratory evidence on the physical, mechanical, dimensional, water-related, optical, chemical, biological, and repair-related properties of conventional heat-polymerized polymethyl methacrylate (PMMA), CAD/CAM-milled PMMA, 3D-printed photopolymers, and transparent formulations; and (2) clinical evidence on complete-denture adaptation, retention, function, tissue response, maintenance, technical complications, and patient-reported outcomes. Evidence was identified through PubMed searches and reference-list screening. Original laboratory and clinical studies, together with selected case reports relevant to definitive complete dentures, were synthesized thematically rather than statistically pooled. Some laboratory comparisons favored milled PMMA for selected mechanical properties, whereas findings on fit and retention varied by system and measurement method. Results for printed resins also varied according to formulation, printing orientation, and post-curing conditions. Clinical comparisons showed differences in individual outcomes, but studies that changed several elements of the treatment pathway could not isolate the effect of the base resin. Evidence on transparent bases remains limited and consists mainly of laboratory comparisons, with little comparative long-term clinical evidence. Material selection should consider the specific resin and processing protocol, the completed prosthesis, and patient needs. Transparent bases may provide an aesthetic option but require evaluation of their mechanical, biological, functional, and optical properties.

1. INTRODUCTION

The denture base is the part of a complete denture that rests on the supporting oral tissues and to which the artificial teeth are attached (International Organization for Standardization, 2013). Its adaptation to the supporting tissues and the peripheral border seal are important contributors to retention (Darvell and Clark, 2000). The resin is exposed to functional and accidental stresses; flexural stiffness and surface hardness are among the properties used to characterize its mechanical behavior (Phoenix et al., 2004). Denture base materials should therefore not be judged by a single strength value alone (International Organization for Standardization, 2013; Phoenix et al., 2004).

ISO 20795-1:2013 classifies denture base polymers, specifies requirements, and provides test methods for properties including flexural strength, flexural modulus, residual methyl methacrylate, water sorption, and solubility (International Organization for Standardization, 2013). These tests characterize material properties under defined laboratory conditions; they do not directly measure the clinical performance of a completed denture. Clinical studies provide complementary evidence at the prosthesis

and patient levels by assessing fit and retention, patient satisfaction, and post-insertion maintenance (Maniewicz et al., 2024; Iwaki et al., 2024; Kim et al., 2021).

Comparisons among manufacturing pathways should be interpreted in light of both resin formulation and processing conditions, rather than the manufacturing label alone. Artopoulos et al. (2013) found greater processing deformation in the visible-light-polymerized urethane dimethacrylate system than in the PMMA systems they tested. Al-Dwairi et al. (2020) reported higher flexural strength, flexural modulus, and impact strength for the milled PMMA blanks they investigated than for their conventional heat-polymerized comparator. Li et al. (2021) showed that post-curing conditions altered the surface characteristics, flexural strength, and cytotoxicity of a 3D-printed denture base polymer. Together, these studies show why conventional, milled, and printed describe manufacturing pathways rather than uniform material classes; final properties also depend on formulation and processing history (Al-Dwairi et al., 2020; Li et al., 2021).

Appearance is another consideration when selecting a denture base. Pink pigmentation is used to reproduce gingival color, whereas a clear acrylic base can allow the patient's own mucosal color to remain visible through the prosthesis, as described in a case report of definitive complete dentures (Sushma et al., 2016). Sushma et al. (2018) compared clear and pink heat-polymerized acrylic resins using flexural, tensile, compressive, and impact tests. Their findings apply to the formulations and test conditions examined and should not be generalized to all transparent denture base materials.

The aim of this narrative review is twofold: first, to synthesize material-level evidence on the composition, manufacturing, and physical, mechanical, dimensional, water-related, optical, biological, and repair-related properties of resins used for definitive removable complete dentures; and second, to synthesize clinical evidence on the performance of complete dentures, including adaptation, retention, function, tissue response, maintenance, technical complications, and patient-reported outcomes. A further objective is to distinguish findings attributable to a specified denture-base material from findings that reflect a broader conventional or digital treatment workflow. Accordingly, the review asks: how do the composition and processing of conventional, milled, 3D-printed, and transparent denture-base materials influence their material properties and, where clinical evidence is available, the performance and patient-relevant outcomes of removable complete dentures?

2. REVIEW METHODOLOGY

2.1 Search strategy

This narrative review considered publications that examined resin materials used for removable complete dentures. PubMed was searched to identify relevant records, and the reference lists of selected primary studies were checked to locate additional publications. Original journal articles were consulted to verify bibliographic details and reported findings. Search terms combined concepts for complete dentures and denture base resins (including "complete denture," "denture base resin," "polymethyl methacrylate," "PMMA," "CAD/CAM," "milled denture," "3D printing," "photopolymer," "clear acrylic," and "transparent denture base") with terms for material properties and clinical outcomes (including "flexural strength," "fracture resistance," "fit," "retention," "water sorption," "solubility," "residual monomer," "biocompatibility," "cytotoxicity," "Candida albicans," "repair," "bond strength," "patient satisfaction," and "oral health-related quality of life").

2.2 Eligibility criteria

Eligibility was determined at two complementary levels. Material-level studies were eligible when they reported original in vitro evidence on resin formulations or denture-base specimens intended for, or directly relevant to, definitive removable complete dentures. Eligible materials included conventional heat-polymerized PMMA, CAD/CAM-milled PMMA, 3D-printed photopolymers, clear or transparent acrylic formulations, and cold- or autopolymerized acrylic resins when directly relevant to denture-base properties or interfaces. Specimens could be standardized discs, bars, plates, or denture bases rather than finished prostheses. Relevant material outcomes included mechanical, physical, dimensional, water-related, optical, chemical, biological, microbiological, and repair or bonding properties.

Clinical-level studies were eligible when they involved edentulous participants receiving definitive maxillary and/or mandibular complete dentures and reported outcomes relevant to adaptation, retention, stability, chewing, speech, tissue response, maintenance, technical complications, or patient-reported outcomes. Eligible designs included randomized and crossover trials, prospective follow-up studies, retrospective observational studies, and controlled clinical comparisons.

Complete-denture workflow comparisons were also retained when the exact base-resin formulation was not reported, provided that the participants and outcomes met the clinical criteria above. Such studies were classified and interpreted as workflow-level evidence; they were not used to attribute observed differences specifically to resin chemistry or to a particular base material.

Selected case reports were eligible when they documented a definitive complete-denture base formulation, a clinically relevant use of a clear or transparent base, or a material-related clinical issue directly relevant to complete dentures. Case reports were treated as descriptive evidence of feasibility or clinical experience, not as comparative evidence of effectiveness.

2.3 Exclusion criteria

Publications were excluded when they focused on removable partial dentures, nonmetal-clasp dentures, or other prostheses not intended as definitive complete dentures; did not address denture-base resins or a property relevant to complete denture use; focused exclusively on denture teeth, liners, adhesives, or other prosthetic components without examining their interaction with the denture base; concerned temporary or non-definitive materials without relevance to definitive complete dentures; or consisted of editorials, letters, or conference abstracts without a full report. Secondary reviews were not treated as primary evidence in the synthesis; relevant reviews were consulted to identify additional primary studies and to contextualize the findings.

2.4 Data extraction

For each eligible publication, the review considered study design, resin formulation, manufacturing and post-processing steps, specimen shape and dimensions, aging and conditioning methods, comparison groups, participant characteristics, follow-up period, and outcome measures. For clinical studies, we also recorded whether the denture-base formulation was identified and whether the comparison isolated a base material or combined several treatment components, such as impression-taking, scanning, design, tooth arrangement, and fabrication. This distinction was used to interpret findings as material-specific, base/fabrication-level, or workflow-level evidence, as appropriate. Findings from standardized specimens, denture bases, completed prostheses, and patients were retained at the level at which they were obtained.

3. MATERIAL CLASSES AND MANUFACTURING PATHWAYS

3.1 PMMA-based materials and milling blanks

PMMA is a common polymer used in complete denture bases and is covered by the denture-base polymer requirements in ISO 20795-1:2013. Commercial PMMA denture-base resins are not identical: polymerization conditions and formulation-related features, including modifiers and rubber toughening, can affect properties such as flexural stiffness and surface hardness (International Organization for Standardization, 2013; Phoenix et al., 2004; Al-Dwairi et al., 2020). Conventional heat-polymerized acrylic and industrially polymerized milling blanks therefore have different processing histories, even though both are classified as PMMA. With CAD/CAM milling, a prepolymerized blank is machined to match the denture base designed on the computer. Because the blank is polymerized before machining, the base is not formed by polymerizing acrylic dough in its final shape; nevertheless, the accuracy of the completed base remains dependent on the digital and manufacturing workflow (Steinmassl et al., 2018). Additive manufacturing follows a different process: the denture base is built layer by layer from a light-sensitive resin and is then washed and post-cured. Its final properties depend on the resin formulation as well as on printing settings and post-processing protocols (Li et al., 2021; Aati et al., 2022).

3.2 Additive manufacturing and formulation-specific properties

Printed denture base resins are not a single chemical class. The term "3D-printed resin" describes a manufacturing route, not one standardized formulation. Studies comparing printed materials with conventional PMMA should therefore report, where available, the specific resin, printing orientation, washing procedure, post-curing conditions, and finishing protocol, because these factors have been shown to influence measured surface and mechanical properties (Li et al., 2021; Aati et al., 2022; Al-Dulaijan et al., 2022; Gad et al., 2022a). In this review, material composition, manufacturing method, and appearance are treated as separate characteristics. Transparency is an optical property of a formulation, whereas conventional processing, milling, and printing describe how the material is shaped and processed. Neither transparency nor the manufacturing route, by itself, establishes the clinical performance of the completed denture; this distinction is important when interpreting the laboratory

and case-report evidence on clear acrylic and the comparative data for digital dentures (Sushma et al., 2016; Sushma et al., 2018; Lawson et al., 2026).

4. POLYMERIZATION AND POST-PROCESSING

4.1 Polymerization and residual monomer

Polymerization forms the polymer network and can affect dimensional stability, residual monomer content, mechanical properties, and biological response. In their comparison, Artopoulos et al. (2013) found greater processing deformation in the light-polymerized urethane dimethacrylate system than in the PMMA systems they tested. The two processing methods used for PMMA, compression and injection molding, produced similar results. Residual monomer matters because incomplete polymer conversion can affect both the material's properties and its interaction with tissues. Lung and Darvell (2005) found that extending the processing time reduced the amount of residual methyl methacrylate (MMA) in denture base acrylic. Bayraktar et al. (2006) also showed that MMA levels are influenced by the polymerization method, curing conditions, and storage in water. Together, these findings show that residual monomer levels depend not only on the formulation, but also on processing conditions and subsequent storage.

Khan et al. (2026) compared residual methyl methacrylate and water sorption in printed, milled, and conventional heat-cured denture-base materials. Residual MMA was detected in all groups, with the lowest reported concentration in the printed group and the highest in the heat-cured group. In contrast, water sorption was greatest in the printed group and lowest in the milled group. This single in vitro comparison illustrates that a lower residual-monomer value does not necessarily correspond to lower water uptake, and its findings should not be generalized beyond the tested products.

4.2 Post-curing of printed photopolymers

Post-curing is particularly important for printed photopolymers. Li et al. (2021) found that post-curing protocols affected the surface properties, flexural strength, and cytotoxicity of a 3D-printed denture base polymer. The final material is therefore determined not only by the resin formulation but also by printing, washing, post-curing, and the other steps used to finish the denture.

Aati et al. (2022) compared post-curing times of 0, 5, 10, and 20 minutes. Flexural strength and flexural modulus increased with longer exposure, although the 10- and 20-minute groups did not differ significantly. Water sorption increased with post-curing time, with the 20-minute group showing significantly greater sorption than the uncured group; in contrast, solubility was significantly lower after 10 and 20 minutes than in the uncured and 5-minute groups. Six-month storage in artificial saliva reduced flexural strength and modulus. These findings show that longer post-curing can improve selected mechanical outcomes and reduce solubility, but may also increase water sorption; the effects should therefore be considered together rather than described as uniformly beneficial. Al-Dulaijan et al. (2022) also showed that the effects of printing orientation and curing time depended on the material. Post-curing had a clearer effect on hardness, whereas changes in surface roughness were less consistent across the conditions they tested. Post-curing should therefore not be assumed to improve every clinically relevant property to the same extent. The material that requires clinical evaluation is the denture base after all manufacturing steps have been completed. Washing, post-curing, finishing, polishing, conditioning, and storage can influence the measured properties of printed and conventional specimens (Lung and Darvell, 2005; Li et al., 2021; Aati et al., 2022; Al-Dulaijan et al., 2022). Comparative studies should describe these steps clearly so that their findings can be interpreted and reproduced.

5. DIMENSIONAL ACCURACY AND TISSUE-SURFACE ADAPTATION

Dimensional accuracy describes how closely a denture base matches its intended or reference shape. Tissue-surface adaptation describes the relationship between the intaglio surface and the supporting tissues. These measurements are related, but neither should be used as a substitute for clinical retention (Steinmassl et al., 2018; Yoon et al., 2020). In a laboratory comparison based on scanned master casts, Steinmassl et al. (2018) found smaller mean geometric deviations for the CAD/CAM denture bases than for conventionally fabricated bases. The size of the deviation nevertheless varied among the four CAD/CAM systems tested. The findings support improved geometric congruence for those specific systems under the study conditions; they do not establish that every digital system will produce the same result. Yoon et al. (2020) compared pack-and-press, five-axis milled, and digital light processing (DLP) denture bases in 9 participants with 12 edentulous arches. No statistically significant differences were found among the three techniques in absolute tissue-surface adaptation. Relative adaptation differed at selected

maxillary regions, while mandibular measurements did not show significant differences between DLP and milling. The findings indicate that adaptation varies by anatomical site and measurement approach rather than following a single overall ranking.

Geometric congruence and tissue-surface adaptation should not be interpreted as direct measurements of clinical retention. Complete-denture retention depends importantly on base adaptation and the peripheral border seal, together with saliva-related fluid effects and muscular control (Darvell and Clark, 2000). Dimensional measurements should therefore be interpreted alongside clinical retention, stability, and patient comfort rather than as substitutes for these outcomes.

6. MECHANICAL PROPERTIES AND REINFORCEMENT

6.1 Interpreting mechanical properties

Mechanical tests characterize different aspects of material behavior. Flexural strength describes the stress sustained before failure in bending, whereas flexural modulus describes stiffness. Fracture toughness characterizes resistance to crack initiation and propagation; impact tests assess response to sudden loading, and fatigue tests examine behavior under repeated loading. These measures are distinct and should not be treated as interchangeable indicators of overall quality (International Organization for Standardization, 2013; Diaz-Arnold et al., 2008; Mann and Ruse, 2022). Phoenix et al. (2004) compared the mechanical and thermal properties of six commercial PMMA denture base resins. The rubber-modified materials were more flexible and had lower flexural stiffness and surface hardness than some of the other materials tested. The findings illustrate that a formulation change intended to improve one characteristic may alter other properties as well. Diaz-Arnold et al. (2008) compared four heat-polymerized PMMA materials with a visible-light-polymerized urethane dimethacrylate resin. The urethane dimethacrylate material had higher flexural strength under both static and cyclic testing, but it also showed lower load limits, brittle-type behavior, and greater variability. The results demonstrate why a high flexural-strength value should be interpreted together with failure behavior and response to repeated loading.

6.2 Conventional, milled, and printed materials

Al-Dwairi et al. (2020) found that the milled PMMA materials they tested had higher flexural strength, flexural modulus, and impact strength than the conventional heat-polymerized material used for comparison. These results indicate favorable mechanical performance for those specific prepolymerized blanks under the laboratory conditions of the study. The findings for printed materials are less consistent. Gad et al. (2022a) reported lower flexural strength, impact strength, and hardness for the printed polymer they examined than for the heat-polymerized comparator. Yu et al. (2024), however, found higher flexural strength and flexural modulus in a different printed formulation than in the milled and conventional materials they tested. This difference remained after thermocycling. Arora et al. (2024) also reported formulation-specific differences in a comparison of a 3D-printed resin, milled PMMA, Polyan IC, and SR Ivocap. Milled PMMA showed greater compressive strength and better color stability than the printed material, whereas flexural strength and surface hardness were similar. Polyan IC showed higher hardness and flexural strength than the printed resin. Because Polyan IC is a distinct material system, these findings should not be generalized to PMMA formulations as a group. Srinivasan et al. (2021a) evaluated the biocompatibility, mechanical properties, and surface roughness of six milled and 3D-printed resin groups. No significant differences in cell-based biocompatibility were detected among the tested groups; however, selected material pairs differed in ultimate strength, elastic modulus, and toughness. Fouda et al. (2023), in a comparison of 120 specimens representing heat-polymerized, milled, and 3D-printed resins, reported higher flexural strength, elastic modulus, and surface hardness for the milled groups, followed by heat-polymerized and then 3D-printed materials. The flexural strength and modulus of the printed materials nevertheless exceeded the clinically acceptable values applied by the authors. These findings reinforce the importance of evaluating individual formulations and test conditions. Fracture tests show why no single mechanical measurement can describe overall material performance. Mann and Ruse (2022) found that their printed material had greater fracture toughness than the conventional and milled materials in their comparison. However, prolonged storage in water reduced the work of fracture in all groups they investigated. Lawson et al. (2026) compared printed, milled, and conventional denture base materials using mechanical, optical, and physical tests. For dry testing, all but one of the 3D-printed materials had flexural strength values that were higher than or equivalent to those of the reference materials; under wet testing, this was true for all printed materials. Their wet-tested flexural strength values were also higher than their corresponding dry-tested values. Wet testing increased displacement before fracture in the 3D-printed materials but decreased it in the reference materials. Only two 3D-printed formulations had fracture toughness similar to that of the reference materials. These findings show that the response to water exposure depends on both

the material and the mechanical outcome; flexural strength and fracture toughness should therefore be considered separately. Taken together, the laboratory comparisons do not support a simple ranking of conventional, milled, and printed materials. Milled PMMA performed favorably in selected tests (Al-Dwairi et al., 2020; Fouda et al., 2023), whereas printed formulations produced mixed results across flexural strength, modulus, hardness, and fracture toughness (Gad et al., 2022a; Yu et al., 2024; Mann and Ruse, 2022; Lawson et al., 2026). Differences in resin chemistry, degree of conversion, cross-linking, printing settings, post-curing, specimen geometry, conditioning, and failure mode may contribute to the variation. It is therefore more appropriate to assess each formulation under clearly described test conditions than to assume that one manufacturing method is always mechanically superior (Al-Dwairi et al., 2020; Gad et al., 2022a; Lawson et al., 2026). Additional studies published within the review period reinforce this material-specific pattern. Aliyeva et al. (2026) compared compression-molded, fluid-resin, milled, and 3D-printed PMMA specimens; the tested printed group had the lowest flexural strength, elastic modulus, and surface hardness and the highest surface roughness, while thermocycling affected the material groups differently. Elazzouni et al. (2026), after 5,000 thermocycles, reported an increase in roughness in all three tested materials, with the greatest change in the printed resin and the smallest in milled PMMA; the milled material also showed the least reduction in hardness. These findings concern specific commercial products and laboratory aging protocols, not clinical durability. A 2025 systematic review and meta-analysis likewise reported higher pooled flexural strength and surface hardness for milled than for 3D-printed denture bases, but noted substantial heterogeneity related to material formulation, printing orientation, and post-curing (Azab et al., 2025). As these pooled outcomes were predominantly laboratory measurements, they cannot establish a universal clinical ranking.

6.3 Reinforcement and prosthesis geometry

Reinforcement strategies are intended to modify how a denture base responds to stress, particularly its resistance to bending or fracture. Their effects depend on the reinforcing material and on its amount, distribution, orientation, and interaction with the resin matrix, as well as on the geometry of the denture (Zidan et al., 2020; Rana et al., 2021). Zidan et al. (2020) studied complete maxillary dentures made from high-impact PMMA containing zirconia nanoparticles. Adding 5 wt% zirconia increased the calculated equivalent flexural strength before cyclic loading. After 250,000 loading cycles, however, the differences between the reinforced groups and the control group were no longer statistically significant. This result highlights the need to test reinforcement under repeated loading: an initial improvement does not necessarily remain after the material has been subjected to functional stress over time. Rana et al. (2021) examined glass-fiber and orthopedic-mesh reinforcement in maxillary PMMA denture bases. After cyclic fatigue loading in a chewing simulator, specimens were subjected to static failure-load testing. The dental glass-fiber mesh group had the highest mean failure load (692.33 ± 75.41 N), compared with 487.40 ± 51.72 N and 486.94 ± 52.39 N in the two orthopedic-mesh groups and 281.41 ± 30.51 N in the unreinforced control. The reinforcing material, base thickness, and specimen weight were associated with failure load. These results apply to the denture-base configurations and loading protocol tested and should not be interpreted as a clinical comparison of complete dentures (Rana et al., 2021). Reinforcement should be assessed in configurations that approximate the finished denture whenever possible. Results from standardized specimens are more clinically informative when considered alongside denture geometry, repeated loading, and the location and mechanism of failure (Zidan et al., 2020; Rana et al., 2021).

7. TRANSPARENT DENTURE-BASE FORMULATIONS

7.1 Indications and definitive use

A transparent denture base offers an aesthetic alternative to pink-pigmented acrylic by allowing the patient's own oral tissues to contribute to the visible appearance of the prosthesis. Definitive use has been described in individual case reports (Dabas et al., 2011; Sushma et al., 2016). The suitability of a clear resin depends on its actual formulation and intended indication. A resin intended for a trial appliance, surgical guide, or other temporary application should not automatically be considered appropriate for a definitive denture. Before clinical use, its intended indication and the relevant mechanical, physical, and biological requirements should be checked against the manufacturer's instructions and applicable denture-base standards (International Organization for Standardization, 2013). Dabas et al. (2011) described a split mandibular complete denture for a patient with xerostomia. The prosthesis consisted of a clear heat-polymerized acrylic base segment and a removable pink acrylic tooth-bearing segment. After the patient had worn the denture for an initial adjustment period, two reservoirs were created in the clear base in the bilateral premolar regions. The reservoirs were filled with an artificial saliva substitute. The clear acrylic allowed the extent of the reservoirs and the level of the substitute to be visualized. At follow-up, the patient reported substantial relief

of dry-mouth symptoms and satisfaction with the prosthesis. This case illustrates a specific functional use of clear acrylic in a mandibular denture; it does not provide comparative evidence on the mechanical properties or long-term performance of a fully transparent complete denture base.

7.2 Evidence from clear and pigmented acrylics

Sushma et al. (2018) compared clear and pink heat-polymerized acrylic denture base resins using flexural, tensile, compressive, and impact tests. No statistically significant differences were reported between clear and pink resins for tensile strength (30.90 ± 1.66 vs. 31.30 ± 8.17 MPa; $p = 0.881$), flexural strength (75.60 ± 17.21 vs. 76.10 ± 14.13 MPa; $p = 0.944$), compressive strength (84.60 ± 2.50 vs. 85.40 ± 16.22 MPa; $p = 0.879$), or impact strength (11.50 ± 5.10 vs. 11.90 ± 1.37 MPa; $p = 0.814$). Fortes et al. (2017) compared microwave-cured acrylic specimens made from a colorless resin without nylon fibers and medium-pink resin with and without nylon fibers. No statistically significant differences were found among the three groups for the measured properties ($p > 0.05$). These findings apply to the specific formulation and test conditions used in that study. Yesil Duymus et al. (2016) compared the Vickers hardness of four denture base materials, including heat-cured clear and pink acrylic resins, using 20 specimens per group. Mean hardness was 16.23 ± 1.85 HV for the clear acrylic and 18.57 ± 1.35 HV for the pink acrylic; the overall difference among the four material groups was statistically significant ($p < 0.001$). The clear acrylic therefore showed a numerically lower hardness value than the pink heat-cured material under the conditions tested. However, the reported p value refers to the overall comparison across all four groups and does not establish a statistically significant pairwise difference between the clear and pink acrylics. This laboratory result concerns surface hardness only and does not establish clinical inferiority, equivalence in other mechanical properties, or long-term clinical performance. Sushma et al. (2016) also reported a case in which heat-polymerized clear acrylic was used as a permanent denture base to meet a patient's aesthetic preference. A single case cannot show whether the material is more effective than other options, but it does document that a clear base can be used for a definitive denture in a selected patient.

7.3 Chemical composition and tissue compatibility

Transparency does not identify the chemical substances present in a material or determine how it may interact with oral tissues. Pfeiffer and Rosenbauer (2004) compared four materials marketed as hypoallergenic alternatives with a heat-polymerized PMMA control. Residual MMA content was lower in some of the alternatives, and no residual MMA was detected in two formulations. Only one alternative showed significantly lower water sorption than the PMMA control, whereas water solubility was not significantly lower for the alternatives. The study did not specifically evaluate transparent acrylic; it therefore provides indirect evidence that the chemical and water-related properties of a denture base should be assessed according to its actual composition rather than its appearance or marketing description. Koutis and Freeman (2001) described contact stomatitis in a 71-year-old edentulous man after he received a new acrylic denture. Patch testing identified sensitivity to 2-hydroxyethyl methacrylate but not to methyl methacrylate (MMA). This case illustrates why suspected material intolerance should be investigated by identifying the substance involved rather than assuming that MMA is responsible for every reaction associated with acrylic materials. Transparent acrylic may be an aesthetic option when the specific formulation is intended for definitive denture fabrication. The available clear-acrylic studies address selected mechanical properties and individual clinical applications; they do not establish long-term clinical equivalence or show that transparency itself reduces residual monomer release, prevents allergic reactions, or limits microbial colonization (Sushma et al., 2016; Sushma et al., 2018; Pfeiffer and Rosenbauer, 2004; Koutis and Freeman, 2001). These properties require independent evaluation of the actual material rather than inference from its appearance.

8. WATER-RELATED AND OPTICAL PROPERTIES

8.1 Water sorption and solubility

Water exposure can alter the mass, dimensions, and mechanical behavior of denture base polymers. Water sorption describes water uptake by the polymer, whereas solubility describes the loss of soluble constituents under specified test conditions. The ISO standard provides defined methods for measuring these properties, and experimental results indicate that values depend on material composition and processing conditions (International Organization for Standardization, 2013; Polat et al., 2003; Aati et al., 2022). Polat et al. (2003) compared denture base polymers with and without short glass fibers. They found that the processing method affected water sorption and solubility, but adding the fibers did not significantly improve dimensional accuracy. This suggests that water-related behavior and dimensional accuracy should be assessed as separate properties. Gad et

al. (2022b) compared three commercial 3D-printed denture-base resins with heat-polymerized acrylic and measured water sorption, solubility, and translucency before and after thermal cycling. The study reported formulation-dependent differences across these outcomes, supporting the need to assess each printed resin separately rather than treating 3D-printed materials as a uniform group.

8.2 Optical and color stability

Color stability also depends on the material and the conditions to which it is exposed. Alfouzan et al. (2021) tested printed and conventional denture resins after aging, mechanical brushing, and immersion in a staining solution. Under these combined test conditions, two of the printed formulations showed less color change than the conventional material used for comparison. Lawson et al. (2026) also examined the optical and water-related properties of these materials. One of the 3D-printed materials was more translucent and another was more opaque than the reference materials, while only one printed material absorbed more water than the reference materials. These findings indicate that optical and physical properties also vary between printed resin formulations. Gad et al. (2021) examined translucency in heat-polymerized PMMA modified with zirconia, silica, or diamond nanoparticles. Most nanoparticle-modified groups showed lower translucency than the unmodified control, although selected low-concentration zirconia and silica groups did not differ significantly. This was a study of nanoparticle-modified PMMA, not a clinical evaluation of definitive transparent dentures; it nevertheless demonstrates that additives can change the optical behavior of a base resin. Arora et al. (2024) also found that color stability differed among the tested denture-base systems, with the 3D-printed resin showing the least color stability in that comparison. For transparent denture bases, maintaining the intended appearance involves more than limiting color change. Staining and changes in translucency may affect the aesthetic result, and the magnitude of these changes varies among formulations and exposure conditions (Alfouzan et al., 2021; Lawson et al., 2026). Optical stability should therefore be assessed alongside the mechanical and biological properties of the selected resin.

9. BIOLOGICAL INTERACTIONS: LEACHABLES, CYTOTOXICITY, AND MICROBIAL ADHESION

9.1 Leachable constituents and cellular responses

Biological tests of denture base materials examine substances released from the polymer and the response of cells exposed to these substances under controlled conditions. Using U-937 human monoblastoid cells, Cimpan et al. (2000) found that cell-death responses to eluates from denture base acrylic resins depended on exposure concentration and duration. Huang et al. (2001) also reported differences in cytotoxicity among denture base materials; in their cell models, the self-cured material produced the greatest response. These experiments describe material responses in defined laboratory systems. They do not reproduce the full oral environment or establish the tissue response that will occur in every patient. Their findings should therefore be interpreted as evidence of potential biological effects under the tested conditions, not as direct predictions of clinical injury (Cimpan et al., 2000; Huang et al., 2001). It is also important to measure substances released from completed CAD/CAM dentures, rather than relying only on tests of the raw material. Steinmassl et al. (2017) found that the CAD/CAM dentures in their study did not necessarily release less MMA than conventional dentures. One of the CAD/CAM groups released more. In a later study, Srinivasan et al. (2022) found greater MMA release from the milled dentures than from the printed dentures at 24 hours. Washing and coating reduced the release from the printed formulation they tested. These findings show that the manufacturing label alone cannot predict how much residual MMA a denture will release. MMA is also only one of the substances that may be released, so it cannot fully represent a material's biological profile.

9.2 In vitro surface properties and microbial adhesion

In vitro studies have characterized surface roughness, wettability, and microhardness in denture-base resins (Al-Dwairi et al., 2019; Fouda et al., 2024). Separate experiments have directly examined Candida adhesion and biofilm formation on selected acrylic formulations (Nevzatoğlu et al., 2007; da Silva et al., 2023; Koujan et al., 2023; Osman et al., 2023). Findings vary across material formulations and experimental protocols; surface measurements alone should not be treated as direct evidence of microbial behavior. Al-Dwairi et al. (2019) compared wettability, surface roughness, and microhardness in two CAD/CAM PMMA blocks and a conventional heat-polymerized PMMA. The conventional material showed the greatest surface roughness, while contact angle and hardness differed between the two milled brands. Because this study did not directly measure microbial adhesion, its findings provide information about surface characteristics rather than evidence of a microbial outcome. Nejatidanesh et al. (2026) compared milled, 3D-printed, heat-polymerized, and injection-molded denture-base materials. Their

milled and printed materials had lower measured roughness than the conventional groups, while wettability and hardness differed among products; porosity did not differ significantly. Ünal et al. (2026), in a separate comparison, found no significant difference in roughness among the conventional, milled, and printed groups, although contact angle and microhardness varied, with the milled material showing the highest and the printed material the lowest microhardness. The differing results underline the influence of formulation, finishing, and test protocol; they do not justify predicting Candida adhesion or denture-stomatitis risk from roughness or hardness alone. Nevzatoğlu et al. (2007) found that Candida albicans adhered more readily to silicone-based resilient liners than to acrylic denture base materials. Among the acrylic materials they tested, however, surface finish did not produce significant differences in adherence. This suggests that microbial attachment cannot be explained by one surface feature alone. da Silva et al. (2023) examined Candida albicans adhesion and biofilm formation on 3D-printed denture base resins. Metabolic activity was higher on both printed materials they tested, but only one of them had significantly higher colony counts than the conventional comparator. Fouda et al. (2024), in contrast, found no significant differences in Candida albicans adhesion among the CAD/CAM denture base resins they examined. Koujan et al. (2023) reported greater attachment of Candida albicans to their printed resin than to milled and heat-polymerized PMMA. These different results underline that "printed resin" does not refer to one standard formulation. Microbial behavior depends on the specific material and its surface characteristics. Osman et al. (2023) directly compared conventional, milled, and 3D-printed denture-base resins. After 24 hours, Candida albicans biofilm formation was highest on the printed material and lowest on the milled material. Because this was an in vitro experiment, the findings describe material-associated biofilm behavior under the tested conditions and do not by themselves establish differences in clinical denture-stomatitis risk.

Del Hougne et al. (2026) examined biofilm formation by Streptococcus mutans and Streptococcus sanguinis over 21 days on a 3D-printed resin, a milled PMMA, and a cold-polymerized conventional resin. S. mutans accumulation remained low overall, with material-related differences at selected time points; S. sanguinis formed more biofilm, and the milled material generally showed lower accumulation than the printed and cold-polymerized materials. The conventional comparator in this study was cold-polymerized PALAPress rather than heat-polymerized PMMA, and the organisms were bacteria rather than Candida albicans. The results therefore add species-specific in vitro evidence but should not be interpreted as a direct comparison of fungal colonization or as a clinical estimate of denture-stomatitis risk.

9.3 Clinical microbiological findings

Clinical studies add another perspective. In a randomized crossover trial involving 11 participants, Elsarrif et al. (2026) found lower microbial counts with the printed dentures they tested, while patient satisfaction was slightly higher with the printed dentures, although the difference was not statistically significant. In a randomized clinical trial, Ahmed Teama et al. (2025) followed 24 patients divided into three groups receiving 3D-printed maxillary complete dentures made with unmodified resin, resin reinforced with 0.4 wt% nano-ZrO_2, or resin reinforced with 0.4 wt% nano-TiO_2. Microbial colonization and patient satisfaction were assessed at insertion and during 18 months of follow-up. The nano-ZrO_2 group showed the most sustained antifungal effect against Candida albicans through 18 months, whereas the nano-TiO_2 group showed antifungal effects through 6 months and antibacterial effects through 18 months. Patient satisfaction was higher in both nanoparticle groups than in the unmodified-resin group. The clinical microbiological findings also require cautious interpretation. Elsarrif et al. (2026) included 11 participants and assessed microbial counts through 3 months, whereas Ahmed Teama et al. (2025) included 24 patients allocated to three groups and followed them for 18 months. These trials provide patient-level evidence for the particular printed formulations and protocols that were tested; they do not establish that 3D-printed denture bases as a general category reduce microbial colonization or prevent denture stomatitis (Elsarrif et al., 2026; Ahmed Teama et al., 2025).

10. REPAIRABILITY AND INTERFACIAL BONDING

10.1 Repair of denture-base resins

The serviceability of a complete denture depends not only on its initial properties but also on its resistance to damage and the feasibility of repair. Laboratory studies indicate that repair outcomes vary with the original base material, repair resin, surface preparation, and aging conditions (Minami et al., 2004; Faot et al., 2009; Neshandar Asli et al., 2021; Gibreel et al., 2024). Minami et al. (2004) showed that the bond achieved during denture repair depends on the repair conditions, surface treatment, and aging. Kostoulas et al. (2008) found that glass-fiber reinforcement changed the fracture force, deflection, and toughness of

repaired acrylic dentures. Faot et al. (2009) also reported that repair results depended on the original base and the repair material. Within the system they tested, using the original resin for the repair gave favorable results.

10.2 Tooth–base, relining, and repair-resin bonding

Digital dentures introduce additional interfaces that need to bond securely. Pereira et al. (2026) investigated different surface treatments and thermal cycling in the bonding of 3D-printed teeth to denture bases. Sandblasting with aluminum oxide produced shear bond strength values comparable to those of the heat-cured PMMA control in both thermocycled and non-thermocycled specimens. It was also the only treatment that significantly increased surface roughness. These findings highlight the importance of surface pretreatment when bonding printed teeth to denture bases. Tooth–base bonding is also system-dependent. Diemer et al. (2026) compared combinations of milled, printed, and prefabricated denture teeth with milled, printed, and autopolymerized denture bases. In their in vitro test, monolithic dentures had the highest fracture forces; among adhesively bonded combinations, a conventional base with prefabricated teeth showed the highest bond strength, whereas a printed base with printed teeth showed the lowest. The study used multiple manufacturer-specific combinations and small groups, so the findings should be interpreted as system-specific rather than as a general comparison of all digital and conventional dentures. Al Kaba et al. (2026) also found significant differences in tooth–base fracture load among seven manufacturer-specific configurations (10 specimens per group). The monolithic milled group had the highest mean fracture load (504.7 ± 76.0 N), whereas a milled base bonded to prefabricated teeth had the lowest (232.8 ± 47.7 N); two printed-base groups with bonded teeth exceeded the compression-molded comparator. These results differ in detail from other interface studies and reinforce that the tooth material, base material, bonding design, and whether the denture is monolithic all influence the outcome. This was an in vitro fracture-load test, not a clinical study of denture breakage. In studies of repairs to printed denture bases, Neshandar Asli et al. (2021) found that surface preparation affected both surface roughness and flexural strength; mechanical grinding performed favorably in their comparison. Gibreel et al. (2024) measured the shear bond strength between autopolymerizing repair resin and denture bases made by conventional, milled, and printed methods. Bond strength depended on the base material and the pretreatment used. The printed substrate had the lowest values among the materials tested, while roughening the surface improved the bond. Hard relining is a related but distinct maintenance procedure from fracture repair. Ünal et al. (2026) found that tensile bond strength to two hard reline materials depended on both the denture-base material and the reline product. One reline material bonded more strongly than the other to the tested heat-polymerized and printed bases, while the difference was not significant for the milled base. These results support product-specific testing of relining interfaces and should not be interpreted as evidence about the strength of a repaired fracture. Albazroun et al. (2026) evaluated hard and soft liners bonded to two milled, two printed, and one heat-polymerized denture-base resin with 5,000 thermal cycles applied before and after the relining procedure. For the hard liner, sandblasting increased shear bond strength in most tested systems; for the soft liner, bur roughening improved bonding in selected milled and conventional groups, but not in the two printed groups. The study supports material- and liner-specific surface preparation rather than one universal relining protocol. Its laboratory results complement, but do not replace, clinical assessment of relined dentures.

These studies support evaluating the denture as an assembly of components and interfaces. Base strength, tooth-to-base bonding, and repair behavior provide different information; favorable properties of the base alone do not ensure a durable prosthesis if the interfaces are weak or difficult to repair (Minami et al., 2004; Pereira et al., 2026; Gibreel et al., 2024).

11. CLINICAL PERFORMANCE OF COMPLETE DENTURES

The clinical part of the review evaluates how definitive complete dentures perform in use, how oral tissues respond, how patients experience treatment, and what maintenance is required. The level of inference depends on the comparison. Studies that compare specified denture bases or base materials can inform base-level performance; studies that also change impression methods, scanning, design, tooth arrangement, or other treatment stages evaluate the overall workflow. Unless the base-resin formulation is identified and isolated, their findings should not be interpreted as evidence that one resin chemistry is superior (Kattadiyil et al., 2015; Maniewicz et al., 2024; Peampring et al., 2026).

11.1 Comparative clinical trials

In a paired clinical comparison involving 15 participants, Kattadiyil et al. (2015) reported higher satisfaction ratings for digital dentures and a shorter clinical fabrication time. These results suggest that digital methods may offer workflow advantages, but fabrication time and patient satisfaction are separate outcomes and should be interpreted independently. In a double-blind,

randomized crossover trial, Srinivasan et al. (2021b) compared milled and 3D-printed complete removable dental prostheses in 15 edentulous participants. No significant between-group differences were found in patient satisfaction, oral health-related quality of life, final denture choice, clinician-rated denture quality, chewing efficiency, or maximum voluntary bite force. The 3D-printed dentures required more maintenance visits. They also required more adjustment time ($p = 0.0003$) and higher adjustment costs ($p = 0.021$). Thus, patient-reported and functional outcomes were comparable in this trial, but the printed dentures required more post-insertion care. Ohara et al. (2022), in a randomized crossover trial involving 15 participants, found higher patient-satisfaction ratings for conventional dentures in phonetics, ease of cleaning, stability, comfort, and general satisfaction. Nevertheless, three participants preferred and used the 3D-printed dentures. This finding provides an important counterpoint to studies reporting advantages for digital workflows. Zupancic Cepic et al. (2023) reported a mixed pattern in a prospective randomized crossover study of 10 patients: digital dentures showed better maxillary stability, whereas conventional dentures had better polishing. Overall clinical-quality scores and OHIP-20 results did not differ significantly between approaches. Deng et al. (2023), in a randomized pilot clinical trial involving 10 patients, found no significant difference in satisfaction scores; the digital workflow reduced average clinical and laboratory operation times and produced statistically better occlusal stability than the conventional approach. In a randomized, single-blinded crossover trial involving eight participants, Kang et al. (2024) found that conventional dentures showed higher measured masticatory efficiency and better patient-rated pronunciation than digital dentures, while overall patient satisfaction and maximum masticatory force did not differ significantly. In a crossover randomized controlled trial involving 18 participants, Iwaki et al. (2024) found that printed dentures were non-inferior to conventional dentures in terms of oral health-related quality of life after one month; patient satisfaction did not differ significantly between the two approaches. In a pilot randomized crossover trial, Keeling et al. (2025) recruited 17 participants, of whom 14 completed the study. The printed dentures were produced by 3D-printing the gingival and palatal portions of the bases and then fitting conventional denture teeth. Oral health-related quality of life improved with both treatment approaches, but participants preferred the conventional dentures. The printed-denture group experienced seven breakages (one denture broke four times) and six tooth debondings. These findings show why patient-reported benefits and technical reliability need to be assessed together: a favorable patient rating does not replace evidence about how well the prosthesis withstands use. Emera et al. (2025), in a randomized crossover trial involving 20 completely edentulous patients, found no significant differences between conventional and 3D-printed complete dentures in overall OHIP-EDENT scores or chewing efficiency through six months. Both approaches were associated with improved oral health-related quality of life after treatment. Rechlin et al. (2026), in an exploratory randomized crossover pilot study of 15 patients, reported satisfactory clinical outcomes with both methods. Numerical oral health-related quality-of-life scores favored digital dentures, but no statistically significant between-group differences were detected; the authors emphasized the small sample size. Ribeiro et al. (2026), in a randomized crossover trial involving 23 edentulous patients, found no significant between-group differences in oral health-related quality of life or masticatory performance. Conventional dentures received higher satisfaction ratings for chewing, taste, and aesthetics and were associated with earlier functional adaptation, whereas digitally fabricated dentures required fewer mandibular base adjustments. In a multicenter randomized crossover trial involving 23 patients, Peampring et al. (2026) compared conventional dentures made with selective-pressure impressions with digital dentures made using a mucostatic digital workflow. Each set was used for four weeks. Digital dentures received higher ratings for treatment duration, comfort, confidence, chewing ability, aesthetics, and overall satisfaction; speech and pronunciation ratings did not differ significantly, and OHIP-14 outcomes were similar. Because both the impression concept and fabrication workflow differed, the findings represent a comparison of treatment approaches rather than the isolated effect of the denture-base resin.

11.2 Clinical fit, adaptation, retention, and stability

AlHelal et al. (2017) compared milled and conventional maxillary denture bases in 20 participants. Both bases were made from the same definitive impression, and vertical dislodgement was measured repeatedly. The milled bases showed greater resistance to vertical dislodgement under the conditions of this clinical comparison; the study does not establish that geometric accuracy alone caused the difference. Emera et al. (2022) compared conventional and 3D-printed complete dentures in 10 edentulous patients. Adaptation and retention were measured at insertion and after 3 and 6 months. Mean misfit and retention did not differ significantly between the two approaches, and both groups showed satisfactory retention during follow-up. Maniewicz et al. (2024) compared conventional, milled, and printed maxillary denture bases in a controlled crossover study. Of the 20 participants recruited, 19 completed the study. Retention did not differ significantly at the posterior palatal or right tuberosity sites; at the left tuberosity, the comparison favored the digital bases. Conventional bases nevertheless showed smaller geometric

deviations from the reference cast. Taken together, these studies show that geometric congruence and clinical retention are related but distinct outcomes. A smaller deviation from a reference cast does not necessarily produce greater retention at every intraoral site, and retention results may vary by measurement location and study protocol (Darvell and Clark, 2000; AlHelal et al., 2017; Emera et al., 2022; Maniewicz et al., 2024).

11.3 Post-insertion maintenance and patient-reported outcomes

The need for adjustments and other maintenance after denture delivery is an important part of clinical performance. Kim et al. (2021) retrospectively reviewed records for 420 heat-polymerized conventional complete dentures and 217 3D-printed complete dentures fabricated in a predoctoral clinical setting. The records showed fewer cases of maxillary pain and visible ulcers in the printed-denture group, but aesthetic concerns were more common in that group. Clark et al. (2021) also found fewer pre-delivery and postoperative visits with digitally fabricated dentures in a university clinic, although remake rates were similar between groups. Because this was a retrospective, non-randomized chart review, treatment-selection and workflow differences may have influenced the results. The findings should therefore be interpreted as evidence about service delivery rather than proof of superior material performance. Cristache et al. (2020) followed 35 patients who received complete dentures made with a hybrid nanocomposite based on PMMA reinforced with 0.4 wt% TiO_2 nanoparticles and an additive CAD/CAM protocol. Mean Oral Health Impact Profile for Edentulous Patients (OHIP-EDENT) scores fell from 52.57 ± 8.16 before treatment to 20.43 ± 4.42 after 18 months, indicating a substantial reduction in the reported oral health-related impact during follow-up. Because the study had a single-cohort design, however, the improvement cannot be attributed specifically to the titanium dioxide-containing material or to additive manufacturing. These clinical studies reinforce the need to evaluate the completed prosthesis rather than infer success from one material property. Patient-reported outcomes integrate aspects of comfort, function, and perceived oral health, but they cannot by themselves identify which material characteristic caused a reported improvement (Srinivasan et al., 2021b; Iwaki et al., 2024; Emera et al., 2025; Peampring et al., 2026). As contextual secondary evidence, Sivaswamy et al. (2026) synthesized 12 clinical studies comparing 3D-printed complete dentures with conventional and milled dentures. Conventional dentures showed a small retention advantage over printed dentures (P = .04), whereas retention did not differ significantly between printed and milled dentures (P = .36). No significant differences were found for patient satisfaction, oral health-related quality of life, masticatory force, or clinician satisfaction. The review searched four databases through April 2025, so it predates several clinical trials published later in 2025 and 2026 that are discussed above. It provides a useful contextual synthesis but is not counted as an independent primary study in the present narrative review; its conclusions should also be interpreted in light of the small number and size of the underlying trials. Selected clinical investigations and case reports meeting the complete-denture eligibility criteria are summarized in Table 1. The table includes both comparative studies and descriptive reports; these designs provide different levels of evidence and should not be interpreted as equivalent.

Table 1. Selected clinical investigations and case reports of definitive removable complete dentures

Study	Design and sample	Material or workflow evaluated	Main clinical findings
Dabas et al. (2011)	Case report; 1 patient with xerostomia	Split mandibular complete denture with a clear heat-polymerized acrylic reservoir segment and a removable pink tooth-bearing segment	Reservoirs contained a saliva substitute; the patient reported substantial relief of dry-mouth symptoms and satisfaction with the prosthesis. It does not provide comparative material-performance evidence.
Kattadiyil et al. (2015)	Paired clinical comparison; 15 participants	Digital and conventional complete dentures	Digital dentures received higher patient satisfaction ratings and required less clinical fabrication time
Sushma et al. (2016)	Case report; 1 edentulous patient	Maxillary and mandibular complete dentures with a definitive clear heat-cured acrylic base	The clear base allowed the patient's mucosal pigmentation to remain visible. The report documents an aesthetic application, not comparative effectiveness or long-term durability.

Study	Design and sample	Material or workflow evaluated	Main clinical findings
AlHelal et al. (2017)	Clinical comparison; 20 participants	Milled and conventional maxillary denture bases	Milled bases required greater vertical dislodgement forces than conventional bases
Yoon et al. (2020)	Clinical adaptation study; 9 participants, 12 edentulous arches	Pack-and-press, milled, and DLP denture bases	No significant differences in absolute tissue-surface adaptation among the three techniques; relative adaptation differed at selected maxillary sites
Cristache et al. (2020)	Prospective single cohort; 35 patients	Complete dentures with a PMMA–TiO_2 hybrid nanocomposite and additive CAD/CAM protocol	OHIP-EDENT scores improved during the 18-month follow-up
Clark et al. (2021)	Retrospective chart review; 314 charts reviewed, with data extracted for 242 conventional and 39 digital dentures	Conventional and digitally fabricated complete dentures	Digital dentures required fewer pre-delivery and postoperative visits; remake rates did not differ significantly
Srinivasan et al. (2021b)	Randomized crossover; 15 participants	Milled and 3D-printed complete dentures	No significant differences in patient-reported or functional outcomes; printed dentures required more maintenance visits, adjustment time, and adjustment costs
Kim et al. (2021)	Retrospective record review; 420 conventional and 217 printed dentures	Conventional and printed complete dentures	Fewer records of maxillary pain or ulcers with printed dentures, but more aesthetic concerns
Emera et al. (2022)	Clinical comparison; 10 participants	Conventional and 3D-printed complete dentures	No significant differences in denture-base adaptation or retention at insertion, 3 months, or 6 months
Ohara et al. (2022)	Randomized crossover trial; 15 participants	3D-printed and conventional complete dentures	Conventional dentures scored higher for phonetics, cleaning, stability, comfort, and general satisfaction; 3 participants preferred and used printed dentures
Deng et al. (2023)	Randomized pilot clinical trial; 10 participants	Digital and conventional complete dentures	Satisfaction scores did not differ significantly; digital treatment reduced clinical and laboratory operation times and improved occlusal stability
Zupancic Cepic et al. (2023)	Prospective randomized crossover; 10 participants	Digital and conventional complete dentures	Overall clinical-quality and quality-of-life scores were similar; digital dentures had better upper stability, while conventional dentures had better polishing
Kang et al. (2024)	Randomized crossover; 8 participants	Digital scanning/printing versus conventional treatment	Conventional dentures showed higher measured masticatory efficiency and better patient-rated pronunciation, while overall patient satisfaction and maximum masticatory force were similar

Study	Design and sample	Material or workflow evaluated	Main clinical findings
Iwaki et al. (2024)	Randomized crossover; 18 participants	Printed and conventional complete dentures	Printed dentures were non-inferior for OHIP-EDENT-J; patient satisfaction did not differ significantly
Maniewicz et al. (2024)	Controlled crossover; 20 recruited, 19 completers	Conventional, milled, and printed maxillary denture bases	Retention varied by measurement site; conventional bases showed smaller geometric deviations
Ahmed Teama et al. (2025)	Randomized clinical trial; 24 patients (8 per group)	Unmodified 3D-printed maxillary complete dentures versus bases reinforced with 0.4 wt% nano-ZrO_2 or nano-TiO_2	Nano-ZrO_2 showed an antifungal effect through 18 months; nano-TiO_2 showed antifungal effects through 6 months and antibacterial effects through 18 months. Satisfaction was higher in both reinforced groups than in the unmodified-resin group
Emera et al. (2025)	Randomized crossover trial; 20 participants	3D-printed and conventional complete dentures	No significant differences in overall OHIP-EDENT scores or chewing efficiency through 6 months
Keeling et al. (2025)	Pilot randomized crossover; 17 recruited, 14 completers	Printed bases with prefabricated teeth versus conventional complete dentures	Participants preferred conventional dentures; the printed group had seven breakages and six tooth debondings
Elsarrif et al. (2026)	Randomized crossover trial; 11 participants	3D-printed and conventional complete dentures	Microbial counts were lower with printed dentures at 1 and 3 months; patient satisfaction was slightly higher but not significantly different
Rechlin et al. (2026)	Exploratory randomized crossover pilot; 15 participants	Digitally and conventionally fabricated complete dentures	Both methods produced satisfactory clinical outcomes; numerical OHRQoL scores favored digital dentures, but between-group differences were not statistically significant
Ribeiro et al. (2026)	Randomized crossover trial; 23 participants	3D-printed and conventional complete dentures	OHRQoL and masticatory performance did not differ significantly; conventional dentures scored higher for chewing, taste, and aesthetics, while digital dentures needed fewer mandibular base adjustments
Peampring et al. (2026)	Multicenter randomized crossover trial; 23 participants	Conventional selective-pressure impression workflow versus mucostatic digital workflow	Digital dentures received higher ratings for treatment duration, comfort, confidence, chewing, aesthetics, and overall satisfaction; OHIP-14 and speech outcomes were similar

Note. The table combines selected clinical studies discussed in Sections 5, 7, 9, and 11; it is a cross-cutting summary rather than a separate or exhaustive evidence set. Where a study compares an overall conventional or digital treatment pathway, or does not identify and isolate the base-resin formulation, the results are workflow-level findings and should not be attributed to resin chemistry alone. Single-cohort studies and case reports describe outcomes or feasibility but do not establish comparative effectiveness. Laboratory-only comparisons are discussed in the relevant material-property sections and are not included in this clinical table.

12. EVIDENCE SYNTHESIS AND CLINICAL IMPLICATIONS

12.1 Integrated interpretation of the evidence

The clinical value of a denture base resin depends on how its measured properties are expressed in the completed prosthesis. Dimensional accuracy may contribute to tissue-surface adaptation, while retention also depends on border seal and saliva-related effects. Stiffness and fracture resistance contribute to structural behavior; surface properties are relevant to microbial adhesion; and chemical composition is relevant to residual monomer release and cellular response (Steinmassl et al., 2018; Darvell and Clark, 2000; Mann and Ruse, 2022; da Silva et al., 2023; Pfeiffer and Rosenbauer, 2004). Each proposed link must nevertheless be assessed with the appropriate clinical outcome rather than assumed from a laboratory measurement alone. The studies reviewed here do not show that any one manufacturing method—conventional processing, milling, or 3D printing—is consistently superior. Some milled PMMA formulations showed favorable mechanical properties (Al-Dwairi et al., 2020; Fouda et al., 2023; Aliyeva et al., 2026; Elazzouni et al., 2026), whereas findings on fit and retention varied by system, anatomical site, and measurement method (Steinmassl et al., 2018; Yoon et al., 2020; AlHelal et al., 2017; Maniewicz et al., 2024). Printed photopolymers also varied by formulation and test conditions (Gad et al., 2022a; Yu et al., 2024; Lawson et al., 2026; Arora et al., 2024; Aliyeva et al., 2026). Clinical studies reported differences in individual outcomes rather than a consistent advantage across all aspects of performance (Srinivasan et al., 2021b; Ohara et al., 2022; Iwaki et al., 2024; Keeling et al., 2025; Emera et al., 2025). This variation is consistent with the range of factors examined in the included studies: resin chemistry, polymerization method and degree of conversion, processing history, printing orientation, post-curing, finishing, denture geometry, tooth–base bonding, aging conditions, and clinical follow-up (Artopoulos et al., 2013; Aati et al., 2022; Al-Dulaijan et al., 2022; Pereira et al., 2026; Diemer et al., 2026; Ünal et al., 2026). Comparisons based only on the labels conventional, milled, or printed therefore provide an incomplete description of the material and workflow being evaluated. A clinically meaningful assessment should consider several outcomes together. Retention and stability describe how the denture behaves on its supporting tissues; mucosal findings provide information about tissue response; functional tests and patient-reported measures address different aspects of daily use; and fractures, tooth debonding, adjustments, relining, repairs, and replacement provide information about serviceability over time (Kim et al., 2021; Srinivasan et al., 2021b; Keeling et al., 2025; Minami et al., 2004; Gibreel et al., 2024).

The review distinguishes three related but separate levels of evidence: properties measured in the material itself, the behavior of the completed denture, and outcomes reported by patients. Standardized laboratory tests characterize material properties, clinical measurements evaluate prosthesis performance, and patient-reported instruments capture aspects of experience and oral-health impact. These levels inform one another, but they are not interchangeable (International Organization for Standardization, 2013; Maniewicz et al., 2024; Iwaki et al., 2024).

12.2 Priorities for future research

Future studies should connect standardized laboratory testing with prospectively recorded clinical outcomes. Priorities include repeated loading, long-term aging of denture-base resins, repair durability, mucosal response, microbial colonization under standardized hygiene conditions, maintenance requirements, tooth–base bonding and reline-interface durability, and patient-reported outcomes. Transparent formulations particularly require prospective evaluation of optical stability, stain resistance, and patient-rated appearance over longer periods of use, because the current evidence is dominated by laboratory comparisons and case reports (Sushma et al., 2016; Sushma et al., 2018; Gad et al., 2021; Gad et al., 2022b; Lawson et al., 2026).

13. CONCLUSIONS

Denture base resins contribute to the fit, structural behavior, tissue interaction, appearance, and serviceability of complete dentures. These outcomes are influenced by resin formulation, polymerization, manufacturing and post-processing, denture design, surface condition, and the integrity of interfaces between prosthetic components. Laboratory tests are essential for characterizing mechanical, physical, chemical, and biological properties, but no single test demonstrates superior clinical performance. Clinical assessment should also consider adaptation and retention, tissue response, chewing and speech, patient-reported outcomes, technical complications, and maintenance. Favorable results have been reported for specific conventional, milled, and printed materials in particular areas of performance. However, differences between resin formulations and processing protocols, together with mixed clinical findings, mean that none of the three manufacturing methods can be ranked as universally superior. Material selection should be based on evidence for the specific resin and fabrication protocol, as well as the patient's functional needs, anatomy, aesthetic preferences, and likely maintenance requirements. Transparent denture bases

may offer an aesthetic option for selected patients. In vitro comparisons of particular clear and pigmented formulations have generally found no statistically significant differences in the properties measured, although lower hardness values have been observed for clear acrylic without a demonstrated significant pairwise difference. The clinical use of clear acrylic in definitive complete dentures is documented mainly in case reports, and comparative long-term clinical evidence remains limited. As with conventional pigmented bases, definitive transparent bases need to be assessed for chemical composition, tissue compatibility, structural performance, optical stability, and maintenance requirements. Overall, the evidence supports selecting denture base materials according to the properties of the specific resin and the needs of the completed prosthesis.

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AUTHOR CONTRIBUTIONS

Neada Hysenaj: Conceptualization, Methodology, Investigation, Writing—Original Draft, and Supervision.

Belisa Kaleci: Investigation, Data Curation, and Writing—Review & Editing.

Eni Jani: Investigation, Data Curation, and Writing—Review & Editing.

Xhanina Lulaj: Investigation, Formal analysis, and Writing—Review & Editing.

Desara Zazaj: Investigation, Formal analysis, and Writing—Review & Editing.

Vergjini Mulo: Investigation, Validation, and Writing—Review & Editing.

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REFERENCES

[1] Aati, S., Akram, Z., Shrestha, B., et al., 2022. Effect of post-curing light exposure time on the physico-mechanical properties and cytotoxicity of 3D-printed denture base material. Dent Mater 38(1), 57–67. https://doi.org/10.1016/j.dental.2021.10.011

[2] Ahmed Teama, E.M., Amin Rashad, H.M., Mohamed Shakal, E.A.E., et al., 2025. Clinical and microbial study of reinforced 3D-printed maxillary denture base resin: a randomized trial. BMC Oral Health 25, 1192. https://doi.org/10.1186/s12903-025-06601-2

[3] Al Kaba, E., Alfaraj, A., Chu, T.-M.G., et al., 2026. Comparison of tooth fracture load between different conventional and CAD-CAM denture base materials. J Prosthodont. Published online 7 July 2026. https://doi.org/10.1111/jopr.70187

[4] Al-Dulaijan, Y.A., Alsulaimi, L., Alotaibi, R., et al., 2022. Comparative evaluation of surface roughness and hardness of 3D-printed resins. Materials (Basel) 15(19), 6822. https://doi.org/10.3390/ma15196822

[5] Al-Dwairi, Z.N., Tahboub, K.Y., Baba, N.Z., et al., 2019. A comparison of the surface properties of CAD/CAM and conventional polymethylmethacrylate (PMMA). J Prosthodont 28(4), 452–457. https://doi.org/10.1111/jopr.13033

[6] Al-Dwairi, Z.N., Tahboub, K.Y., Baba, N.Z., et al., 2020. A comparison of the flexural and impact strengths and flexural modulus of CAD/CAM and conventional heat-cured polymethyl methacrylate (PMMA). J Prosthodont 29(4), 341–349. https://doi.org/10.1111/jopr.12926

[7] Albazroun, Z., Aldobais, F.A., Aldehaileb, S., et al., 2026. The effect of different surface treatment on shear bond strength of soft and hard liners to CAD-CAM and conventional denture base resins: in vitro comparative study. Front Dent Med 7, 1736153. https://doi.org/10.3389/fdmed.2026.1736153

[8] Alfouzan, A.F., Alotiabi, H.M., Labban, N., et al., 2021. Color stability of 3D-printed denture resins: effect of aging, mechanical brushing and immersion in staining medium. J Adv Prosthodont 13(3), 160–171. https://doi.org/10.4047/jap.2021.13.3.160

[9] AlHelal, A., AlRumaih, H.S., Kattadiyil, M.T., et al., 2017. Comparison of retention between maxillary milled and conventional denture bases: a clinical study. J Prosthet Dent 117(2), 233–238. https://doi.org/10.1016/j.prosdent.2016.08.007

[10] Aliyeva, N., Ürün, M.N., Polat, S., 2026. Mechanical and surface properties of PMMA denture base resins fabricated by compression molding, fluid resin, milling, and 3D printing techniques. BMC Oral Health. Published online 5 September 2026. https://doi.org/10.1186/s12903-026-09796-0

[11] Arora, O., Ahmed, N., Nallaswamy, D., et al., 2024. Denture base materials: An in vitro evaluation of the mechanical and color properties. J Dent 145, 104993. https://doi.org/10.1016/j.jdent.2024.104993

[12] Artopoulos, A., Juszczyk, A.S., Rodriguez, J.M., et al., 2013. Three-dimensional processing deformation of three denture base materials. J Prosthet Dent 110(6), 481–487. https://doi.org/10.1016/j.prosdent.2013.07.005

[13] Azab, A., Abdelhady, W.A., Elwakeel, E., et al., 2025. Systematic review and meta-analysis of mechanical properties of 3D printed denture bases compared to milled and conventional materials. Sci Rep 15, 29207. https://doi.org/10.1038/s41598-025-14288-2

[14] Bayraktar, G., Guvener, B., Bural, C., et al., 2006. Influence of polymerization method, curing process, and length of time of storage in water on the residual methyl methacrylate content in dental acrylic resins. J Biomed Mater Res B Appl Biomater 76(2), 340–345. https://doi.org/10.1002/jbm.b.30377

[15] Cimpan, M.R., Cressey, L.I., Skaug, N., et al., 2000. Patterns of cell death induced by eluates from denture base acrylic resins in U-937 human monoblastoid cells. Eur J Oral Sci 108(1), 59–69. https://doi.org/10.1034/j.1600-0722.2000.00730.x

[16] Clark, W.A., Brazile, B., Matthews, D., et al., 2021. A comparison of conventionally versus digitally fabricated denture outcomes in a university dental clinic. J Prosthodont 30(1), 47–50. https://doi.org/10.1111/jopr.13273

[17] Cristache, C.M., Totu, E.E., Iorgulescu, G., et al., 2020. Eighteen months follow-up with patient-centered outcomes assessment of complete dentures manufactured using a hybrid nanocomposite and additive CAD/CAM protocol. J Clin Med 9(2), 324. https://doi.org/10.3390/jcm9020324

[18] da Silva, M.D.D., Nunes, T.S.B.S., Viotto, H.E.C., et al., 2023. Microbial adhesion and biofilm formation by Candida albicans on 3D-printed denture base resins. PLoS One 18(10), e0292430. https://doi.org/10.1371/journal.pone.0292430

[19] Dabas, N., Phukela, S.S., Yadav, H., 2011. The split denture: managing xerostomia in denture patients: a case report. J Indian Prosthodont Soc 11(1), 67–70. https://doi.org/10.1007/s13191-011-0056-y

[20] Darvell, B.W., Clark, R.K.F., 2000. The physical mechanisms of complete denture retention. Br Dent J 189(5), 248–252. https://doi.org/10.1038/sj.bdj.4800734

[21] Del Hougne, M., Mitzscherling, A., Ewald, A., et al., 2026. In vitro biofilm formation on 3D-printed, milled, and conventionally manufactured denture base resins. Bioengineering (Basel) 13(4), 424. https://doi.org/10.3390/bioengineering13040424

[22] Deng, K., Wang, Y., Zhou, Y., et al., 2023. Comparison of treatment outcomes and time efficiency between a digital complete denture and conventional complete denture: a pilot study. J Am Dent Assoc 154(1), 32–42. https://doi.org/10.1016/j.adaj.2022.09.016

[23] Diaz-Arnold, A.M., Vargas, M.A., Shaull, K.L., et al., 2008. Flexural and fatigue strengths of denture base resin. J Prosthet Dent 100(1), 47–51. https://doi.org/10.1016/S0022-3913(08)60136-5

[24] Diemer, I., Hahnel, S., Rosentritt, M., et al., 2026. Bond strength of denture teeth to denture bases in CAD/CAM-milled, printed, and conventional fabrication techniques. Quintessence Int 57(2), 106–113. https://doi.org/10.3290/j.qi.b6740653

[25] Elazzouni, D.H.M., Zafar, M.S., Alkhureif, A.A., et al., 2026. Physicochemical and mechanical comparison of denture base materials after artificial aging. BMC Oral Health 26, 1557. https://doi.org/10.1186/s12903-026-08745-1

[26] Elsarrif, H.R., Elawady, A.F., Refai, O.M., 2026. Assessment of microbial adherence and patient satisfaction with conventional and digital 3D-printed complete removable dentures: a crossover randomized controlled clinical trial. J Prosthodont 35(1), 37–46. https://doi.org/10.1111/jopr.70017

[27] Emera, R.M.K., Shady, M., Alnajih, M.A., 2022. Comparison of retention and denture base adaptation between conventional and 3D-printed complete dentures. J Dent Res Dent Clin Dent Prospects 16(3), 179–185. https://doi.org/10.34172/joddd.2022.030

[28] Emera, R.M.K., Al Sultani, Z.F., Mahanna, F.F., 2025. Comparison of patients' oral health-related quality of life and chewing efficiency between conventional and 3D-printed complete dentures: a crossover clinical trial. J Dent Res Dent Clin Dent Prospects 19(4), 233–241. https://doi.org/10.34172/joddd.025.44430

[29] Faot, F., da Silva, W.J., da Rosa, R.S., et al., 2009. Strength of denture base resins repaired with auto- and visible light-polymerized materials. J Prosthodont 18(6), 496–502. https://doi.org/10.1111/j.1532-849X.2009.00470.x

[30] Fortes, C.B.B., Collares, F.M., Leitune, V.C.B., et al., 2017. Influence of dye and nylon fibers on microwave-cured acrylic resin properties. RGO Rev Gaúch Odontol 65(1), 8–12. https://doi.org/10.1590/1981-86372017000100013150

[31] Fouda, S.M., Gad, M.M., Abualsaud, R., et al., 2023. Flexural properties and hardness of CAD-CAM denture base materials. J Prosthodont 32(4), 318–324. https://doi.org/10.1111/jopr.13535

[32] Fouda, S.M., Gad, M.M., Abualsaud, R., et al., 2024. In vitro evaluation of Candida albicans adhesion and related surface properties of CAD/CAM denture base resins. Eur J Dent 18(2), 579–586. https://doi.org/10.1055/s-0043-1774319

[33] Gad, M.M., Abualsaud, R., Alqarawi, F.K., et al., 2021. Translucency of nanoparticle-reinforced PMMA denture base material: An in-vitro comparative study. Dent Mater J 40(4), 972–978. https://doi.org/10.4012/dmj.2020-296

[34] Gad, M.M., Fouda, S.M., Abualsaud, R., et al., 2022a. Strength and surface properties of a 3D-printed denture base polymer. J Prosthodont 31(5), 412–418. https://doi.org/10.1111/jopr.13413

[35] Gad, M.M., Alshehri, S.Z., Alhamid, S.A., et al., 2022b. Water sorption, solubility, and translucency of 3D-printed denture base resins. Dent J (Basel) 10(3), 42. https://doi.org/10.3390/dj10030042

[36] Gibreel, M., Perea-Lowery, L., Garoushi, S., et al., 2024. Effect of different surface treatments on shear bond strength of autopolymerizing repair resin to denture base materials processed with different technologies. J Prosthodont Res 68(4), 549–557. https://doi.org/10.2186/jpr.JPR_D_23_00149

[37] Huang, F.M., Tai, K.W., Hu, C.C., et al., 2001. Cytotoxic effects of denture base materials on a permanent human oral epithelial cell line and on primary human oral fibroblasts in vitro. Int J Prosthodont 14(5), 439–443. PMID: 12066639.

[38] International Organization for Standardization, 2013. ISO 20795-1:2013. Dentistry—Base polymers—Part 1: Denture base polymers. Geneva: ISO.

[39] Iwaki, M., Akiyama, Y., Qi, K., et al., 2024. Oral health-related quality of life and patient satisfaction using three-dimensional printed dentures: a crossover randomized controlled trial. J Dent 150, 105338. https://doi.org/10.1016/j.jdent.2024.105338

[40] Kang, Y.J., Oh, K.C., Kim, G.Y., et al., 2024. Comparative evaluation of digitally fabricated complete dentures versus conventional complete dentures: a randomized, single-blinded, cross-over clinical trial. J Prosthet Dent 132(2), 408–418. https://doi.org/10.1016/j.prosdent.2022.05.013

[41] Kattadiyil, M.T., Jekki, R., Goodacre, C.J., et al., 2015. Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting. J Prosthet Dent 114(6), 818–825. https://doi.org/10.1016/j.prosdent.2015.08.001

[42] Keeling, A., Osnes, C., Davda, K., et al., 2025. A pilot randomised controlled trial to compare 3D-printed versus conventionally fabricated complete dentures. Eur J Prosthodont Restor Dent 33(4), 370–378. https://doi.org/10.1922/EJPRD_2835Keeling09

[43] Khan, S., Musani, S., Godil, A., et al., 2026. In-vitro comparison of residual monomer content and water sorption of printed, milled and conventional heat-cured poly methylmethacrylate denture base resin. Int J Prosthodont. Published online 19 August 2026. https://doi.org/10.11607/ijp.9459

[44] Kim, T.H., Huh, J.B., Lee, J., et al., 2021. Retrospective comparison of post-insertion maintenances between conventional and 3D-printed complete dentures fabricated in a predoctoral clinic. J Prosthodont 30(S2), 158–162. https://doi.org/10.1111/jopr.13322

[45] Kostoulas, I., Kavoura, V.T., Frangou, M.J., et al., 2008. Fracture force, deflection, and toughness of acrylic denture repairs involving glass fiber reinforcement. J Prosthodont 17(4), 257–261. https://doi.org/10.1111/j.1532-849X.2007.00276.x

[46] Koujan, A., Aggarwal, H., Chen, P.H., et al., 2023. Evaluation of Candida albicans adherence to CAD-CAM milled, 3D-printed, and heat-cured PMMA resin and efficacy of different disinfection techniques: an in vitro study. J Prosthodont 32(6), 512–518. https://doi.org/10.1111/jopr.13583

[47] Koutis, D., Freeman, S., 2001. Allergic contact stomatitis caused by acrylic monomer in a denture. Australas J Dermatol 42(3), 203–206. https://doi.org/10.1046/j.1440-0960.2001.00517.x

[48] Lawson, N.C., Safadi, Y., Alford, A., et al., 2026. Flexural strength, fracture toughness, translucency, stain resistance, and water sorption of 3D-printed, milled, and conventional denture base materials. J Prosthodont 35(4), 553–560. https://doi.org/10.1111/jopr.13955

[49] Li, P., Lambart, A.L., Stawarczyk, B., et al., 2021. Postpolymerization of a 3D-printed denture base polymer: impact of post-curing methods on surface characteristics, flexural strength, and cytotoxicity. J Dent 115, 103856. https://doi.org/10.1016/j.jdent.2021.103856

[50] Lung, C.Y.K., Darvell, B.W., 2005. Minimization of the inevitable residual monomer in denture base acrylic. Dent Mater 21(12), 1119–1128. https://doi.org/10.1016/j.dental.2005.03.003

[51] Maniewicz, S., Imamura, Y., El Osta, N., et al., 2024. Fit and retention of complete denture bases: Part I—Conventional versus CAD-CAM methods: A clinical controlled crossover study. J Prosthet Dent 131(4), 611–617. https://doi.org/10.1016/j.prosdent.2022.07.006

[52] Mann, R.S., Ruse, N.D., 2022. Fracture toughness of conventional, milled and 3D-printed denture bases. Dent Mater 38(9), 1443–1451. https://doi.org/10.1016/j.dental.2022.06.029

[53] Minami, H., Suzuki, S., Minesaki, Y., et al., 2004. In vitro evaluation of the influence of repairing condition of denture base resin on the bonding of autopolymerizing resins. J Prosthet Dent 91(2), 164–170. https://doi.org/10.1016/j.prosdent.2003.10.023

[54] Nejatidanesh, F., Savabi, O., Khodaei, M., et al., 2026. Comparative evaluation of surface properties of milled, 3D-printed, and conventional denture base materials: Implications for clinical use. Int J Prosthodont 39(4), 569–575. https://doi.org/10.11607/ijp.9285

[55] Neshandar Asli, H., Rahimabadi, S., Babaee Hemmati, Y., et al., 2021. Effect of different surface treatments on surface roughness and flexural strength of repaired 3D-printed denture base: an in vitro study. J Prosthet Dent 126(4), 595.e1–595.e8. https://doi.org/10.1016/j.prosdent.2021.07.005

[56] Nevzatoğlu, E.U., Ozcan, M., Kulak-Ozkan, Y., et al., 2007. Adherence of Candida albicans to denture base acrylics and silicone-based resilient liner materials with different surface finishes. Clin Oral Investig 11(3), 231–236. https://doi.org/10.1007/s00784-007-0106-3

[57] Ohara, K., Isshiki, Y., Hoshi, N., et al., 2022. Patient satisfaction with conventional dentures vs. digital dentures fabricated using 3D-printing: a randomized crossover trial. J Prosthodont Res 66(4), 623–629. https://doi.org/10.2186/jpr.JPR_D_21_00048

[58] Osman, R.B., Khoder, G., Fayed, B., et al., 2023. Influence of fabrication technique on adhesion and biofilm formation of Candida albicans to conventional, milled, and 3D-printed denture base resin materials: a comparative in vitro study. Polymers (Basel) 15(8), 1836. https://doi.org/10.3390/polym15081836

[59] Peampring, C., Sanohkan, S., Rojanarat, P., et al., 2026. Evaluating patient satisfaction and oral health impact profile-14 (OHIP-14): a multicenter crossover study comparing selective pressure impression conventional dentures with mucostatic digital dentures. Int J Prosthodont 39(7), 127–133. https://doi.org/10.11607/ijp.9519

[60] Pereira, A.K.D.H.C., Costa, R.T.F., Leão, R.D.S., et al., 2026. Effectiveness of different surface treatments on bond strength between 3D-printed teeth and denture base. J Prosthodont 35(8), 1281–1289. https://doi.org/10.1111/jopr.13941

[61] Pfeiffer, P., Rosenbauer, E.U., 2004. Residual methyl methacrylate monomer, water sorption, and water solubility of hypoallergenic denture base materials. J Prosthet Dent 92(1), 72–78. https://doi.org/10.1016/j.prosdent.2004.04.003

[62] Phoenix, R.D., Mansueto, M.A., Ackerman, N.A., et al., 2004. Evaluation of mechanical and thermal properties of commonly used denture base resins. J Prosthodont 13(1), 17–27. https://doi.org/10.1111/j.1532-849X.2004.04002.x

[63] Polat, T.N., Karacaer, O., Tezvergil, A., et al., 2003. Water sorption, solubility and dimensional changes of denture base polymers reinforced with short glass fibers. J Biomater Appl 17(4), 321–335. https://doi.org/10.1177/0885328203017004006

[64] Rana, M.H., Shaik, S., Hameed, M.S., et al., 2021. Influence of dental glass fibers and orthopedic mesh on the failure loads of polymethyl methacrylate denture base resin. Polymers (Basel) 13(16), 2793. https://doi.org/10.3390/polym13162793

[65] Rechlin, J., Beuer, F., Nicic, R., et al., 2026. Clinical performance and patients' satisfaction of digitally versus conventionally fabricated dentures: a randomized controlled pilot study. Dent J (Basel) 14(4), 221. https://doi.org/10.3390/dj14040221

[66] Ribeiro, A.K.C., Veríssimo, A.H., Porto de Freitas, R.F.C., et al., 2026. Functional and patient-reported outcomes of 3-dimensional-printed vs conventionally fabricated complete dentures: a randomized crossover clinical trial. J Am Dent Assoc. Published online 2 July 2026. https://doi.org/10.1016/j.adaj.2026.03.027

[67] Sivaswamy, V., Cahyanto, A., Varma, S.R., Matinlinna, J.P., 2026. Clinical outcomes of 3D printed complete dentures: a systematic review and meta-analysis. J Prosthet Dent 136(1), 60–68. https://doi.org/10.1016/j.prosdent.2026.02.003

[68] Srinivasan, M., Kalberer, N., Kamnoedboon, P., et al., 2021a. CAD-CAM complete denture resins: an evaluation of biocompatibility, mechanical properties, and surface characteristics. J Dent 114, 103785. https://doi.org/10.1016/j.jdent.2021.103785

[69] Srinivasan, M., Kalberer, N., Fankhauser, N., et al., 2021b. CAD-CAM complete removable dental prostheses: a double-blind, randomized, crossover clinical trial evaluating milled and 3D-printed dentures. J Dent 115, 103842. https://doi.org/10.1016/j.jdent.2021.103842

[70] Srinivasan, M., Chien, E.C., Kalberer, N., et al., 2022. Analysis of the residual monomer content in milled and 3D-printed removable CAD-CAM complete dentures: an in vitro study. J Dent 120, 104094. https://doi.org/10.1016/j.jdent.2022.104094

[71] Steinmassl, P.A., Wiedemair, V., Huck, C., et al., 2017. Do CAD/CAM dentures really release less monomer than conventional dentures? Clin Oral Investig 21(5), 1697–1705. https://doi.org/10.1007/s00784-016-1961-6

[72] Steinmassl, O., Dumfahrt, H., Grunert, I., et al., 2018. CAD/CAM produces dentures with improved fit. Clin Oral Investig 22(8), 2829–2835. https://doi.org/10.1007/s00784-018-2369-2

[73] Sushma, R., Farias, A., Khandagale, T.S., et al., 2016. Use of heat cure clear acrylic as a permanent denture base material: a case report. J Res Dent 4(3), 86–89. https://doi.org/10.19177/jrd.v4e3201686-89

[74] Sushma, R., Vande, A.V., Malvika, S.R., et al., 2018. A comparative study of the mechanical properties of clear and pink colored denture base acrylic resins. Ann Afr Med 17(4), 178–182. https://doi.org/10.4103/aam.aam_65_17

[75] Ünal, M., Çelikkol, O., Güler, E., 2026. Comparison of surface properties, microhardness, and tensile bond strength of conventional, milled, and 3D-printed denture base materials: An in vitro study. BMC Oral Health. Published online 20 August 2026. https://doi.org/10.1186/s12903-026-09664-x

[76] Yesil Duymus, Z., Ozdogan, A., Ulu, H., Ozbayram, O., 2016. Evaluation the Vickers hardness of denture base materials. Open J Stomatol 6(4), 114–119. https://doi.org/10.4236/ojst.2016.64014

[77] Yoon, S.N., Oh, K.C., Lee, S.J., et al., 2020. Tissue surface adaptation of CAD-CAM maxillary and mandibular complete denture bases manufactured by digital light processing: a clinical study. J Prosthet Dent 124(6), 682–689. https://doi.org/10.1016/j.prosdent.2019.11.007

[78] Yu, H.J., Kang, Y.J., Park, Y., et al., 2024. A comparison of the mechanical properties of 3D-printed, milled, and conventional denture base resin materials. Dent Mater J 43(6), 813–821. https://doi.org/10.4012/dmj.2024-080

[79] Zidan, S., Silikas, N., Haider, J., et al., 2020. Evaluation of equivalent flexural strength for complete removable dentures made of zirconia-impregnated PMMA nanocomposites. Materials (Basel) 13(11), 2580. https://doi.org/10.3390/ma13112580

[80] Zupancic Cepic, L., Gruber, R., Eder, J., et al., 2023. Digital versus conventional dentures: a prospective, randomized cross-over study on clinical efficiency and patient satisfaction. J Clin Med 12(2), 434. https://doi.org/10.3390/jcm12020434