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SYSTEMATIC REVIEW

Influence of aging and manufacturing techniques on the physical and mechanical stability of occlusal device materials: A systematic review

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ABSTRACT

Statement of problem. Computer-aided design and computer-aided manufacturing (CAD-CAM) has introduced alternatives to the conventional fabrication of occlusal devices, though data on their physical, mechanical, and long-term durability remain limited.

Purpose. The purpose of this systematic review was to assess the stability of the physical and mechanical properties of occlusal device materials subjected to degradation.

Material and methods. This review was registered in the open science framework (OSF) (osf.io/rjgs6) and involved 8 databases and nonpeer-reviewed sources, supplemented by manual screening. Independent study selection followed predefined criteria, and the risk of bias was assessed with the RoBDEMAT tool.

Results. Across 21 studies, milled composite resins outperformed 3-dimensionally (3D) printed and heat-polymerized or autopolymerized polymethyl methacrylate (PMMA) under artificial degradation, with printing and postpolymerization parameters influencing the physicomechanical stability of 3D printed composite resins.

Conclusions. Milled materials exhibited the greatest stability, heat-polymerized PMMA demonstrated intermediate performance, and autopolymerized resins performed the worst. Despite greater degradation susceptibility, advances in formulation and postprocessing suggest promising potential for 3D printed resins. (J Prosthet Dent 2026;136:69-80)

Occlusal devices are conservative and reversible interventions that are frequently used as initial management for temporomandibular disorders (TMDs) and parafunctional habits such as bruxism.[1–3] Their effectiveness is based on neuromuscular reprogramming, retrodiscal decompression, and orofacial protection,[4] promoting condyle-disc alignment,[1,2,5] pain relief, dental protection, and the functional stabilization of the stomatognathic system.[6–8] Clinical effectiveness relies on supervised use, periodic adjustments,[5] and the use of durable materials to ensure long-term clinical performance.[9–14]

Different materials and techniques have been used for the fabrication of these devices, including composite resins based on urethane dimethacrylate (UDMA), polymethyl methacrylate (PMMA), or polyamides, selected according to the clinical indication.[5,6,15] Conventional techniques involve material processing through injection, thermoforming, or muffle polymerization.[3,9–11] Rigid materials have been preferred for their dimensional stability, retention, and ease of repair.[6] However, a meta-analysis[16] reported no significant

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Clinical Implications

Digital workflows using computer-aided design and computer-aided manufacturing (CAD-CAM) compatible materials have been well established for the fabrication of occlusal devices. However, understanding the combined effects of different aging methodologies may help link in vitro degradation to clinical longevity.

differences in masticatory function or orofacial pain relief between rigid and flexible devices. PMMA stands out for its low cost and technical simplicity but has limitations such as polymerization shrinkage, dimensional instability, and porosity.[5,6]

With computer-aided design and computer-aided manufacturing (CAD-CAM) technology, polymer-based composite resins have been incorporated into digital workflows through additive (AM) and subtractive manufacturing (SM), offering greater efficiency, predictability, standardization,[7,17,18] and fewer postfabrication adjustments.[19] Subtractively manufactured composite resins have been reported to exhibit better mechanical properties compared with 3-dimensionally (3D) printed materials,[3,20] largely associated with industrial polymerization,[3] which may enhance physicomechanical stability and contribute to improved treatment adherence and clinical longevity.[4,5,17] The durability of polymeric materials depends on intrinsic factors, such as chemical composition and degree of crosslinking,[17,21–23] as well as extrinsic factors, including oral environment exposure, functional and parafunctional loads, patient habits, and hygiene protocols.[1,2,21,24]

In vitro studies have provided methodological strategies for understanding the degradation mechanisms of dental materials, as they enable controlled and reproducible simulation of oral conditions[6,7,9,10,24] using chemical, physical, mechanical, and hygiene-related aging protocols.[9–11,14,25–28] However, the multifactorial and synergistic nature of oral degradation, driven by thermal, chemical, mechanical, and biological interactions[29] has limited direct extrapolation of in vitro findings to clinical outcomes, as physiological variables, such as pH, temperature, saliva, and mechanical loads, interact synergistically and nonlinearly.[29,30]

Artificial aging methodologies frequently simulate surface wear,[9,10,12,25–27,29,31,32] including 2-body wear associated with parafunctional solid-to-solid contact,[12,25–27,31,33,34] and 3-body wear, which more closely reproduces physiological mastication.[9,29,33] Abrasive wear has been commonly simulated using brushing cycles with dentifrices,[11,21,24,28] while functional stresses have been reproduced through compressive, tensile, and shear loading.[24] Chemical stability and discoloration susceptibility have been assessed via immersion in aqueous solutions, artificial saliva, or staining media, reflecting hydrolytic degradation and dye diffusion.[14,21,27,28,30,32,35,36] Combining multiple aging protocols may better approximate clinical conditions and improve predictions of material durability.

Previous evidence, however, suggests similar wear behavior among thermopolymerized, milled, and 3D printed polymers, outperforming thermoformed materials.[37] Considering that physicomechanical stability is a key determinant of the clinical longevity of occlusal devices[4] and that diverse degradation methodologies have been applied,[9,11,24,30] a systematic review comparing different aging protocols when assessing the physicomechanical properties of occlusal device materials is lacking. Therefore, this review aimed to identify materials with superior physicomechanical performance under degradation. The null hypothesis was that subtractively manufactured and 3D printed composite resins would not outperform conventionally processed polymers.

MATERIAL AND METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[38] and registered in the Open Science Framework (OSF). The population, intervention, comparison, outcome, and study design (PICOS) framework included occlusal devices, degradation, different materials, physicomechanical properties, and experimental studies.

Searches were performed in the Embase, LILACS, PubMed, ScienceDirect, Scopus, and Web of Science databases, as well as in nonpeer-reviewed literature (Google Scholar and ProQuest) in April 2025. The search strategy was customized (Supplemental Table 1, available online), with no restrictions on publication date or language. Reference lists of selected studies were also screened. Study selection was manually conducted by independent reviewers (V.M.S., J.D.C.T., J.M.C.S., I.F.). Studies evaluating the effects of different degradation methodologies on the physical and mechanical properties of materials used for occlusal devices were included, as detailed in Table 1. Studies without material comparisons, using materials not intended for occlusal devices or of secondary nature, were excluded.

Duplicate references were identified using software tools (EndNote; Clarivate Analytics, Rayyan; Qatar Computing Research Institute). Titles and abstracts were screened, followed by full-text assessment. Disagreements were resolved by consensus with an additional reviewer (M.L.C.V.). Cohen kappa (κ) analysis was performed to assess interrater agreement, demonstrating high concordance for screening (κ=.84), full-text selection (κ=.96), and risk of bias assessment (κ=.93).[39] Two independent authors (L.P.O., A.C.R.)

Table 1. Main methodological characteristics of articles included

Authors, Year	Groups	Aging Method	Physical Properties	Mechanical Properties
Ateş et al, 2024	HP (Castdon Transparent; Dreve Dentamid GmbH); 3DP at 0 degrees (Dental LT Clear Resin v2, Formlabs), 3DP at 45 degrees (Dental LT Clear Resin v2, Formlabs); 3DP at 90 degrees (Dental LT Clear Resin v2, Formlabs); SM (bre.CAM Splint, bredent GmbH & Co KG); PEEK (BioHPP, bredent GmbH & Co KG)	Two-body thermo-mechanical	Volume loss, Wear	-
Berli et al, 2020	AP (ProBase Cold, Ivoclar AG); AP (Palapress Clear, Kulzer GmbH); AP (Esthetic Blue Clear, Candulor); SM (Temp Premium Flexible Transpa, Zirkonzahn); SM (Idodentine PMMA Transparent, UniÓn Dental S.A); SM (Yamahachi PMMA Clear, Yamahachi Dental MFG); 3DP (Freeprint Splint, DETAX GmbH); (8) 3DP (LuxaPrint Ortho Plus, DMG GmbH); 3DP (NextDent Ortho Clear, Vertex-Dental B.V.)	Thermal	Sorption and solubility	Flexural strength, Martens and Vickers hardness
Carvalho-Silva et al, 2025	AP (HR Clear, TDV), and 3DP (Cosmos Splint PR, Yller Biomateriais SA)	Simulated toothbrushing	Surface roughness	Knoop hardness
Domanic et al, 2020	HP (SR Ivocap Heat-Polymerized, Ivoclar AG); TP (Valplast, Valplast International Corp.); Flexible TP (SR Ivocap Elastomer, Ivoclar AG); LP (Eclipse, Dentsply International)	Two-body thermo-mechanical	Volume loss	-
ElGndy et al, 2023	HP (Dental Yellow Clear, Harz Lab); HP (Rapid Simplified Heat-Polymerized Clear Acrylic Resin, Vertex-Dental B.V.); TP (Crystal Plate, Bioart)	Two-body mechanical	Surface roughness, Volume loss.	-
Gibreel et al, 2021	SM (ProArt CAD Splint, Ivoclar AG); SM (Therapon Transpa, Zirkonzahn); SM (Temp Premium Flexible Transpa, Zirkonzahn); SM (Cast, Degos Dental GmbH); SM (Aqua, Dental GmbH); AP (Palapress, Kulzer GmbH); AP (Paladon 65, Kulzer GmbH)	Storage (Dry/distilled water)	Sorption and solubility	Flexural strength, Elastic modulus, Vickers hardness, Fracture toughness, and Fracture work
Gibreel et al, 2022	AP (Paladon 65, Kulzer GmbH); AP (Palapress, Kulzer GmbH); SM (Cast, Degos Dental); SM (Aqua, Degos Dental); 3DP (Temp Premium Flexible Transpa, Zirkonzahn); 3DP (IMPRIMO LC Splint, Scheu-Dental); 3DP (IMPRIMO LC Splint Flex, Scheu-Dental); 3DP (KeySplint Soft, Keystone); 3DP (V-Print Splint Comfort, VOCO)	Two-body mechanical	Surface roughness, Volume loss	Vickers hardness
Grymak et al, 2022	HP (Vertez Rapid Simplified, Vertex); SM (Ceramill a-splint, Amann Girrbach AG); 3DP at 0 degrees (Freeprint Ortho, Detax); (3.2) 3DP printed at 45 degrees (Freeprint Ortho, Detax); 3DP printed at 90 degrees (Freeprint Ortho, Detax); 3DP printed at 0 degrees (KeySplint Soft, Keystone); 3DP printed at 45 degrees (KeySplint Soft, Keystone); 3DP printed at 90 degrees (KeySplint Soft, Keystone); 3DP printed at 0 degrees (DentalClear, Asiga); 3DP printed at 45 degrees (DentalClear, Asiga); 3DP printed at 90 degrees (DentalClear, Asiga); 3DP printed at 0 degrees (FreePrint Splint, Detax); 3DP printed at 45 degrees (FreePrint Splint, Detax); 3DP printed at 90 degrees (FreePrint Splint, Detax)	Two-body mechanical	Volume loss, Vertical loss, Surface area, Surface morphology, and Surface roughness	-
Hickl et al, 2022	HP (Palapress Vario, Kulzer); TP (Erkodur-al, Erkodent); SM (Optimill Crystal Clear, Dentona); 3DP (Splint Flex, VOCO); 3DP (V-Print, VOCO)	Storage in demineralized water, coffee (Cafet, Netto), red wine (Red Wine Sweet), cleaning tablets (Kukident Active Plus, Kukident), and simulated toothbrushing	Surface roughness, Scratch depth.	-
Lutz et al, 2019	3DP (FotoDent Splint, Dreve Dentamid GmbH); SM (Temp Basic Transpa, Zirkonzahn GmbH); HP (Castdon, Dreve Dentamid GmbH)	Two-body mechanical	-	Fracture strength
Maleki et al, 2024	3DP (GR-22 Flex, Pro3dure Medical); 3DP (GR-10 Guide, Pro3dure Medical); 3DP (ProArt Print Splint Clear, Ivoclar AG); 3DP (V-Print Splint, VOCO); 3DP (V-Print Splint Comfort, VOCO); SM (BioniCut, bredent); SM (EldyPlus, DentalPlus); SM (ProArt CAD, Ivoclar AG); SM (Temp Premium Flexible, Zirkonzahn); SM (Thermeo, Pro3dure Medical); HP (PalaXPress Clear, Kulzer GmbH); HP (Pro Base Cold, Ivoclar AG)	Storage aging (deionized water for 24 h or 90 days); Thermal	-	Flexural strength, Elastic modulus, and Martens hardness
Patzelt et al, 2022	AP (ProBase Cold, Ivoclar AG); SM (inCoris PMMA Guide, Dentsply Sirona)	Two-body thermo-mechanical	-	Wear resistance
Raffaini et al, 2023	3DP (Cosmos Splint, Yller); SM (Vipi Block, VIPI); HP (Heat-Polymerized Acrylic, ClÁssico Artigos OdontolÓgicos)	Simulated toothbrushing	Color stability, Surface roughness	Flexural strength
Rosello Jimenez et al, 2023	SM (Clear Splint Disc, Astron Dental Corporation); 3DP (KeyPrint, Keystone Industries); 3DP (Freeprint Splint 2.0, Detax GmbH & Co KG); 3DP (Luxaprint Ortho Plus, DMG GmbH); 3DP (V-Print Splint, VOCO GmbH)	Simulated toothbrushing; Storage (water at 21/37 °C / dry storage); Thermal	-	Tensile strength, Elastic modulus, and Vickers hardness

Table 1 (*Continued*)

Authors, Year	Groups	Aging Method	Physical Properties	Mechanical Properties
Rosentritt et al, 2023	AP (Palapress Vario Transparent, Kulzer); TP (Erkodur, Erkodent); SM (Optimill Crystal Clear, Dentona); 3DP (LuxaPrint Ortho Plus, DMG); 3DP (KeySplint Soft, Keystone Industries)	Storage (water/ coffee/ cleaning tablets (Kukident Active Plus, Kukident)/ Red wine/ Dry); Simulated toothbrushing	-	Vickers hardness, Martens hardness, Indentation hardness, Indentation modulus, Elastic work analysis of indentation, and Indentation creep
Santis et al, 2025	3DP (Dima Print Ortho, Kulzer); 3DP (SprintRay Splint, SprintRay); HP (Heat-Polymerized Acrylic, ClÁssico Artigos OdontolÓgicos)	Storage (deionized water/artificial saliva); Two-body mechanical	Dimensional change	Flexural strength, and Knoop hardness
Santos et al, 2023	AP (VipiFlash, VIPI); HP (VipiCril Plus, VIPI); 3DP (Cosmos Splint Clear, Yller Biomateriais)	Two-body thermo-mechanical	-	Flexural strength
Sousa et al, 2025	3DP (Prizma Biosplint, MakertechLabs); Microwave HP (Vaporwave, VIPI) + Sealant (Plaseal Sealant, Kulzer GmbH); HP (Vaporwave, VIPI) + silicone polishing tips containing aluminum oxide (Kit Ultra PA102030, DhPro); Microwave HP (Vaporwave, VIPI) + silicone polishing tips containing aluminum oxide (Kit Ultra PA102030, DhPro) + Sealant (Plaseal Sealant, Kulzer GmbH); Microwave HP (Vaporwave, VIPI) + TriHawk polishing protocol: Orange disk (TH ACR 300, Trihawk) + Pink disk (TH ACR 301 F, Trihawk); Microwave HP (Vaporwave, VIPI) + TriHawk polishing protocol: Orange disk (TH ACR 300, Trihawk) + Pink disk (TH ACR 301 F, Trihawk) + Sealant (Plaseal Sealant, Kulzer GmbH); Microwave HP (Vaporwave, VIPI)	Two-body thermo-mechanical	Surface Roughness	Vickers hardness
Väyrynen et al, 2016	Epoxy-based 3DP printed at 0 degrees (Somos WaterShed XC 11122, DSM); Epoxy-based 3DP printed at 45 degrees (Somos WaterShed XC 11122, DSM); 3DP printed at 90 degrees (Somos WaterShed XC 11122, DSM); AP (Palapress, Heraeus Kulzer GmbH)	Storage (dry/distilled water)	Sorption	Flexural strength, and Flexural modulus
Wesemann et al, 2021	HP (PalaXpress, Kulzer GmbH); SM (ProArt CAD Splint, Ivoclar AG); 3DP (Dental LT Clear, Formlabs Dental); 3DP (Dental LT Clear V2, Formlabs Dental); 3DP (V-Print Splint, VOCO)	Two-body thermo-mechanical	-	Vickers hardness, Flexural strength, and Elastic modulus
Weżgowiec et al, 2024	AP (Villacryl H Plus 0, Everall7); TP (Duran, Scheu-Dental GmbH); LP (Durasplint LC, Scheu-Dental GmbH); and 3DP (Dental LT Clear, Vertex Dental)	Storage (distilled water)	-	Shore hardness, and Flexural strength

HP, heat-polymerized resin; AP, autopolymerized resin; SM, subtractive manufacturing resin; 3DP, 3D printing resin; TP, thermoformable polymer; LP, light-polymerized resin; PEEK, Poly ether ether ketone; -, not evaluated.

used the RoBDEMAT tool to evaluate the methodological quality of the included studies. This tool comprises 4 domains and 9 items classified as adequate (green), inadequate (yellow), not reported, or not applicable (red).[40]

RESULTS

After duplicate removal, 545 references were identified. Following title and abstract screening, 27 studies were selected for full-text assessment, of which 9 were excluded for various reasons (Supplemental Table 2, available online). Three additional studies were retrieved through reference list screening of the included articles and consultation with subject-matter experts (Supplemental Table 3, available online). Ultimately, 21 studies[10–14,21,24–36,41] were included in the review (Fig. 1). Methodological limitations were identified and are summarized in Figure 2. The different degradation protocols and the physical and mechanical properties evaluated across the included studies were organized into tables (Tables 2–5) according to the following methodologies: thermomechanical degradation,[9,25,35,42] thermal degradation,[10,13,42] mechanical degradation,[12,25–27,30,32,34,35] immersion in solution,[14,21,28,31,33,36,37] and simulated toothbrushing.[11,21,25,29] The materials evaluated included autopolymerizing PMMA,[10–12,14,28,29,33–35,37,42] heat-polymerized PMMA,[9,13,21,25–29,31,42] manually manipulated photopolymerizable resins,[30,37] elastomericresins,[29,30] thermoformable polymers,[21,29,30,32,37] AM resins,[9–12,14,21,25–27,29,31,32,34,36,37,42] and CAD-CAM composite resins.[9,10,12,21,25–27,29,31,33–36]

Interactions between occlusal device materials and antagonist surfaces were explored using enamel,[12,25,26,29] polyetheretherketone (PEEK),[31] ceramics,[9,29,31,32,34] and metal alloys.[27] Ceramics exhibited greater abrasiveness than enamel[29] and PEEK,[9,31] particularly multilayer zirconia, which was more aggressive than lithium disilicate.[9] Milled composite resins consistently demonstrated superior performance, with lower volumetric loss, compared with heat-polymerized PMMA[25,26] or 3D printed resins.[9,12,25,26,29,33] Some studies reported similar performance (P=.26) between 3D printed resins and autopolymerized PMMA,[34] while others found advantages of 3D printed resins over heat-polymerized PMMA[27,31] and thermoformed resins.[31] However, 1 study[33] reported higher wear (P<.05) for 3D printed resins compared with milled materials.

Under thermocycling, AM resins showed lower flexural performance than milled materials (P<.001)[10,30] and autopolymerized PMMA (P<.001).[10] Mechanical results for microhardness (P<.001)[13] and flexural strength (FS) (P<.001) showed the greater susceptibility of 3D printed resins to degradation after simulated toothbrushing compared with microwave[13] or water-bath-polymerized PMMA.[41] However, printed polymers may exhibit better color stability (P=.001) compared with milled materials.[24] In brushing protocols, 3D printed resins outperformed heat-polymerized PMMA in hardness (P=.001) and surface roughness (P=.001),[11] whereas another study reported lower hardness compared with milled composite resins and heat-polymerized PMMA (P≤.001).[28] Regarding roughness, Hickl et al[16] found greater stability for CAD-CAM composite resins than printed ones (P<.001), and Raffaini et al[21] reported more favorable results for 3D printed resins (P=.005) compared with milled materials. Consistently, milled composite resins demonstrated higher FS than 3D printed resins or heat-polymerized (P<.001).[24]

Among immersion protocols, studies varied in duration (1,[21,28,30] 14,[21,28] 28,[21,28] 30,[32] 90,[30] and 120 days[35]) and in

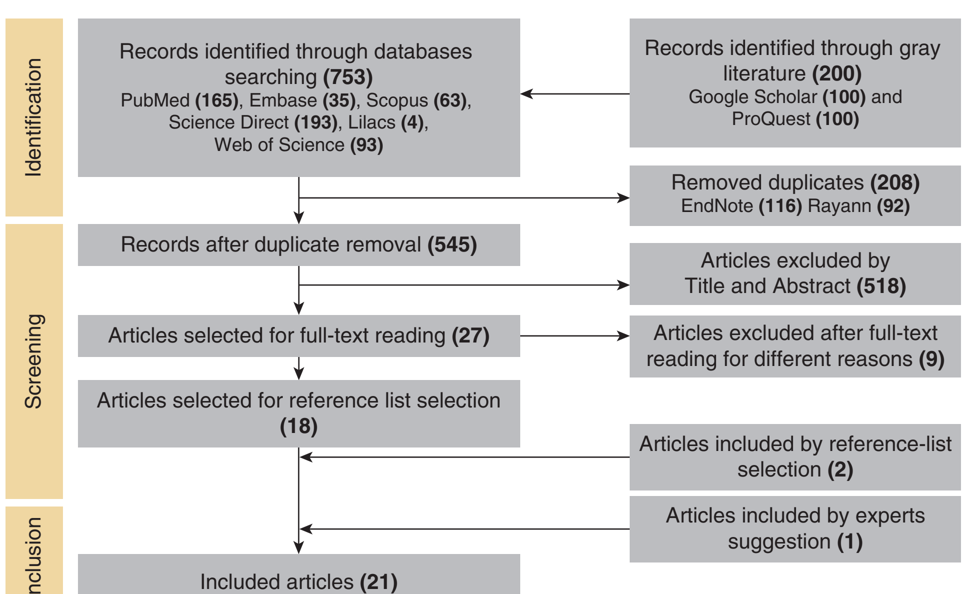

Figure 1. Flow of information through different phases of systematic review.

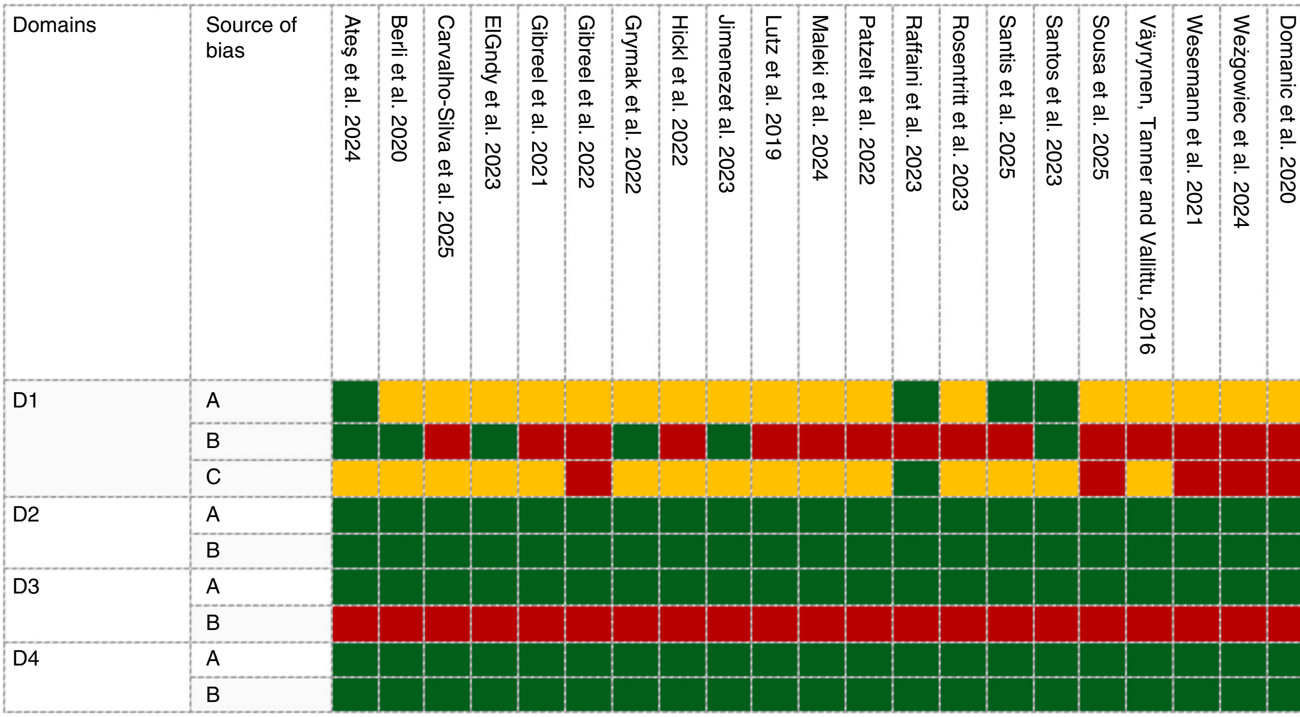

Figure 2. Risk of bias divided into domains and grouped into high risk (*red*), low risk (*green*), and some concerns (*yellow*). D1 - Planning and allocation bias, D2 - Bias in specimen and specimen preparation, D3 - Bias in outcome assessment, D4 - Bias in data processing and reporting. D1. A - Control groups (positive, negative, or standard)? D1. B - Randomization process (well conducted and reported)? D1. C - Power analysis (rationale or justification for sample size chosen)? D2. A - Specimen selection (standardized of specimen and materials according to purpose)? D2. B - Identical experimental conditions (storage, experimental, and treatment conditions standardized among specimens)? D3. A - Testing procedures (reported in sufficient detail for reproducibility)? D3. B - Operator (blindness)? D4. A - Statistical analysis (appropriated and reported in sufficient detail)? D4. B - Outcomes (reported in sufficient detail)?

the media used, including distilled,[14,32,35,36] demineralized,[21,28] and deionized water,[27,30] coffee,[21,28] red wine,[21,28] cleaning tablets,[21] and disinfectant solutions.[28] Milled polycarbonate-based composite resins showed lower mechanical properties than autopolymerized PMMA but exhibited reduced water sorption and solubility.[32] The 3D printed composite resins demonstrated lower sorption and solubility than milled composite resins and heat-polymerized PMMA.[30] Rosentritt et al[28] reported a microhardness decrease only for autopolymerized PMMA and 3D printed composite resins, while milled composite resins and polyethylene terephthalate (PET) remained stable.[28] FS was more affected in 3D printed composite resins than in milled ones,[30] although formulations for rigid occlusal devices showed better mechanical performance (P<.001 to.048),[30] color, and gloss stability (P≤.014)[21] than flexible composite resins. Moreover, milled PMMA exhibited greater gloss stability (P<.05) but similar color behavior (P>.05) than autopolymerized PMMA.[21]

DISCUSSION

The null hypothesis that subtractively manufactured and 3D printed composite resins would not outperform conventionally processed polymers was partially rejected as aging methodologies were found to differentially affect the physicomechanical performance and structural integrity of occlusal device materials. Evidence has consistently supported the superior performance of milled materials,[9,10,12,24–26,28,30,32,35] whereas 3D printed resins, although still inferior to heat-polymerized PMMA, have been reported to exhibit promising properties that merit further investigation.[11,24,31,35]

Milled composite resins outperform thermoformed polymers, 3D printed resins, and both autopolymerized and heat-polymerized PMMA,[9,10,12,24–26,28,30,33,35] primarily because of industrial polymerization under high temperature (>100 °C) and pressure (>150 MPa), which reduces porosity, increases the degree of conversion (DC%), and ensures high material homogeneity.[17,18,42] These conditions have been reported to promote effective chain crosslinking, minimize structural defects, enhance stress dissipation,[17,35] and allow high inorganic filler loading (up to 85 wt%), frequently described as hybrid ceramics, although their chemical nature has not been fully reflected.[18]

Polymerization converts monomeric C=C bonds into polymeric C-C bonds,[17] and higher DC% produces densely crosslinked networks with fewer structural

Table 2. Description of mechanical aging studies (via two-body wear) and their main findings

Authors, Year	Material Antagonists	Characteristics	Results	Conclusion
Ateş et al, 2024	Steatite, Zirconia (Mechatronik GmbH), Lithium disilicate glass-ceramic (IPS e.max CAD), and Zirconia-reinforced lithium silicate (Celtra Duo).	Three-body wear; 50 N; 1.6 Hz; 120 000 cycles; thermocycling	Material, antagonist, and interaction affected wear (*P*<.001). PEEK showed low wear regardless of antagonist (*P*≥.058). SM second-best overall performance. 3DP orientation-dependent. HP demonstrated generally poor performance	Ceramic-reinforced PEEK showed superior wear resistance. Horizontally printed resins suffered highest wear
Domanic et al, 2020	Zirconia (inCoris TZI, Sirona Dental Systems), Lithium disilicate glass-ceramic (IPS e.max Press, Ivoclar AG), and Dental enamel (human enamel, third human molar).	Three-body wear; 50 N; 30 000 cycles; dry and in demineralized water at 30 °C.	Antagonist and material interaction significantly influenced wear effects (*P*<.001). Wet and dry conditions had no significant effect on wear (*P*=.179). Highest mean wear observed in LP (0.318 μm^3), and lowest in thermoformable polymer (0.134 μm^3)	Eclipse showed higher wear than Valplast. Among combinations, IPS e.max Press-Eclipse under 30,000 dry cycles showed higher wear (0.419 μm^3), than InCoris TZI C–Valplast (0.09 μm^3)
ElGndy et al, 2023	PEEK (Bre CAM BioHPP, bredent GmbH & Co.), and metal-ceramic crown	Two-body wear; 50 N; 75 000 cycles	Aging increased surface roughness (*P*<.001), HP showed greater susceptibility. Volume loss increased when opposed by metal-ceramic crowns (*P*=.001), and 3DP demonstrated higher susceptibility to aging	3DP exhibited lower wear after 6 months of simulation compared with HP and TP. Metal-ceramic crowns increased wear
Gibreel et al, 2022	Steatite ball	Two-body wear; 20 N; 15 000 cycles	Flexible and 3DP showed greater wear; differences not always significant.	Except for KeySplint Soft, flexible materials based on SM and 3DP polycarbonate showed greater wear
Grymak et al, 2022	Human enamel	Two-body wear; 49 N; 6-12-month simulation	SM and HP showed lowest loss compared to other groups (*P*<.001). Build angle influenced wear in printed resins (*P*<.05).	SM and HP exhibited lower wear than 3DP. Better results are obtained at angles greater than 45 degrees and less than 90 degrees.
Lutz et al, 2019	Human enamel (human upper molars)	Two-body wear; 50 N; 120 000 cycles	Different manufacturing techniques and mastication simulation duration influenced fracture resistance (*P*=.010). SM showed higher wear resistance compared to injected resins (*P*<.001). After 120 000 mastication cycles, SM maintained greater mechanical stability, followed 3DP, while injected resin showed lower values (*P*<.001). 3DP experienced greater volume loss, while SM showed minimal reduction (*P*<.001).	3DP showed lower wear resistance and lower fracture resistance compared with SM and injected resins.
Patzelt et al, 2022	Steatite spherical indenter (6 mm diameter).	Two-body wear; 50 N; 1.2 million cycles; thermocycling	All materials showed similar average wear (*P*=0.26), measuring 518 µm for AP and 539 µm for SM	AP and SM PMMA exhibited similar wear resistance after artificial chewing aging
Santis et al, 2025	Stainless steel	Two-body wear; 20 N; 150 000 cycles	HP showed greater surface loss.	3DP showed better aging resistance than HP
Wesemann et al, 2021	Human premolars	Two-body wear; 20-50 N; 200 000 cycles	AP showed lower wear (0.31 ± 0.10 mm) than 3DP (0.38 ± 0.15 mm), but no significant differences occurred among groups at 20 N (*P*=.594) and 50 N (*P*=.188). Significant differences emerged between groups for hardness (*P*=.001). SM showed higher hardness (*P*<.008), but with no difference in FS with 3DP (*P*=.584). FS and FM differed with material composition (*P*<.05).	Occlusal device materials showed comparable wear resistance after one-year simulation and minimal, similar antagonist enamel wear. However, 3DP showed lower surface hardness, FS and FM than AP and SM.

AP, autopolymerized; FS, flexural strength; HP, heated-polymerized resin; LP, light-polymerized resin; PEEK, polyetheretherketone; SM, subtractive manufactured resin; 3DP, 3-dimensionally printed resin; TP, thermoformable polymers; ZLS, zirconia-reinforced lithium silicate.

Table 3. Description of mechanical aging studies (simulated brushing) and their main findings

Authors, Year	Material Used	Characteristics	Results	Conclusion
Carvalho-silva et al, 2025	Toothpaste (Colgate Total, Colgate-Palmolive Ind.), neutral detergent (YpÊ, Química Amparo Ltda), and soft-bristled toothbrush (Ultraclean 40, Johnson & Johnson)	35,600 cycles; 200 g load; linear motion	3DP showed higher hardness before and after aging ($P=.001$). Brushing influenced hardness ($P=.001$), while cleaning solution had no effect ($P=.001$). Toothpaste increased roughness in AP ($P=.001$).	3DP showed higher microhardness, whereas HP resin exhibited superior FS and greater C. albicans adhesion.
Hickl et al, 2022	Toothbrush (Oral-B 1-2-3, 35 mm, Oral-B) and toothpaste slurry in suspension of 250 g toothpaste in 1:1 demineralized water.	72,000 cycles; 250 g load; circular motion	Brushing affected Rz for all materials ($P<.002$). Toothbrush abrasion produced significant color differences among materials ($P<.001$).	Initial surface quality and polishability were higher in harder materials; soft materials not become rougher after aging
Raffaini et al, 2023	Soft bristles (Tek; Johnson & Johnson Ind. Com. Ltd.), and slurry of toothpaste (Colgate Total 12 Clean Mint; Colgate)	73,000 cycles (≈5 years simulation)	No color difference observed ($P>.05$). SM exhibited greater color change compared to 3DP ($P=.0011$). All materials exceeded color acceptability thresholds. HP showed greater color change than SM ($P=.001$) and 3DP ($P=.0003$), with no differences between SM and 3DP ($P=.9563$). SM exhibited greater roughness change than 3DP ($P=.0049$). SM showed higher FS than 3DP ($P<.05$) and HP ($P<.05$), with no differences between 3DP and HP ($P>.05$)	3DP showed greater color stability and lower roughness, suggesting better long-term durability.
Rosentritt et al, 2023	Toothpaste not specified; Toothbrush (Oral-B 1-2-3 medium bristle, 35 mm).	72,000 cycles; 250 g load; circular motion	SM showed higher hardness values compared to 3DP and AP ($P<.05$).	SM showed better mechanical properties after the brushing protocol. 3DP and AP showed lower hardness.

AP, autopolymerized; FS, flexural strength; HP, heat-polymerized; 3DP, 3-dimensionally printed.

defects.[17,18] Polymeric material composition directly affects performance under masticatory and chemical challenges,[17,18,28,30,42] while efficient chain crosslinking enhances mechanical and physical properties,[17,21–23] and resistance to degradation.[21,28,30] Densely crosslinked and homogeneous networks exhibit lower free volume, which reduces plasticization and hydrolytic degradation because of limited water and saliva diffusion,[10,17,27,28,30,43] as well as component leaching, thereby supporting material biocompatibility.[42,43]

Densely crosslinked polymeric matrices provide more uniform stress distribution, supporting the use of industrially polymerized composite resins for occlusal devices.[30,43–45] However, under parafunctional loading, an appropriate balance of mechanical properties is essential, as overly compliant materials may induce muscular hyperactivity,[35] whereas excessive rigidity may damage antagonist teeth or materials.[30] In contrast, polymeric materials with low crosslink density exhibit increased free volume and heterogeneous conversion, facilitating water diffusion, residual monomer leaching, and subsequent hydrolytic and oxidative degradation.[6,17,28,46,47]

The microstructure of conventional acrylic resins results from bulk polymerization, whereas 3D printed resins have been defined by layered deposition and incremental photopolymerization,[27] producing anisotropic structures with interlaminar interfaces of lower DC% and increased susceptibility to cohesive failure.[17,30,42] These interfaces act as preferential fracture planes because of inferior mechanical properties and localized stress concentrations.[17,30] Their increased permeability facilitates solution diffusion, promoting plasticization, hydrolysis, and leaching of residual components.[17,21,32] Additionally, bottom-up printing may induce oxygen inhibition at the resin-vat interface.[48]

Printing parameters and postprocessing protocols, including postrinsing and postpolymerization, have been reported to directly influence the performance of 3D printed resins.[17,21,27,28,30,44] The validated integration of equipment, materials, and postprocessing systems is essential to ensure predictable and reproducible outcomes; in the absence of manufacturer guidelines, parameter selection becomes empirical and requires preliminary testing.[17] Layer thickness, print orientation, and light intensity have been reported to affect interlaminar coalescence, polymerization depth, porosity, and volumetric density, with print orientation being particularly critical due to resin anisotropy,[17,42–44,48,49] and the formation of discrete interfaces that compromise mechanical performance.[27,48,49]

Print orientation is critical because of the anisotropic nature of photopolymerizable resins, which influences mechanical behavior through variations in light distribution across the XYZ planes.[44,45] Although postrinsing is required to remove unpolymerized surface

Table 4. Description of aging studies by storage in solution and their main results

Authors, Year	Storage Protocol	Results	Conclusion
Gibreel et al, 2021	Immersion for 30 days in 10 mL of distilled water	Water storage reduced FS in all materials (*P*<.05). AP and SM exhibited significant changes (*P*=.007 and *P*<.001). No significant change occurred in fracture work after aging (*P*=.910) for all materials, except for flexible ones. SM showed lower sorption and solubility than other materials (*P*<.001). SM showed lower solubility than AP (*P*<.001)	SM polycarbonate composites resins showed better resistance to water-related degradation than PMMA materials
Hickl et al, 2022	Demineralized water, coffee (Cafet, Netto), red wine (Vino d'Italia, sweet), and cleaning tablets (Kukident Active Plus, Kukident) up to 4 weeks	Storage medium and time affected color, but had no changes after different storage times (*P*>.001)	Storage and solution moderately affected gloss. Surface characteristics and polishability tend to improve in materials with higher hardness. Storage affected roughness of flexible materials
Maleki et al, 2024	Deionized water at 37°C for 24 h and for 90 days	3DP flexible material showed worse FS, FM and Martens hardness among AP and SM (*P*<.001). Overall, 3DP exhibited lower mechanical perfomance than SM, that showed better hardness values compared to AP (*P*≤.041)	3DP show to be more susceptible to long-term water aging than SM
Rosello Jimenez et al, 2023	Water and dry storage; 60-120 days at 21 °C or 37 °C (extraoral/intraoral storage)	After 60 days SM and 3DP showed decreased TS values compared to baseline (*P*<.05), while 3DP soft material exhibited significant increase (*P*<.05). After 120 days, TS values influenced with material composition (*P*<.05). FM influenced with material composition (*P*<.05). Vickers hardness was influenced by both material and aging, with material- and condition-dependent increases or reductions across resins (*P*<.05)	Despite reduced mechanical properties under wet, high-temperature conditions, 3DP outperformed AP. Thus, AP are preferable for high masticatory loads, thin designs, or use beyond 6 months
Rosentritt et al, 2023	Demineralized water, instant coffee, sweet red wine, and a cleaning solution (Kukident Active Plus); up to 4 weeks	SM exhibited higher microhardness values compared to 3DP and AP after immersion in different liquids (*P*<.05)	SM showed superior mechanical properties after brushing protocol. 3DP and AP exhibited lower hardness
Santis et al, 2025	Deionized water (28 days) and artificial saliva (24-84 days)	Aging not affect dimensional stability or FS (*P*<.001). However, dual post-polymerization improved FS of 3DP after aging (*P*<.05). Aging reduced surface hardness (*P*<.05), with lowest values after 84 days in artificial saliva. HP showed greater surface loss (*P*<.05), whereas printed resins showed no differences (*P*>.05)	Materials showed similar wear patterns and aging resistance, while 3DP demonstrated higher wear resistance than HP
Väyrynen et al, 2016	Water at 37 °C; 1-14 days	AP showed higher values for sorption, FS, and surface roughness (Ra, Rp, Rv, Rq, and Rt) compared to 3DP (*P*<.05). 3DP at 0 degrees showed lower FS values (*P*<.05)	AP showed better physical and mechanical performance when stored in dry environment and after immersion in distilled water for up to 14 days
Wężgowiec et al, 2024	Water at 37 °C; 90 days	All materials reduced in hardness, FS, and FM after storage in water (*P*<.05). Thermopolymerizable PMMA showed higher values for mechanical properties, followed by impression resin and thermoformable resin (*P*<.05)	TP showed better mechanical performance after aging in distilled water for 90 days compared to 3DP and TP. LP showed lower surface hardness (*P*<.0001) compared to other materials. Meanwhile, 3DP showed greater hardness (*P*<.0001). All materials showed significant reduction in hardness (*P*<.001). Only HP showed reduction in FS (*P*=.9992) after aging

AP, autopolymerized resin; FM, flexural modulus; FS, flexural strength; HP, heat-polymerized resin; LP, light-polymerizable resin; SM, subtractive manufactured resin; TP, thermopolymerizable polymer; TS, tensile strength.

material, inadequate processing may reduce photoinitiator availability and impair postpolymerization,[17,45] while exposure time, solvent type, and rinsing method can further degrade partially polymerized matrices, resulting in lower DC%.[45,50–52]

During clinical use, occlusal devices have limited exposure to abrasive agents and pigments.[6,36] However, in the oral environment, dental materials are subjected to enzymatic activity, temperature variations, and pH fluctuations.[24,28,36] Acidic conditions from bacterial metabolism, diet, or gastroesophageal reflux, partially buffered by saliva, can disrupt the polymer-filler interface and hydrolyze ester bonds in acrylic and dimethacrylate matrices,[53,54] releasing degradation byproducts.[54] Conversely, alkaline environments may induce saponification, leaching of residual components, and hydrolytic degradation because of the increased diffusion of polar molecules and network expansion.[53] Repeated pH cycling reduces polymer density and mechanical properties, compromising dimensional stability and promoting microcrack formation.[21,28] The extent of degradation depends on polymer composition, bond chemistry, and environmental pH, which collectively modulate microstructure and pore formation.[53,54]

Effective biofilm removal requires combined mechanical and chemical methods,[55] which can alter the physical-

Table 5. Description of thermocycling aging studies and their main findings

Authors, Year	Method	Results	Conclusion
Berli et al, 2020	20,000 cycles (5-55 °C) after baseline water storage	After aging, FS decreased for all materials, with significant reductions observed only for ProBase Cold (P=.022), Freeprint Splint (P=.017), and Nextdent Ortho Clear (P<.001). SM Temp Premium Flexible Transpa and Yamahachi PMMA Clear showed superior FS (P<.001), outperforming Idodentine PMMA Transparent as well as AP and 3DP (P<.001). SM exhibited higher Vickers hardness and greater stability after aging (P<.05). Although AP showed satisfactory hardness, it demonstrated lower aging stability (P<.05). Water sorption significantly affected by both material type and aging (P<.001), with SM and AP showing lower sorption and solubility than 3DP (P<.001)	AP and SM exhibit similar mechanical properties, whereas 3DP are more susceptible to aging, with notable differences observed among 3DP composition
Maleki et al, 2024	5000 cycles (5-55 °C)	For FS values 3DP exhibited lower FS than SM and AP (P<.001). Flexible 3DP presented lowest FM (P<.001) and hardness (P<.001)	3DP and AP showed to be more susceptible to degradation than SM.
Raffaini et al, 2023	1.2 million thermomechanical cycles (5-55 °C)	HP exhibited higher color change, whereas SM and 3DP have no difference (P>.05). However, all materials exhibited color changes exceeding acceptability and perceptibility thresholds. 3DP showed lower roughness changes compared to SM and HP, that have no difference between (P>.05). Before aging, SM demonstrated superior performance compared to 3DP and HP, with no difference between it (P>.05). After aging, no significant differences were observed between SM and 3DP (P>.05), but both outperformed HP (P<.05)	3DP demonstrated greater longevity, with minimal color change and reduced roughness, and aging on its FS, supporting its use for occlusal devices
Rosello Jimenez et al, 2023	2500 cycles (5-55 °C)	Material and aging protocol influence TS (P<.05) and hardness (P>.05). 3DP FM values may increase after aging protocol (P<.05).	Although thermocycling reduced mechanical properties of 3DP, they still outperformed some resins, supporting their use under high masticatory loads, reduced thickness, or service periods exceeding 6 months
Santos et al, 2023	10,000 cycles (5-55 °C) after water storage	For FS, thermopolymerizable resin demonstrated superior performance compared to AP and 3DP (P<.05). After aging, HP exhibited performance similar to AP (P<.05)	3DP exhibited inferior FS compared to AP and HP, particularly after aging, supporting their indication for interim devices
Sousa et al, 2025	Thermocycling (5-55 °C)	Roughness of HP remained unchanged after thermocycling in specimens polished with TriHawk and TriHawk + sealant. After thermocycling, roughness of 3DP increased, regardless material or polishing protocol (P<.001). Microhardness of HP (P<.001) and 3DP reduced in all groups (P<.001)	Roughness and microhardness affected by resin type and polishing protocol

AP, autopolymerized resin; FM, flexural modulus; FS, flexural strength; HP, heat-polymerized resin; TS, tensile strength; 3DP, 3-dimensionally printed resin.

mechanical properties of polymers.[28,30] Overall, milled composite resins exhibit lower sorption and solubility than 3D printed composite resins,[10,30,32] whereas heat-polymerized PMMA shows intermediate performance but remains better than 3D printed resins.[30,32,36] Variations have been primarily related to material composition.[30,35] In photopolymerizable AM composite resins, the inorganic phase critically influences thermal stability, structural integrity, and resistance to degradation through filler type, content, size, and dispersion.[45,56]

The clinical longevity of occlusal devices is critical because of continuous parafunctional loading.[32,53,54] Materials must withstand high masticatory forces,[10] with the International Organization for Standardization (ISO) 20795–1 standard specifying a minimum FS of 65 MPa.[57] Nonetheless, several studies have reported that some 3D printed composite resins[14,24,26,30,32,41] and heat-polymerized or autopolymerized acrylic resins[14,32,36,41] do not meet this threshold, even before aging protocols. Masticatory forces can reach up to 350 N,[54] while parafunctional forces average 770 N.[35,37] Most studies applied mean loads of 50 N,[9,12,29,31,34] whereas Raffaini et al[24] and Santis et al[27] applied 14 N and 20 N, respectively. Mechanical behavior against different antagonists has been evaluated using 2-body wear tests,[9,12,26,27,31,33,34] and 3-body abrasion tests.[29,37] In general, milled materials, such as PEEK[9,31] and PMMA-based composite resins,[12,25,26] outperform 3D printed composite resins, whereas heat-polymerized PMMA exhibits intermediate behavior but remains better than AM-processed materials.[9,12,25,26,29,31,33,36,37,41]

Limitations of this systematic review included the variability of artificial degradation protocols, including differences in test duration, loading parameters, and aging media, which hampers direct comparisons among studies and limits the extrapolation of the results. Moreover, the available evidence is exclusively based on in vitro studies, whose ability to replicate the complexity of the intraoral environment is inherently limited. In addition, substantial methodological heterogeneity related to material composition, manufacturing technologies, and postprocessing procedures, often insufficiently reported, further constrains data interpretation. Collectively, these factors preclude quantitative synthesis and underscore that the findings should be interpreted as descriptive trends rather than definitive classifications of material performance. Accordingly, future research should prioritize methodological standardization, the detailed reporting of experimental protocols, and the clinical validation of findings to more reliably elucidate the physicomechanical stability of these materials under conditions approximating the intraoral environment.

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. Milled materials, such as PEEK and PMMA-based composite resins, tend to exhibit lower sorption and solubility, greater dimensional stability, and better preservation of mechanical properties after degradation protocols when compared with conventional and 3D printed materials.
2. According to the evaluated approaches, 3D printed resins demonstrated greater susceptibility to degradation than milled composite resins, with variations depending on material composition, printing parameters, and postprocessing procedures.
3. Heat-polymerized PMMA showed intermediate performance, with a tendency toward better behavior than 3D printed resins and autopolymerizing PMMA but worse than milled composite resins in some studies.
4. Thermoformed materials tended to present higher sorption, solubility, wear, and greater reductions in mechanical properties after degradation, with the magnitude of these effects varying according to the experimental protocol.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2026.02.045.

REFERENCES

1. Lawson NC, Brown P, Hamdan S, Alford A, Nejat AH. Wear resistance of 3D printed occlusal device materials. *J Prosthet Dent*. 2025;133:576.e1–576.e6.
2. Diken Türksayar AA, Diker B. Effect of layer thickness and polishing on wear resistance of additively manufactured occlusal splints. *J Dent*. 2024;146:105101.
3. de Paula Lopez V, Dias Corpa Tardelli J, Botelho AL, Marcondes Agnelli JA, Cândido Dos Reis A. Mechanical performance of 3-dimensionally printed resins compared with conventional and milled resins for the manufacture of occlusal devices: A systematic review. *J Prosthet Dent*. 2024;132:1262–1269.
4. Nassif M, Haddad C, Habli L, Zoghby A. Materials and manufacturing techniques for occlusal splints: A literature review. *J Oral Rehabil*. 2023;50:1348–1354.
5. Abad-Coronel C, Ruano Espinosa C, Ordóñez Palacios S, Paltán CA, Fajardo JI. Comparative analysis between conventional acrylic, CAD/CAM milled, and 3D CAD/CAM printed occlusal splints. *Materials (Basel)*. 2023;16:6269.
6. Borg H, Azer SS, El Hadary A, Helaly O, Shoeib A, Hassan M. Evaluation of enamel wear by 3 occlusal splint materials: An in vitro study. *J Prosthet Dent*. 2023;130:743.e1–743.e6.
7. Moreira BC, Batista WDS, Hilgert LA, de Medeiros RA. Impact of aging on the mechanical and structural properties of additively manufactured resin for occlusal devices. *J Prosthet Dent*. 2025;134:222.e1–222.e6.
8. Riley P, Glenny AM, Worthington HV, et al. Oral splints for temporomandibular disorder or bruxism: A systematic review. *Br Dent J*. 2020;228:191–197.
9. Ateş G, Demirel M, Donmez MB, Dayan SÇ, Sülün T. Effect of material and antagonist type on the wear of occlusal devices with different compositions fabricated by using conventional, additive, and subtractive manufacturing. *J Prosthet Dent*. 2024;131:1235.e1–1235.e8.
10. Berli C, Thieringer FM, Sharma N, et al. Comparing the mechanical properties of pressed, milled, and 3D-printed resins for occlusal devices. *J Prosthet Dent*. 2020;124:780–786.
11. Carvalho-Silva JM, Marinho VT, Lopez V de P, et al. Printed versus heat-polymerized resin for occlusal devices: Evaluation of physical and mechanical properties after brushing and microbial adhesion. *J Prosthodont*. 2025;34:1–8.
12. Lutz AM, Hampe R, Roos M, Lümkemann N, Eichberger M, Stawarczyk B. Fracture resistance and 2-body wear of 3-dimensionally printed occlusal devices. *J Prosthet Dent*. 2019;121:166–172.
13. Carvalho De Sousa T, Ramos AG, Cristina F, Garcia P, Antonio De Medeiros R. Comparative analysis of polishing protocols on microhardness and surface roughness of occlusal device materials fabricated using microwave-polymerized acrylic or 3D printed resins. *J Prosthet Dent*. 2024;133:596.e1–596.e9.
14. Väyrynen VOE, Tanner J, Vallittu PK. The anisotropicity of the flexural properties of an occlusal device material processed by stereolithography. *J Prosthet Dent*. 2024;146:1–6.
15. Benli M, Eker Gümüş B, Kahraman Y, et al. Surface roughness and wear behavior of occlusal splint materials made of contemporary and high-performance polymers. *Odontology*. 2020;108:240–250.
16. Ferreira GF, Carletti TM, Gama LT, Magno MB, Maia LC, Rodrigues Garcia RCM. Influence of occlusal appliances on the masticatory muscle function in individuals with sleep bruxism: A systematic review and meta-analysis. *Eur J Oral Sci*. 2024;132:1–9.
17. De Melo-Soares V, Cândido Dos Reis A, Lima Da Costa Valente M. Influence of postpolymerization exposure duration on the physical and mechanical properties of 3D printed resins: A systematic review of in vitro studies. *J Prosthet Dent*. 2024;146:1–7.
18. Mainjot AK, Dupont NM, Oudkerk JC, Dewael TY, Sadoun MJ. From artisanal to CAD-CAM blocks: State of the art of indirect composites. *J Dent Res*. 2016;95:487–495.
19. Hammamy M, Rojas-Rueda S, Nejat AH, Hamdan S, Ning H, Lawson NC. Methods of evaluating mechanical properties of 3D printed occlusal device materials: Flexural strength, fracture toughness, and impact strength. *J Prosthet Dent*. 2024;146:1–6.
20. Benli M, Al-Haj Husain N, Ozcan M. Mechanical and chemical characterization of contemporary occlusal splint materials fabricated with different methods: A systematic review. *Clin Oral Investig*. 2023;27:7115–7141.
21. Hickl V, Strasser T, Schmid A, Rosentritt M. Effects of storage and toothbrush simulation on color, gloss, and roughness of CAD/CAM, hand-cast, thermoforming, and 3D-printed splint materials. *Clin Oral Investig*. 2022;26:4183–4194.
22. Ferracane JL, Greener EH. The effect of resin formulation on the degree of conversion and mechanical properties of dental restorative resins. *J Biomed Mater Res*. 1986;20:121–131.
23. Ferracane JL. Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins. *J Dent Res*. 1985;64:435–439.
24. Raffaini JC, Soares EJ, Oliveira RF de L, et al. Effect of artificial aging on mechanical and physical properties of CAD-CAM PMMA resins for occlusal splints. *J Adv Prosthodont*. 2023;15:227–237.
25. Grymak A, Waddell JN, Aarts JM, Ma S, Choi JJE. Evaluation of wear behaviour of various occlusal splint materials and manufacturing processes. *J Mech Behav Biomed Mater*. 2022;126:1–9.
26. Wesemann C, Spies BC, Sterzenbach G, et al. Polymers for conventional, subtractive, and additive manufacturing of occlusal devices differ in hardness and flexural properties but not in wear resistance. *Dent Mater*. 2021;37:432–442.

27. Santis LR de, Fernandes LS, Vasques MT, et al. Aging and post-polymerization effects on conversion degree and properties of additive splint materials. *Braz Oral Res*. 2025;39:e017.
28. Rosentritt M, Hickl V, Rauch A, Schmidt M. Effects of storage and toothbrush simulation on Martens hardness of CAD/CAM, hand-cast, thermoforming, and 3D-printed splint materials. *Clin Oral Investig*. 2023;27:7859–7869.
29. Domanic KY, Aslan YU, Ozkan Y. Two-body wear of occlusal splint materials against different antagonists. *BMC Oral Health*. 2020;20:1–7.
30. Maleki T, Meinen J, Coldea A, Reymus M, Edelhoff D, Stawarczyk B. Mechanical and physical properties of splint materials for oral appliances produced by additive, subtractive and conventional manufacturing. *Dent Mater*. 2024;40:1171–1183.
31. Elgndy A, Shakal M, Ahmad F. Wear evaluation of different occlusal splints. *Eur Chem Bull*. 2023;12:1114–1121.
32. Gibreel M, Perea-Lowery L, Vallittu PK, Lassila L. Characterization of occlusal splint materials: CAD-CAM versus conventional resins. *J Mech Behav Biomed Mater*. 2021;124:1–7.
33. Gibreel M, Perea-Lowery L, Vallittu PK, Garoushi S, Lassila L. Two-body wear and surface hardness of occlusal splint materials. *Dent Mater J*. 2022;41:916–922.
34. Patzelt SBM, Krügel M, Wesemann C, et al. vitro time efficiency, fit, and wear of conventionally-versus digitally-fabricated occlusal splints. *Materials (Basel)*. 2022;15:1–8.
35. Rosello Jimenez JR, Fuchs F, Schmohl L, Schulz-Siegmund M, Koenig A. Aging processes and their influence on the mechanical properties of printable occlusal splint materials. *Polymers (Basel)*. 2023;15:1–9.
36. Weżgowiec J, Małysa A, Więckiewicz M. How does artificial aging affect the mechanical properties of occlusal splint materials processed via various technologies? *Dent Med Probl*. 2024;62:527–535.
37. Grymak A, Aarts JM, Ma S, Waddell JN, Choi JJE. Wear behavior of occlusal splint materials manufactured by various methods: A systematic review. *J Prosthodont*. 2022;31:472–487.
38. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*. 2021;372:n160.
39. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159–174.
40. Delgado AH, Sauro S, Lima AF, et al. RoBDEMAT: A risk of bias tool and guideline to support reporting of pre-clinical dental materials research and assessment of systematic reviews. *J Dent*. 2022;127:104202.
41. Santos Neto OM, Cerqueira GM, Souza JP, Almeida RP, Mazaro JVQ, Zavanelli AC. Flexural resistance of 3D printing resin compared to conventional acrylic resins employed to build occlusal bite splints. *Rev Odontol UNESP*. 2023;52:e2023.
42. de Melo-Soares V, Dos Reis AC, da Costa Valente ML. Effect of oxygen inhibition on 3D printed dental resins: A systematic review. *J Prosthet Dent*. 2025;133:1465.e1–1465.e9.
43. de Melo Soares V, Cândido dos Reis A, Lima da Costa Valente M. The influence of 2,4,6-trimethylbenzoyldiphenylphosphine oxide on the toxicity of dental resins: A systematic review of in vitro studies. *Int J Adhes Adhes*. 2025;138:103452.
44. Soares V de M, dos Reis AC, da Costa Valente ML. Influence of printing angle on the physico-mechanical properties of PMMA-based resins for dental use: A systematic review of in vitro studies. *Int J Prosthodont*. 2025;38:1–24.
45. Gad MM, Fouda SM. Factors affecting flexural strength of 3D-printed resins: A systematic review. *J Prosthodont*. 2023;32:1–9.
46. Dai J, Luo K, Liu Q, et al. Post-processing of a 3D-printed denture base polymer: Impact of a centrifugation method on the surface characteristics, flexural properties, and cytotoxicity. *J Dent*. 2024;147:103–115.
47. Nam OH, Chung SY, Hyun HK, et al. Influence of postprinting cleaning methods on the cleaning efficiency and surface and mechanical properties of three-dimensionally printed resins. *J Prosthodont*. 2024;33:1–10.
48. Gojzewski H, Guo Z, Grzelachowska W, et al. Layer-by-layer printing of photopolymers in 3D: How weak is the interface? *ACS Appl Mater Interfaces*. 2020;12:8908–8914.
49. Young JC, Brinckmann SA, Fertig RS, Lynch SP, Frick CP. Influence of layer thickness and exposure on mechanical properties of additively manufactured polymer-derived SiOC ceramics. *Open Ceram*. 2024;19:100485.
50. Pedro J, De J, LimÍrio O, et al. Mechanical properties of polymethyl methacrylate as a denture base: Conventional versus CAD-CAM resin – A systematic review and meta-analysis of in vitro studies. *J Prosthodont*. 2025;34:1–15.
51. Hwangbo NK, Nam NE, Choi JH, Kim JE. Effects of the washing time and washing solution on the biocompatibility and mechanical properties of 3D-printed dental resin materials. *Polymers (Basel)*. 2021;13:4291.
52. Mayer J, Stawarczyk B, Vogt K, Hickel R, Edelhoff D, Reymus M. Influence of cleaning methods after 3D printing on two-body wear and fracture load of resin-based temporary crown and bridge material. *Clin Oral Investig*. 2021;25:6203–6212.
53. Prakki A, Cilli R, Lia Mondelli RF, Kalachandra S, Pereira JC. Influence of pH environment on polymer based dental material properties. *J Dent*. 2005;33:91–98.
54. Leung BAY, Joe W, Mofarah SS, et al. Unveiling the mechanisms behind surface degradation of dental resin composites in simulated oral environments. *J Mater Chem B*. 2023;11:7707–7720.
55. Ribeiro AB, Tinelli BM, Clemente LM, et al. Effect of hygiene protocols on the mechanical and physical properties of two 3D-printed denture resins characterized by extrinsic pigmentation as well as the mixed biofilm formed on the surface. *Antibiotics*. 2023;12:1350.
56. de Melo-Soares V, Cândido dos Reis A, Lima da Costa Valente M. Influence of cellulose nanoparticles on the mechanical properties of dental acrylic resins: A systematic review of in vitro studies. *Cellulose*. 2025;32:8703–8727.
57. ISO 20795-1:2013. Dentistry—base polymers—part 1: Denture base polymers. Geneva: International Organization for Standardization; 2013.

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