

Effect of Aging on the Mechanical Properties of 3D-Printed Resin-Based Composites for Permanent Dental Restorations: A Systematic Review Protocol

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ADMINISTRATIVE INFORMATION**Support** - No support.**Review Stage at time of this submission** - Preliminary searches.**Conflicts of interest** - None declared.**INPLASY registration number:** INPLASY2026100027

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 6 October 2026 and was last updated on 6 October 2026.

INTRODUCTION

Review question / Objective What is the effect of artificial aging on the mechanical properties of 3D-printed resin composites intended for permanent restorations, compared to those not subjected to aging?

Rationale Additive manufacturing has become an important technology in dentistry, expanding the possibilities for fabricating restorations through digital workflows. Among the materials used in three-dimensional (3D) printing, resin-based composites have gained prominence for the production of long-term restorations because of their ability to produce structures with complex geometries, digital reproducibility, and customized processing. However, the clinical use of these materials requires that their mechanical properties be maintained over time under conditions that may occur during service. Artificial aging protocols are commonly used in laboratory studies to simulate, in an accelerated and controlled manner, different environmental and mechanical challenges to which

restorative materials may be exposed. These protocols vary in exposure medium, temperature, duration, number of cycles, and load intensity, which may contribute to heterogeneity among the available findings. Given the increasing use of 3D-printed resin-based composites for permanent restorations and the diversity of artificial aging protocols used to investigate their mechanical behavior, a systematic synthesis of the available evidence is warranted.

Condition being studied Mechanical behavior of 3D-printed resin-based composites intended for permanent dental restorations following artificial aging.

METHODS

Search strategy The following electronic databases will be searched from inception to September 2026: PubMed/MEDLINE, EMBASE, LILACS, Web of Science, Scopus, and LIVIVO. Grey literature will be searched through Google Scholar and ProQuest Dissertations and Theses.

The search strategy will combine controlled vocabulary and free-text terms related to 3D printing/additive manufacturing, artificial aging, and permanent dental restorations. No outcome terms will be required in the database search strategy. The complete PubMed/MEDLINE search strategy will be adapted for the other databases according to their respective indexing systems. In addition, the reference lists of included studies will be manually screened, and a prospective citation search will be performed. Authors with three or more studies identified in the search results may also be contacted/considered as an additional search source.

("3d print"[Title/Abstract] OR "three dimensional print"[Title/Abstract] OR "3 dimensional print"[Title/Abstract] OR "additive manufactur*[Title/Abstract] OR "additively manufactur*[Title/Abstract] OR "3D-printed"[Title/Abstract] OR "printed resin"[Title/Abstract] OR "printable resin"[Title/Abstract]) AND ("aging"[Title/Abstract] OR "ageing"[Title/Abstract] OR "artificial aging"[Title/Abstract] OR "artificial ageing"[Title/Abstract] OR "accelerated aging"[Title/Abstract] OR "accelerated ageing"[Title/Abstract] OR "degradation"[Title/Abstract] OR "durability"[Title/Abstract] OR "thermocycl*[Title/Abstract] OR "thermal cycl*[Title/Abstract] OR "water storage"[Title/Abstract] OR "water aging"[Title/Abstract] OR "water ageing"[Title/Abstract] OR "water immersion"[Title/Abstract] OR "artificial saliva"[Title/Abstract] OR "hydrothermal"[Title/Abstract] OR "chemical aging"[Title/Abstract] OR "chemical ageing"[Title/Abstract] OR "fatigue"[Title/Abstract] OR "cyclic loading"[Title/Abstract] OR "mechanical aging"[Title/Abstract] OR "mechanical ageing"[Title/Abstract] OR "thermomechanical aging"[Title/Abstract] OR "thermomechanical ageing"[Title/Abstract]) AND ("Crowns"[MeSH Terms] OR "dental restoration, permanent"[MeSH Terms] OR "denture, partial, fixed"[MeSH Terms] OR "Inlays"[MeSH Terms] OR "crown*[Title/Abstract] OR "indirect restoration*[Title/Abstract] OR "definitive restoration*[Title/Abstract] OR "permanent restoration*[Title/Abstract] OR "definitive crown*[Title/Abstract] OR "inlay*[Title/Abstract] OR "onlay*[Title/Abstract] OR "overlay*[Title/Abstract] OR "endocrown*[Title/Abstract] OR "fixed dental prosthes*[Title/Abstract] OR "fixed dental restoration*[Title/Abstract]).

Participant or population 3D-printed resin-based composites intended for permanent dental restorations, including materials indicated by the manufacturer or described by the study as suitable

for definitive, long-term restorations such as crowns, inlays, onlays, veneers, and other definitive indirect restorations.

Intervention Artificial aging of 3D-printed resin-based composites intended for permanent restorations. Aging protocols may include thermal, hydrochemical/chemical, hydrothermal, mechanical, or combined challenges, including thermocycling, water or artificial saliva storage/immersion, accelerated hydrothermal aging, controlled chemical exposure, cyclic loading, fatigue, and masticatory simulation when intended to simulate exposure or functional stress over time.

Comparator The same material or experimental condition not subjected to artificial aging, used as an unaged or reference condition.

Study designs to be included Laboratory in vitro and in situ studies with quantitative data evaluating 3D-printed resin-based composites intended for permanent restorations, subjected to artificial aging and compared with an unaged or reference condition.

Eligibility criteria Studies will be included if they: 1. evaluate 3D-printed resin-based composites intended for permanent dental restorations; 2. subject the materials to at least one artificial aging protocol intended to simulate exposure or functional stress over time; 3. include an unaged or reference condition compatible with the study design; 4. evaluate at least one prespecified mechanical property: microhardness, flexural strength, modulus of elasticity, or fracture toughness; 5. report quantitative data; 6. are in vitro or in situ studies. Studies will be excluded if they: 1. evaluate non-restorative materials, including unfilled resins, temporary/provisional resins, orthodontic resins, complete or removable partial denture resins, occlusal splint resins, or experimental/non-commercial resins; 2. do not use an experimental procedure intended to simulate aging or exposure over time; 3. focus exclusively on post-curing, finishing, polishing, cleaning, surface conditioning, or other processing modifications without an aging protocol; 4. use abrasive wear as the aging protocol; 5. do not include a comparable unaged condition; 6. do not evaluate any of the mechanical properties of interest; 7. focus exclusively on optical, surface, chemical, biological, or other non-mechanical properties; 8. are narrative reviews, systematic reviews, case reports, clinical studies, conference abstracts without full text, cadaver studies, or animal studies.

Information sources PubMed/MEDLINE, EMBASE, LILACS, Web of Science, Scopus, LIVIVO, Google Scholar, and ProQuest Dissertations and Theses. Reference lists of included studies will be manually searched, and prospective citation searching will be performed. Authors with three or more studies identified in the search results may also be considered as an additional source of information. Full texts will be obtained through the CAPES/UnB Periodicals Portal, open-access databases, and interlibrary loan services. When necessary, corresponding authors will be contacted by email to obtain inaccessible full texts.

Main outcome(s) Mechanical properties of 3D-printed resin-based composites following artificial aging, including flexural strength, modulus of elasticity, microhardness, and fracture toughness. Quantitative data will be extracted for aged and unaged conditions. When available, mean values, measures of dispersion, and units of measurement will be recorded.

Additional outcome(s) Other mechanical outcomes, such as fracture resistance or deformation-related properties, will be recorded when evaluated in eligible studies and will be classified and analyzed according to methodological comparability.

Data management Search results will be exported and centralized in EndNote reference management software for reference organization and duplicate removal. After deduplication, records will be imported into Rayyan for blind and independent screening by two reviewers. Data will be extracted independently by two reviewers using a standardized extraction form developed a priori and piloted on a sample of ten included studies. Extracted data will be compared, and discrepancies will be resolved by consensus or consultation with a third reviewer. NotebookLM will be used as an auxiliary tool to assist in identifying, locating, and organizing information in full-text articles; all information obtained with AI assistance will be verified directly against the original articles by the reviewers.

Quality assessment / Risk of bias analysis Risk of bias will be assessed according to study design using the QUIN Tool for in vitro studies and the ROBUST tool for in situ studies. The assessment will be performed independently by two reviewers. Disagreements will be resolved by consensus or, when necessary, by consultation with the third reviewer.

Strategy of data synthesis A quantitative synthesis of the results from included studies will be conducted. Aging protocols will be categorized a priori according to the nature of the applied challenge. When sufficient methodological and outcome comparability exists between at least two studies, meta-analysis of continuous data will be performed using mean difference as the effect measure, inverse variance as the statistical method, and a random-effects model, with τ^2 calculated using Restricted Maximum Likelihood (REML). The 95% confidence interval will be calculated using the Hartung-Knapp-Sidik-Jonkman method. When the same outcome is evaluated using different measurement tools, standardized mean difference will be used. Heterogeneity will be evaluated using χ^2 and I^2 statistics. A p-value <0.10 for χ^2 and I^2 values above 50% will be considered evidence of heterogeneity and explored through subgroup analyses. When quantitative pooling is inappropriate because of methodological or outcome heterogeneity, findings will be presented using a descriptive synthesis without meta-analysis, following the Synthesis Without Meta-analysis (SWiM) reporting guidelines.

Subgroup analysis When a sufficient number of studies and adequate methodological comparability are available, subgroup analyses will be performed according to the type of artificial aging protocol. Prespecified subgroups will include: (1) thermocycling; (2) aqueous storage; (3) hydrothermal aging; (4) mechanical aging; (5) chemical aging; (6) combined protocols; and (7) other aging methods identified in eligible studies. In vitro and in situ studies will be analyzed separately to preserve comparability between experimental designs.

Sensitivity analysis Sensitivity analyses will be performed when sufficient studies are available to assess the robustness of pooled estimates, considering methodological differences and risk of bias among included studies. Where appropriate, analyses may be repeated after excluding studies with higher risk of bias or studies with methodological characteristics that may substantially influence the pooled estimates.

Language restriction No language restrictions will be imposed.

Country(ies) involved Brazil.

Other relevant information The review will follow the methodological principles described in the PRISMA-P 2015 statement. The protocol was

developed as part of the Postgraduate Program in Dentistry at the University of Brasília. The review will be conducted prospectively, and any relevant methodological amendments made after registration will be documented and reported in the final review. Citation searching of included studies will include both retrospective examination of reference lists and prospective identification of subsequent citing publications.

Keywords 3D printing; additive manufacturing; 3D-printed resin composites; permanent dental restorations; artificial aging; mechanical properties; dental materials.

Dissemination plans The results of this systematic review will be submitted for publication in a peer-reviewed international scientific journal and presented at relevant scientific meetings in the fields of dentistry, restorative dentistry, dental materials, and additive manufacturing.

Contributions of each author

Author 1 - Larissa Meireles Rodrigues - Study conceptualization and design; development of the search and selection strategy; study selection; data collection; data analysis; manuscript preparation; and review and approval of the final manuscript.

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