

Long-Term Dental Prostheses Made by Vat Photopolymerisation: Material State, Colour Stability and the Evidence Still Missing for Wear, Biofilm and Clinical Outcome

Translational medical manufacturing

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Abstract

Long-term dental use claims for vat-photopolymerised prosthetic materials require separate evidence layers for material state, optical ageing, mechanical integrity, wear, biofilm behaviour and clinical outcome. This review distinguishes the earlier controlled process and colour literature from additional systematic reviews of definitive restorations and crown-level comparisons available through 2026. The newer literature supports critical discussion of mechanical and fit outcomes, including substantial heterogeneity, but does not establish universal long-term clinical performance for all printing formulations or processing routes. A qualification architecture is proposed that links each claim to a defined final material state and a directly relevant endpoint.

Keywords: long-term dental prostheses · vat photopolymerisation · material state · wear · biofilm · colour · clinical evidence

1. Scope and ownership

ER-463 is restricted to long-term dental prosthetic claims made for parts produced by vat photopolymerisation. The article does not infer wear resistance, biofilm response or clinical durability from process feasibility or colour stability. Its central purpose is to distinguish what the present controlled evidence supports from what still requires direct evidence.

2. Controlled evidence base

The original controlled evidence set comprised two dedicated sources: a review of dental vat photopolymerisation [1] and a review of colour stability [2]. This expanded version also draws on systematic reviews of definitive restorative resins [3], comparative crown-level fracture and fit outcomes [4], mechanical performance against subtractive comparators [5], and the process-to-clinic evidence boundary [6]. Results are attributed to the populations, materials and methods actually examined. Access to some sources is limited to abstracts or publisher excerpts; no unverified study-level findings are inferred.

3. Material state is not a generic label

A dental prosthetic article must name the state being evaluated. Printing route, material identity, build orientation, cleaning, post-cure, conditioning and test age can all define different material states. The process review supports treating vat photopolymerisation as a manufacturing route that requires state definition rather than as a single material category [1]. A result obtained in one state should therefore not be transferred automatically to another.

4. Colour stability is a distinct evidence domain

Colour stability has a dedicated evidence base within vat-photopolymerisation dentistry [2]. That makes it supportable as an explicit review domain. It does not make colour response a proxy for mechanical ageing, surface fouling or clinical survival. Colour should be reported with the exposure condition, measurement method, initial state and duration that produced the observed change.

5. Wear remains an evidence gap

Available broader reviews include laboratory wear endpoints for some printed crown resins [3,5]. That evidence does not resolve comparative, long-term intraoral wear for the full range of material and processing states. Reported wear values require pairing with contact configuration, antagonist, load, environment, cycle history and loss metric; a number from a single study cannot be used as a universal wear allowance.

6. Biofilm remains an evidence gap

No held source establishes biofilm behaviour for the same vat-photopolymerised prosthetic class. Surface roughness, chemistry, cleaning state and ageing may be relevant variables, but this article does not assign their effects without direct evidence. A future biofilm qualification should distinguish initial adhesion, biomass or coverage, community composition where relevant, cleaning response and the post-ageing surface state.

7. Clinical outcome remains an evidence gap

A laboratory material result is not a clinical outcome. Long-term prosthetic performance requires patient-facing evidence with a defined indication, follow-up duration, failure definition and denominator. The available evidence does not close that chain, so no survival rate or clinical superiority claim is made here.

8. Qualification architecture

The minimum architecture is sequential: define the delivered material state; qualify colour as its own response; qualify wear under declared contact and environmental conditions; qualify surface-biological behaviour under a declared conditioning state; and only then interpret clinical evidence for the same indication and product state. Evidence from one layer may motivate the next but cannot replace it.

9. Minimum reporting set

Report resin/material identity, printer and route, build orientation, cleaning and post-cure, conditioning, specimen or prosthesis geometry, colour method and exposure, wear method and counterface if studied, surface state for biological testing, and the clinical indication and follow-up if clinical evidence is used. Missing layers should be labelled as missing rather than filled by analogy.

10. A study matrix for colour and surface performance

The proposed expansion of the assessment begins with a specimen-state matrix. Each result should be linked to material, manufacturing route, orientation, layer setting, washing, post-cure, finishing, conditioning and measurement time. These descriptors permit a comparison to distinguish a material effect from a difference in preparation. They are especially important when a polished conventional specimen is compared with an as-printed surface: the observed contrast then represents two preparation routes, not the manufacturing technology alone.

For colour, the record should identify the colour-difference formula, instrument configuration, background, specimen thickness, baseline and exposure sequence. Values produced by different formulae are not interchangeable merely because each is labelled colour change. A perceptibility threshold and an acceptability threshold also answer different questions. Their use requires a source and an application context rather than selection after examining the result.

A proposed factorial comparison could hold material and finishing constant while varying the processing condition, then repeat the relevant contrast after conditioning. Independent builds would provide the manufacturing replication. Several readings from one specimen would provide measurement replication. Treating those readings as separate manufactured specimens would artificially enlarge the apparent sample.

11. Preserve the distinction between endpoints

An expanded evidence table should have separate columns for colour, surface topography, material loss, microbial response and functional integrity. A blank column would mean that the particular study did not measure that endpoint. It would not mean that the literature contains no evidence for it. This distinction is essential when the retained source set is small.

For a proposed wear comparison, mass loss, volume loss, surface damage and antagonist effects would remain separate observations, with the loading and exposure history attached. For a proposed biofilm comparison, the organism or community, incubation conditions, surface preparation, recovery method and endpoint would be retained. A reduction in one laboratory microbial endpoint should not be restated as reduced clinical disease. Likewise, stable colour does not establish retained mechanical or biological performance.

The practical output would be a claim-by-endpoint matrix rather than an overall ranking of resins. A formulation could perform favourably for one endpoint and remain uncharacterised for another. The decision to extend use would then depend on the missing endpoint relevant to that use. This analytical structure makes the evidence gaps testable without filling them with assumed relationships among aesthetics, wear, colonisation and clinical survival.

12. Evidence synthesis: permanent resin restorations versus milled comparators

A 2026 systematic review of definitive dental restorations identified 42 eligible studies evaluating seven three-dimensionally printed resins. Its central finding is not that printing is universally inadequate, but that several measured mechanical properties of the examined materials, including flexural strength, hardness and roughness-related behaviour, generally trailed CAD-CAM composite blocks. The included work predominantly concerns laboratory comparisons and a bounded range of named formulations. Accordingly, neither the ranking of a specific commercial resin nor a laboratory test result can be transferred to another chemistry, printer, post-curing route or prosthesis design without a matched validation chain [3].

This comparison also clarifies the problem of endpoint substitution. A favourable static flexural strength result is not interchangeable with tooth-supported crown fatigue, occlusal wear, marginal seal, antagonist wear or clinical service life. Even when the same nominal resin is involved, specimens fabricated as standard bars differ from complex crowns in stress concentration, thickness distribution, finishing and loading. A credible review must report specimen class and clinically relevant geometry alongside the material and processing state; pooled numbers stripped of these descriptors invite false equivalence [3,4].

13. Crown-level evidence, uncertainty and heterogeneity

A 2026 systematic review and meta-analysis compared printed and milled resin-based permanent crowns across 14 laboratory studies. In the primary molar-only fracture-resistance comparison, milled crowns showed higher resistance (standardised mean difference, SMD, -1.49; 95% confidence interval -2.25 to -0.73). Under simulated ageing the reported difference was also in favour of milled specimens (SMD -1.75; 95% confidence interval -2.31 to -1.19). These are standardised differences across study distributions, not force values or universal design allowables; no direct minimum service life or survival probability follows from them [4].

For marginal gap, the main pooled comparison did not establish an overall difference and its heterogeneity was extreme (I-squared 99.8%). A narrower sensitivity analysis using tooth-supported direct measurements favoured printed crowns, illustrating how the apparent outcome depends on measurement method and support configuration. The authors characterised the certainty as low to very low and called for better clinical studies. The appropriate engineering inference is a requirement for standardised crown preparation, support, conditioning and gap metrology rather than a categorical declaration that one manufacturing route fits better [4].

Any future quantitative synthesis should predefine separate families of outcomes: ultimate load, fatigue or survival under cyclic loading, wear loss under named antagonist and lubrication, optical ageing, fit by a declared measurement method, and clinical failure. Random-effects pooling cannot repair a mismatch of outcome definitions. Where comparability fails, a structured narrative synthesis and a table of study conditions are more defensible than a single summary effect.

14. Translating laboratory evidence into a clinical qualification pathway

A 2025 systematic review of mechanical comparisons reported 13 eligible in-vitro studies and explicitly identified substantial heterogeneity in materials, fabrication methods and measured properties [5]. A separate 2025 narrative review of temporary and

permanent printed restorations identified incomplete standardisation of pre-printing, printing and post-printing steps and limited clinical and biological evidence [6]. Together these sources support the need for process-state traceability, not a general conclusion that all vat-photopolymerised restorations share the same risk profile.

A qualification sequence can therefore be organised around four non-substitutable gates. First, record the intended indication and delivered article geometry, specifying the finished and conditioned material state. Second, measure relevant optical, mechanical and geometric endpoints after defined manufacturing and ageing sequences with independent build replication. Third, establish surface-biological evidence for the final finished state using an appropriate exposure and endpoint; laboratory adhesion or cytotoxicity findings should not be treated as proof of clinical plaque reduction or patient safety. Fourth, evaluate actual clinical performance using explicit inclusion criteria, follow-up interval, competing failure modes, denominator and censoring method. A pass at an earlier gate authorises further evaluation but cannot substitute for evidence from a later gate [3-6].

Evidence strength must be tracked at the level of the claim. For example, the existence of studies measuring material wear can justify discussing wear as a studied endpoint, but it does not validate a particular long-term clinical wear rate. Likewise, evidence that tested materials differ under accelerated ageing does not determine performance after years of intraoral service without an established ageing-to-clinical correlation. These distinctions prevent a bounded laboratory review from being misrepresented as a longitudinal clinical validation.

15. Comparative evidence: endpoints, ageing and clinical transfer

Evidence for definitive vat-polymerised dental restorations is easily overstated when laboratory strength, colour, wear and clinical survival are considered interchangeable. Strength measured on polished coupons does not directly reproduce a crown with minimum-wall regions, cement interfaces and cyclic occlusal loading. Even a crown fracture test depends on the support abutment, cement, loading direction and fatigue history. A review should preserve these conditions alongside any outcome instead of comparing peak loads without context.

Ageing experiments likewise interrogate different degradation pathways. Water storage is not equivalent to thermocycling, staining is not wear, and surface roughness alone is not a validated surrogate for biofilm-associated clinical outcomes. Comparisons of printed and milled materials should document polymer chemistry, post-cure protocol, specimen finishing and degree-of-conversion measures, where available. Without these descriptors, an apparent technology ranking may reflect specimen preparation rather than the manufacturing route.

A clinically informative research sequence proceeds from controlled material-state characterisation to restoration-level mechanical and surface tests and then to adequately followed patient outcomes. The review should explicitly identify where that chain is broken. Short-term laboratory equivalence can justify further investigation, but not a claim of long-term clinical equivalence or universal suitability.

Critical synthesis: ageing pathways and endpoint comparability

Permanent dental restorations experience water uptake, hydrolytic change, thermal cycling, antagonist abrasion, biofilm exposure and repeated occlusal loads simultaneously. Short-term flexural strength and static fracture resistance cannot alone predict wear, marginal integrity or service life. Studies should be grouped by restoration geometry, post-curing schedule, manufacturing route and ageing exposure rather than pooled solely by the label printed resin.

Wear data require specification of the antagonist, contact force, sliding distance, lubrication, temperature and surface-finishing history. Marginal-gap measurements require stated segmentation or optical measurement resolution and an agreed region of interest. Colour change should distinguish pigment or matrix alteration from surface roughness and staining. Without these conditions, numerical comparisons risk presenting methodological differences as material differences.

A responsible clinical synthesis distinguishes laboratory surrogate endpoints from prospective longevity, retreatment and adverse-event outcomes. It should report which outcomes were directly observed, the duration of follow-up and the role of clinical selection. The appropriate conclusion is conditional on an identified resin, cure protocol, restoration type and monitoring period; it is not a material-class-wide longevity claim.

16. Limitations

It is an evidence-state review, not a claim that wear, biofilm or long-term clinical performance are established for vat-photopolymerised dental prostheses.

17. Conclusions

Published reviews now permit a more developed assessment of dental vat-photopolymerisation, optical stability, laboratory mechanics and crown-level marginal adaptation. The 2026 crown meta-analysis found lower fracture resistance in the printed groups under defined comparisons and strongly method-dependent marginal gap results [4]. Neither result establishes universal clinical inferiority or superiority. Direct long-term clinical outcome evidence, and matched wear and biofilm results for the same final material states, remain necessary for corresponding claims.

Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. The company develops and supplies photoresins and related process materials. No proprietary formulation, manufacturing sequence, process window or comparative product recommendation is disclosed.

Data availability

No new experimental dataset was generated.

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