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Hybrid CAD/CAM Ceramics in Prosthodontics — A Narrative Review

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Abstract

Hybrid restorative materials combine ceramic and polymer phases to support conservative prosthodontic treatment. This narrative review examines their classification, microstructure, mechanical and optical behaviour, bonding, aging and clinical performance. Polymer-infiltrated ceramic networks contain interconnected ceramic and polymer phases, whereas dispersed-filler resin composites contain ceramic particles within a continuous polymer matrix. These structural differences influence stiffness, fracture behaviour, machinability and surface conditioning. Laboratory studies demonstrate favourable milling characteristics and damage tolerance, but material-dependent water sorption, discoloration and adhesive degradation remain concerns. Clinical investigations support selected inlays, partial coverage restorations and single crowns. A recent study of tooth-wear rehabilitation reported follow-up extending to nine years, although its small patient sample and observational design limit generalisation. Survival must also be distinguished from complication-free success, because restorations may remain functional after polishing or repair. Surface treatment should follow the specific material's instructions rather than a common protocol for all hybrid blocks. Hybrid materials are useful options for adhesive, minimally invasive restorations but cannot be assumed to replace lithium disilicate or zirconia across all indications. Further comparative clinical trials should report material-specific survival, maintenance requirements and patient-centred outcomes.

Keywords: Hybrid Ceramics; Computer-Aided Design; Polymer-Infiltrated Ceramic Network; Resin Composites; Adhesive Dentistry; Prosthodontics.

Introduction

Computer-aided design and computer-aided manufacturing (CAD/CAM) have broadened the range of indirect restorative materials available to prosthodontists. Ceramic and ceramic-like materials differ substantially in their constituent phases, making composition more

informative than commercial terminology when comparing their behaviour.[1] Incorporating a polymer phase into a ceramic network can increase deformation before fracture and alter crack propagation, providing a rationale for conservative adhesive restorations.[2]

The term "hybrid ceramic" is used inconsistently. This review distinguishes polymer-infiltrated ceramic network (PICN) materials from dispersed-filler resin composite blocks while recognising that both may be grouped within resin-matrix ceramics.[1] It critically discusses their structure, properties, bonding, aging and clinical applications. The synthesis is narrative rather than systematic; it does not provide pooled estimates or formal evidence grades.

Classification and microstructure

PICN materials consist of a porous ceramic scaffold infiltrated with polymer, producing two interpenetrating networks. Microstructural examination of VITA Enamic (VITA Zahnfabrik, Bad Säckingen, Germany) confirmed this architecture, and properties intermediate between porcelain and resin composite.[3] The ceramic framework contributes rigidity, while the polymer phase modifies the fracture response. Experimental PICNs showed greater crack deflection than dense ceramic, with properties varying according to ceramic network density.[2]

Dispersed-filler CAD/CAM composites instead contain ceramic particles within a continuous polymer matrix. Their performance should not be inferred from PICN studies. Comparative testing has demonstrated significant differences in flexural strength, modulus, resilience and milled margin quality among commercially available blocks.[4] Consequently, material selection requires identification of the actual microstructure, rather than reliance on the terms "hybrid" or "nanoceramic".

Mechanical performance and machinability

Flexural strength, elastic modulus and fracture toughness describe different aspects of performance and should not be treated as interchangeable measures. Coldea et al. reported flexural strengths of 131–160 MPa and elastic moduli of 16.4–28.1 GPa for experimental PICNs of different ceramic densities.[2] In a commercial PICN, Della Bona et al. measured an elastic modulus of approximately 38 GPa and fracture toughness of 1.09 MPa√m using different methods.[3] These findings illustrate why a single "dentin-like" modulus or toughness range cannot represent every hybrid material.

Awada and Nathanson found that the tested resin-based blocks combined comparatively low stiffness with favourable resilience and milled margin quality.[4] This supports their machinability but does not establish superior clinical longevity. Lower stiffness permits deformation under load; whether this benefits the restored tooth depends on restoration geometry, supporting tissues and the adhesive interface.

Fatigue testing adds information beyond a single load-to-fracture measurement. El Zhawi et al. observed substantial resistance to repeated contact loading in PICN crowns, but also identified chipping, bulk fracture and subsurface damage under accelerated testing.[5] Thus, polymer incorporation does not eliminate crack development. Laboratory loading protocols remain models of clinical behaviour rather than direct predictions of years of service.

Wear and optical behaviour

Wear should be evaluated for both the restoration and opposing enamel. Mörmann et al. found that several permanent CAD/CAM materials, including the tested hybrid ceramic, displayed two-body wear comparable to enamel under their experimental conditions. Toothbrushing reduced gloss and increased roughness in

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most groups.[6] These findings do not justify a universal claim that hybrid materials cause less antagonist wear than every conventional ceramic.

Colour stability is also material-dependent. In a coffee-thermocycling experiment, Acar et al. reported greater colour change for the tested resin nanoceramic than for PICN, while lithium disilicate showed the smallest change. Specimen thickness significantly influenced the results.[7] The practical implication is to consider surface finish, restoration thickness and anticipated staining exposure when selecting materials for visible regions. Laboratory discoloration should not be equated directly with inevitable clinical failure.

Aging and adhesive management

The polymer phase introduces susceptibility to water-related degradation. Wendler et al. found reduced fracture toughness after water storage in the tested CAD/CAM resin composites, while strength and fatigue responses differed among products.[8] Therefore, water sorption, fatigue and interfacial degradation require material-specific assessment; a favourable initial strength value cannot establish long-term stability. Aging protocols also differ between studies, restricting direct comparisons.

Bonding depends on surface topography, exposed phases and the resin-cement system. Elsaka demonstrated that the effects of conditioning and water storage on bond strength differed between PICN and resin nanoceramic specimens.[9] A single surface-treatment protocol is therefore inappropriate for all hybrid blocks. Comparisons of mechanical and chemical conditioning also show material-dependent responses.[10]

For silica-rich PICN, hydrofluoric-acid conditioning followed by silanisation is an established approach; for many dispersed-filler composites, controlled airborne-particle abrasion followed by the specified primer or adhesive is used. The exact etchant concentration, exposure time, abrasion parameters and coupling agent must follow the current instructions for the selected product.[9,10] Hydrofluoric-acid treatment of an indirect restoration must be performed extraorally. Isolation, surface cleanliness and a compatible cementation system remain essential to applying these protocols reliably.

Localised defects may be amenable to composite repair after appropriate surface conditioning. Elsaka reported differences in repair bond strength among repair systems applied to PICN.[11] This supports repair as a potential maintenance strategy, but laboratory bond strength alone does not establish the service life of a repaired restoration. Repairability should therefore be discussed as an advantage with an ongoing maintenance requirement.

6. Clinical performance and applications

Clinical evidence is more useful when outcomes are linked to a defined material and restoration type. In a prospective study of 103 PICN restorations in 47 patients, Spitznagel et al. reported three-year survival of 97.4% for inlays and 95.6% for partial coverage restorations. Corresponding success estimates were lower, at 84.8% and 82.4%, and marginal discoloration and roughness increased over time.[12] Survival therefore does not necessarily indicate an unchanged, intervention-free restoration.

A separate cohort involving 76 PICN single crowns in 34 patients reported estimated three-year survival of 93.9% and success of 92.7%. Four unacceptable fractures required replacement; neither secondary caries nor debonding was recorded during that observation period.[13] These results support selected single-crown use, but cannot establish equivalent outcomes for other resin-containing blocks or implant-supported crowns.

Longer follow-up is emerging. Oudkerk et al. evaluated 580 PICN restorations in 24 patients treated for tooth

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wear, with observation extending to nine years. Estimated nine-year survival was 98.4%, compared with success of 79.7%; minor chipping was the main complication. Posterior restorations and very thin areas had greater fracture risk.[14] The large number of restorations arose from a small patient cohort, with unequal follow-up and no randomised comparator, limiting generalisation.

Taken together, these clinical studies support a selective role for PICN in inlays, partial coverage restorations, single crowns and conservative tooth-wear rehabilitation.[12-14] They do not provide a basis for universal recommendations covering endocrowns, long-span bridges, cantilevers or extensive implant prostheses. Occlusal loading, remaining tooth structure, available restorative space, adhesive isolation and the product's authorised indications should guide individual decisions. Severe parafunction warrants particular caution rather than an automatic material choice based on stiffness alone.

Limitations and future perspectives

The evidence combines laboratory experiments with clinical cohorts that differ in restoration design, follow-up and definitions of failure. Material-dependent aging and bonding responses make pooled claims about all "hybrid ceramics" misleading.[8-10] This narrative review is also limited by selective literature coverage and the absence of systematic risk-of-bias assessment.

Future research should compare individual products and restoration types using standardised reporting of survival, complication-free success, repair frequency, antagonist wear and patient satisfaction. Trials should account for multiple restorations within the same patient and report the number remaining under observation. Development priorities include more stable polymer–filler interfaces and durable adhesion; proposed bioactive or self-healing formulations require clinical validation before therapeutic benefits can be claimed.

Conclusion

Hybrid CAD/CAM materials offer useful options for conservative adhesive prosthodontics, provided PICN and dispersed-filler composites are distinguished. Their machinability and potential repairability must be balanced against aging, staining and maintenance. Available clinical findings support selected PICN applications, but do not establish superiority over conventional ceramics or justify extension to every prosthodontic indication. Material-specific evidence, appropriate bonding and careful case selection remain central to their use.

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