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Review Article

Is it really not Necessary Retention and Resistance form of Cavity Preparation for Composite Restoration?

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Abstract

The question arises, given the introduction of adhesive dentistry, whether the classic mechanical concepts of retention and resistance form for composite resin restorations continue to hold. This systematic review critically evaluates clinical, laboratory, and finite element analysis evidence regarding the influence of cavity preparation design on the long-term clinical success of direct composite restorations. A systematic search of the databases PubMed, Scopus, and Web of Science was conducted to identify the relevant studies for this review. Taken together, the available evidence indicates that, despite today's adhesive systems affording excellent adhesion to the tooth, restorations placed without proper retention and resistance form fail significantly more often in high-stress, multi-surface, or high C-factor cavities. In contrast, small Class I and Class III cavities with margins in enamel and non-carious cervical lesions without occlusal wear facets seem to be predictably restored, even with adhesive-only preparations, over the short to medium term. This is especially true for restorations placed in high C-factor cavities, non-carious cervical lesions with occlusal wear facets, and severely compromised teeth. This evidence shows that retention and resistance forms are important factors in increasing the longevity of restorations, decreasing the risk of catastrophic fracture, and allowing the possibility of restoration repair. Adhesive systems should be considered supplements to mechanical retention and not replacements for it; however, the required amount of mechanical features is approached from a risk-stratified rather than an absolute approach.

Introduction

The advent of acid etching and adhesive systems ushered in a new era in restorative dentistry. For the first time, composite resins could be bonded directly to the tooth structure [1]. Consequently, in this new era of minimally invasive cavity preparation, many clinicians accepted that the traditional concepts of mechanical retention and resistance form in operative dentistry, as established by G.V. Black, might not apply to composite restorations [2].

Nowadays, modern adhesive systems vary from traditional multi-step etch-and-rinse to universal adhesives, allowing more modes of application [1]. Moreover, today's composite materials have superior mechanical properties, decreased polymerization shrinkage, and better wear resistance [1,3]. Consequently, this has enabled direct composite restorations to be indicated in more cases, including large cusp-replacing restorations and endodontically treated teeth [4,5].

However, the main question is still: Is adhesion enough to ensure the longevity of restorations? More clinical and laboratory studies have indicated that this is not the case. Occlusal loading is cyclic; the oral cavity experiences extreme temperature changes, and the adhesive interface is continuously exposed to hydrolytic and enzymatic degradation [6,7]. Therefore, even the best adhesive interface will deteriorate over time, and restorations without additional mechanical retention may fail earlier under certain conditions [8].

G.V. Black's original cavity preparation concepts emphasized mechanical retention through undercuts, dovetails, and parallel walls [2]. Retention form prevents dislodgement along the path of insertion, while resistance form prevents fracture

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of the restoration or tooth under masticatory loads [2]. The introduction of adhesive systems theoretically eliminated the need for mechanical retention by creating micromechanical and chemical bonds to enamel and dentin [1]. However, early adhesion studies reported high failure rates, prompting refinements in both materials and techniques. Current universal adhesives containing functional monomers such as 10-MDP provide reliable bonding to multiple substrates [9]. Nevertheless, laboratory bond strengths do not necessarily predict clinical performance, as aging, moisture, and cyclic loading compromise adhesive interfaces [6].

This review aimed to critically discuss whether retention and resistance forms are needed for composite restorations. It is based on data from clinical trials, in vitro studies, and finite element analyses and discusses situations where an adhesive-only approach would be sufficient.

Methods

Two independent reviewers systematically searched the literature in the PubMed/MEDLINE, Scopus, and Web of Science databases for articles published between January 2000 and December 2026. The search string used was: (“cavity preparation” OR “retention form” OR “resistance form” OR “cavity design”) AND (“composite restoration” OR “resin composite” OR “adhesive restoration”) AND (“clinical survival” OR “fracture resistance” OR “retention rate”).

The inclusion criteria were clinical studies with a minimum follow-up of 2 years; in vitro studies with a standardized protocol; finite element analysis studies with validation of the model against experimental data; and the English language. Case reports, expert opinions, studies on primary teeth, and clinical studies with follow-up of less than one year were excluded.

Results and discussion

Evidence for retention form

Clinical Studies on Non-Carious Cervical Lesions: Non-carious cervical lesions (NCCLs) represent ideal test cases for adhesive-only restorations, as they lack mechanical retention features. Oginni and Adeleke [10] compared composite restorations in NCCLs with and without occlusal wear facets over two years. The retention rate was significantly lower in lesions with occlusal wear facets (63.9%) compared to those without (74.4%), despite identical adhesive protocols. The cumulative survival at two years was 46.5% versus 61.2%, respectively. Within the limitations of a two-year clinical study, adhesive retention on its own may not be able to withstand the premature failure caused by occlusal stress directed toward the cervical region. The authors conclude that differentiating stress-induced lesions (with wear facets) from other cervical lesions is very important clinically, as the former may require additional mechanical considerations.

Core Material Studies: Michalakis et al. [8] investigated retention and resistance of maxillary premolars restored with cast metal crowns, comparing no core material versus amalgam or composite resin cores. Teeth that lost more than half of their coronal structure but retained a minimum 2 mm axial wall height – providing natural mechanical retention – demonstrated significantly higher failure loads than those restored with artificial cores. Mean tensile failure loads were 381.02 N (no core), 277.34 N (amalgam core), and 250.77 N (composite core). Compressive failure loads followed the same pattern: 741.21 N, 584.75 N, and 465.78 N, respectively.

Crucially, in specimens without core material, only one interface (cast restoration/tooth) was prone to failure, whereas in core-restored groups, two weak interfaces existed (cast restoration/core material/tooth). This is more evidence supporting the preservation of natural tooth tissue for mechanical retention instead of relying on bonding to core materials.

Self-Adhering Composites: Farshad et al. [11] reviewed self-adhering composites designed to eliminate separate adhesive steps. Although these materials simplify procedures, they exhibited higher microleakage in several studies compared to conventional composites used with etch-and-rinse or self-etch adhesives. A systematic review similarly concluded that self-adhering composites show reduced bonding durability under aging protocols [12]. The review concluded that while self-adhering composites may be adequate for conservative restorations in low-stress areas, their reliability for larger or high-stress restorations remains uncertain due to inferior bonding performance, highlighting that eliminating mechanical retention features cannot fully compensate for reduced adhesive efficacy.

Evidence for resistance form

Cavity Design and Fracture Strength: Susila Anand et al. [13] compared box-shaped versus concave (U-shaped) cavity designs with a 4-degree taper using empirical testing and finite element analysis. The concave design demonstrated significantly higher compressive strength (49 MPa versus 33 MPa for the box design) regardless of the composite material used. Finite element analysis showed 59% improvement in strength with the concave design. Critically, when the box cavity was used, material properties significantly affected strength values; when the concave design was used, there was no difference between materials. Thus, an appropriate design, which relates to the resistance form, may compensate for the disadvantages of some materials, but material properties alone will lead to unpredictable behavior when a preparation design is not appropriate.

Preparation, Design, and Failure Patterns: Hofsteenge et al. [14] evaluated four preparation designs in compromised molars: undermined inlay (70% intercuspal width), extended inlay (100% width), restricted overlay (1.5 mm cusp coverage), and extended overlay (4 mm cusp coverage). Although no significant difference in fracture strength was observed among groups, failure modes differed dramatically. Cusp coverage restorations (restricted and extended overlay) exhibited significantly more destructive failures and were less often repairable compared to inlay preparations. The restricted

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overlay group had only 18.8% repairable failures versus 75% for undermined inlay and 81.3% for extended inlay.

Finite element analysis showed that inlay preparations exhibited greater tooth deformation (99 and 104 × 10^{-4} mm) compared to overlay preparations (92 and 72 × 10^{-4} mm). Higher tooth deformation correlated with less stress concentration in the root and more favorable (repairable) fractures. Thus, the authors concluded that even a tooth with undermined cusps should be restored without cusp coverage; resistance form is gained through remaining cusp tissue and not by restoring the tooth with artificial cusp coverage to prevent catastrophic failure.

MOD Cavity Dimensions: Başgül et al. [4] evaluated endodontically treated teeth restored with MOD preparations, retention slots, or cuspal coverage preparations using nano-hybrid composite, short fiber-reinforced composite, or CAD/CAM nano-ceramic blocks. MOD preparations exhibited significantly higher marginal deterioration at both the gingival and occlusal margins compared to the retention slot or cuspal coverage groups. Regarding fracture resistance, MOD cavities showed significantly lower values (mean 964.5-1275.8 N depending on material) compared to retention slots (1425.3-2013.6 N) or cuspal coverage (1473.7-2415.1 N). Notably, non-restorable fractures occurred significantly more frequently in the cuspal coverage group, consistent with Hofsteenge et al. [14]. A similar finding was reported by Gunwal MK et al. [15] in an in vitro study of MOD cavities restored with composite. In conclusion, the study recommended short fiber-reinforced composite restoration after cuspal coverage preparation for better fracture resistance and marginal adaptation in MOD cavity endodontically treated teeth; however, when cusp coverage is not possible, retention slot preparations may be considered.

Deep Cavities and High C-Factor: Wafaie et al. [16] compared the fracture resistance of molars with Class II MOD cavities restored with bulk-fill, no-cap flowable bulk-fill, and conventional resin composites. Intact teeth demonstrated the highest fracture resistance (2969 N immediate, 2798 N delayed). Among restored groups, bulk-fill and conventional composites showed superior fracture resistance to the no-cap flowable bulk-fill composite. The effect of 6-month water storage was significant in decreasing the fracture resistance of all groups, confirming that adhesive interfaces can be deteriorated with time and that restorations without mechanical resistance features are among the most affected in this laboratory model.

Endodontic Access Cavity Design: Ninkovic et al. [17] investigated minimally invasive truss access cavities (preserving dentinal bridge) compared to traditional endodontic access cavities with cuspal reduction. TREC design showed significantly higher fracture resistance than TEC but also produced more unrestorable fractures (55% versus 25%). The study demonstrated that adaptation with high-viscosity fiber-reinforced composite is difficult in TREC, increasing porosity, especially open porosity, at the interface with tooth tissue. Therefore, even when advanced materials are used, the design of the cavity influences adaptation, and preservation of tooth tissue for resistance may not result in better outcomes if there are difficulties in adapting materials.

Patient and operator factors as confounding variables

DeMarco et al. [5] reviewed 33 long-term studies on the longevity of composite restorations and concluded that variations between composite materials should not affect restoration longevity if materials are adequately handled. The number of restored surfaces – directly related to cavity size and complexity – reduced longevity in 75% of studies. A 17-year prospective evaluation confirmed that restoration failure correlates more strongly with cavity size than with material type [18]. These findings imply that retention and resistance are not theoretical mechanical concepts but relate to clinical outcomes, as larger restorations involving multiple surfaces tend to fail more frequently regardless of the adhesive used.

Ulku and Unlu [19] retrospectively evaluated 189 posterior composite restorations, finding that secondary caries correlated with elevated plaque scores, and multi-surface restorations faced a higher failure risk. Notably, Class V restorations showed the highest failure rate (23.53%), challenging the direct relationship between the number of surfaces and failure. This review concluded that self-adhering composites may be used to restore low-stress areas conservatively; however, due to their poorer bonding performance, their reliability in large or high-stress restorations is questionable. These results highlight that the reduction or absence of mechanical retention features cannot be compensated for by the sole use of adhesion in many clinical scenarios.

Clinical scenarios where adhesive retention alone may suffice

The present review focuses on situations requiring mechanical retention, but contemporary evidence also identifies some scenarios where adhesive-only preparations demonstrate acceptable short-to-medium term outcomes:

Small Class I cavities with enamel margins (≤1/3 intercuspal distance, occlusal contact-free areas): It was noted that self-adhering composites in such low-stress cavities showed comparable 2-year retention to conventional composites with separate adhesive steps [11,12,20].

Class III cavities: The low C-factor geometry and absence of direct occlusal loading make mechanical undercuts unnecessary, provided meticulous enamel etching is achieved [1].

NCCLs without occlusal wear facets: It reported that NCCLs without wear facets had 74.4% 2-year retention with adhesive-only preparation—substantially higher than the 63.9% in wear facet-present lesions [10,21]. This suggests that occlusal stress direction, not NCCL presence per se, determines retention needs.

Limitations of this list: Long-term data (≥5 years) remain unavailable for most of these exceptions, and patients with parafunctional habits were excluded from the supporting studies.

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Synthesis and clinical recommendations

Most of the evidence presented indicates that current adhesive systems have improved bonding to an extent that retention and resistance forms can be reduced in some situations, but they are never eliminated. The essential clinical recommendations are summarized in Table 1.

- **Clinical recommendations**Small Class I and III cavities with margins on enamel in low-stress areas may only require adhesive preparations for up to 3-5 years, though longer follow-up is needed.
- Class II, IV, and V cavities should include mechanical retention features such as undercuts, grooves, and slots. These apply to high C-factor or high-stress situations.
- Bulk-fill composites do not eliminate the need for resistance form; cavity design remains critical regardless of material type.
- When possible, preserve cusps instead of providing cusp coverage; fractures are more easily repaired in inlay preparations.
- In endodontically treated teeth, retention slots may sometimes eliminate the need for full cusp coverage, depending on biomechanical considerations.
- All internal line angles should be rounded to avoid areas of stress concentration.

Limitations and future research

Most of the included studies are short- to mid-term in duration (2-5 years) at best, while clinical failures typically occur later. Moreover, high-risk patients such as bruxers or those with poor oral hygiene were systematically excluded, further limiting the external validity of the findings. Another important limitation relates to the inconsistent use of definitions for retention and resistance forms, which prevented meta-analyses. In addition, in vitro studies cannot realistically simulate the clinical environment.

Based on this, future studies should focus on long-term RCTs (≥ 10 years) on adhesive-only versus mechanically retained cavity preparations; the definition and standardization of terms regarding cavity design; and the development of an aging protocol that combines cyclic loading, thermocycling, and an enzymatic challenge.

Table 1: Summary of evidence: necessity of retention and resistance form in different clinical scenarios.

Clinical situation	Retention form necessary	Resistance from necessary
Small Class I (enamel margins)	Low	Low
Class II (proximal box)	Moderate (retention grooves)	High (rounded internal angles)
Class V (NCCL) with wear facet	High	Moderate
Endodontically treated premolar (MOD)	High (retention slots)	High (cusp coverage or slots)
Compromised molar with undermined cusp	Moderate (undercut)	High (preserve cusp rather than overlay)
Deep MOD (high C-factor)	High	High

Conclusion

Mechanical retention and resistance forms will remain highly advisable for most stress-bearing, multi-surface, and high C-factor cavities, even with today's adhesive systems. However, some small Class I and Class III restorations with enamel margins and some NCCLs without occlusal wear facets may be restored for up to 2 to 5 years with an adhesive-only preparation.

Therefore, the retention of adhesives to mechanical retention does not represent an actual replacement of retention; cavity preparation should involve balancing conservation with adequate retention/resistance features to each specific clinical case.

Author contributions

Hong-Jin Yu conceptualized the study, conducted the literature review, drafted the manuscript, and contributed to data interpretation and manuscript revision. Chol-Jun Hwang, Hong-Jin Pak, Song-Man Sin, Yong-Ho Kim, Rong-Jo Paek, and Kum-Hyok Choe contributed to the scientific review, critical revision of the manuscript, interpretation of evolutionary and geriatric concepts, and final approval of the submitted version. All authors read and approved the final manuscript.

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Conflict of interest statement

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Ethical considerations

This manuscript is a narrative review based exclusively on previously published literature and publicly available scientific sources. No human participants, animals, clinical samples, or confidential patient data were directly involved in this study. Therefore, ethical approval and informed consent were not required. The authors have ensured that all referenced studies were appropriately cited and discussed in accordance with academic and ethical publishing standards.

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