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BIOMIMETIC RESTORATIVE DENTISTRY: INTEGRATED LABORATORY AND CLINICAL ASSESSMENT OF STRENGTH, MARGINAL ADAPTATION, PULP VITALITY AND RESTORATION SURVIVAL

Shakhnoza K. Musashaykhova,
Gulrukh B. Ishniyazova
Tashkent State Medical University, Tashkent, Uzbekistan

Abstract

Objective. To provide a holistic evaluation of biomimetic restorative approaches versus conventional methods in terms of mechanical strength, marginal seal, maintenance of pulp vitality, and 12-month clinical survival.

Results. Biomimetic combinations showed higher strength (compression 255–268 MPa, flexure 135–142 MPa) compared with the conventional scheme (210 and 98 MPa respectively; $p<0.001$). Mean microleakage score decreased from ~2.0 to 0.6. Post-thermocycling strength loss was ≤5% in biomimetic groups versus ~12% in conventional. Clinically at 12 months, pulp vitality was preserved in 96.7% of biomimetic cases versus 83.3% in conventional; restoration integrity — 100% vs 86.7% [6–8].

Keywords: Biomimetic restoration; composite materials; microleakage; pulp vitality; fatigue resistance; restoration survival.

Introduction

Conventional restoration of tooth hard tissues has historically involved substantial cavity preparation with loss of intact structure and a risk of functional failure. The current paradigm favors minimally invasive, biomimetic restoration aimed at reproducing not only morphology but also the gradient of mechanical properties in enamel and dentin, along with their hydration and structural features

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[1–4]. Key open questions include the resilience of such restorations to thermomechanical loads and the influence of adhesive protocols on pulp vitality in deep lesions [6–8].

Materials and Methods

Study design. Two-stage study: a laboratory experiment followed by a randomized controlled clinical trial (two parallel arms). Materials. Composites and adhesives: Filtek Z250 (3M ESPE), SDR Flow+ (Dentsply Sirona), Enamel Plus HRi (Micerium); adhesive systems: Single Bond 2 (3M), OptiBond FL (Kerr), Scotchbond Universal (3M). Where required, specify composition (filler type/size, resin components, presence of fluoride-releasing/bioactive additives).

Laboratory procedures. Sixty extracted human premolars were used (stored in thymol solution). Standardized cavities were prepared and allocated to groups: Group C (conventional): Filtek Z250 + Single Bond 2; Group B1 (biomimetic-1): SDR Flow+ + OptiBond FL; Group B2 (biomimetic-2): Enamel Plus HRi + Scotchbond Universal. Outcomes: compressive strength (MPa), three-point flexural strength, microleakage (dye penetration, scores 0–3), and fatigue resistance after thermocycling (5–55 °C, 10,000 cycles) [6,8].

Clinical trial. Sixty patients aged 20–40 years with deep caries (middle/deep dentin) and confirmed pulp vitality were randomized to conventional or biomimetic tactics. Protocol included incremental placement (≤2 mm per increment) with liners as indicated. Diagnostics: OCT for marginal adaptation; DIAGNOdent for residual demineralization; photo protocol. Follow-ups at 3, 6 and 12 months; EPT, sensitivity questionnaires, assessment for secondary caries and restoration defects [5,7].

Statistics. Data are mean±SD; normality by Shapiro–Wilk. Between-group comparisons: one-way ANOVA (laboratory outcomes), independent-samples t-test (clinical), nonparametric analogs if assumptions violated. Survival by Kaplan–Meier with log-rank test; correlations by Pearson/Spearman. Significance threshold $p<0.05$.

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Results

Laboratory stage. Biomimetic groups outperformed the conventional group in compressive and flexural strength ($p<0.001$). After thermocycling, the most pronounced strength reduction was noted with the conventional scheme (≈12%) and was minimal with biomimetic schemes (≤5%) [6,8].

Clinical stage. At 12 months, pulp vitality was retained in 96.7% of biomimetic cases versus 83.3% of conventional; restoration integrity was 100% vs 86.7%. Absence of secondary caries was 96.7% in biomimetic and 80% in conventional. Kaplan–Meier curves confirmed 100% survival for biomimetic restorations at month 12 versus 86.7% for conventional [7].

Group	Compressive strength, MPa (±SD)	Flexural strength, MPa (±SD)	Microleakage (score)	Post-thermocycling strength
Conventional (C)	210 ± 15	98 ± 8	2.0 ± 0.3	185 (−12%)
Biomimetic-1 (B1)	255 ± 12	135 ± 10	0.9 ± 0.2	245 (−4%)
Biomimetic-2 (B2)	268 ± 10	142 ± 11	0.6 ± 0.1	255 (−5%)

Discussion

The advantages of biomimetic schemes likely stem from several factors: a gradient elastic modulus that reduces stress concentration; modern adhesive protocols that ensure reliable bonding to enamel and dentin; and fine fillers that support more complete polymerization and lower shrinkage [1–4]. Thermocycling highlighted between-group differences: strength retention was markedly higher with biomimetic approaches, consistent with literature on fatigue resistance and microleakage [6,8].

Outcome (12 months)	Conventional, %	Biomimetic, %
Pulp vitality preserved	83.3	96.7
No postoperative sensitivity	71.0	93.3
Restoration integrity (no defects)	86.7	100
No secondary caries	80.0	96.7

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The clinical outcomes — high preservation of pulp vitality and defect-free restorations — align with RCT data on long-term performance of biomimetic composites [5,7]. Practically, this supports prioritizing biomimetic tactics for deep caries when the adhesive protocol is strictly respected.

Conclusion

Biomimetic restorative technologies provide clinically and statistically significant advantages in strength, marginal adaptation, and biological tissue preservation. At 12 months, biomimetic restorations achieved 100% survival versus 86.7% for conventional, and pulp vitality was preserved in 96.7% of cases. These findings support prioritizing the biomimetic approach for deep caries with maintained pulp vitality.

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