

Wear Resistance and Longevity of Contemporary Dental Restorative Materials

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Abstract: The durability of dental restorative materials is critical for maintaining oral function, aesthetics, and patient satisfaction over time. Contemporary materials, including composite resins, glass ionomer cements, ceramics, resin-modified glass ionomers, hybrid ceramics, and high-strength polymers, offer diverse mechanical properties and wear resistance profiles suitable for posterior and anterior restorations. This study aims to evaluate the wear resistance, surface degradation, and long-term clinical performance of commonly used dental restorative materials under simulated masticatory conditions and in vivo follow-up. A total of 200 restorations were evaluated over a five-year period, including direct composite restorations, indirect CAD/CAM ceramic inlays/onlays, and glass ionomer restorations. Wear measurements were assessed using profilometry, digital imaging, and clinical evaluation scales, while longevity was recorded through survival analysis of restoration integrity, fracture, marginal adaptation, and secondary caries incidence. Results indicate that high-strength ceramics and hybrid CAD/CAM materials exhibit superior wear resistance and minimal surface degradation, maintaining functional and aesthetic integrity over time, whereas conventional composite resins

demonstrate moderate wear, influenced by filler content, polymerization technique, and occlusal load. Glass ionomer-based materials display faster surface wear, especially under heavy occlusal stress, but offer fluoride release and ease of repair. Overall, material selection should balance mechanical performance, aesthetic requirements, and clinical handling characteristics to optimize long-term restoration success. This comprehensive evaluation highlights the importance of evidence-based material choice, patient-specific occlusal assessment, and regular monitoring to ensure longevity and functional outcomes.

Keywords: Wear resistance, Longevity, Dental restorative materials, Composite resins, Ceramics, Glass ionomer cements, Hybrid ceramics, CAD/CAM restorations, Surface degradation, Clinical performance, Occlusal load

Introduction: Dental restorative materials must withstand complex functional and environmental challenges, including masticatory forces, thermal changes, chemical exposure, and microbial activity. Wear resistance and long-term durability are fundamental to preserving occlusal integrity, preventing secondary caries, and maintaining patient aesthetics. Contemporary dental materials offer varied compositions, from traditional amalgam to high-performance ceramics and hybrid resins, each with unique advantages and limitations. Composite resins provide aesthetic adaptability but are susceptible to polymerization shrinkage and gradual surface wear. Glass ionomer cements offer chemical adhesion to tooth structure and fluoride release but lower mechanical strength. Ceramics, particularly zirconia and lithium disilicate, demonstrate superior hardness, wear resistance, and aesthetic properties, yet their brittleness and cost can limit use. Hybrid CAD/CAM materials combine ceramic and polymer benefits, offering fracture resistance and ease of milling, while resin-modified glass ionomers improve mechanical stability while retaining chemical bonding and fluoride release. Understanding the wear mechanisms, including abrasive, adhesive, fatigue, and corrosive wear, is critical for predicting material performance and guiding clinical decisions. This study evaluates contemporary restorative materials in terms of wear resistance, mechanical longevity, surface degradation, and overall clinical success to inform evidence-based material selection and improve patient outcomes.

Materials and Methods: Two hundred restorative samples were included, representing direct composite resins, glass ionomer cements, resin-modified glass ionomers, hybrid ceramics, high-strength CAD/CAM ceramics, and polymer-based materials. Standardized cavity preparations were performed, followed by restoration using manufacturer-recommended protocols, including incremental placement, polymerization with LED curing units, and polishing procedures. Wear resistance was evaluated using in vitro mastication simulators applying cyclic loading equivalent to five years of clinical function, combined with thermal cycling between 5°C and 55°C. Surface roughness and volume loss were measured with 3D profilometry and optical scanning techniques. In vivo assessment included 120 restorations placed in patients with varying occlusal forces, evaluated at six months, one year, three years, and five years for surface wear, marginal

adaptation, fracture incidence, secondary caries, and color stability. Statistical analysis included repeated measures ANOVA for wear comparisons, Kaplan–Meier survival analysis for longevity, and regression modeling to identify material-specific predictors of clinical performance. Ethical approval and informed consent were obtained prior to patient enrollment.

Materials: 1. Microhybrid composite resins characterized by high filler loading and particle size distribution for enhanced wear resistance, stored in light-proof containers to prevent premature polymerization. 2. Nanohybrid composite resins offering improved polishability and aesthetic properties, stored at controlled room temperature to maintain material integrity. 3. Conventional glass ionomer cements providing chemical adhesion and fluoride release, stored in dry, cool conditions to prevent moisture contamination. 4. Resin-modified glass ionomers combining polymerization-based mechanical reinforcement with ionic bonding, stored under manufacturer-recommended conditions to preserve shelf life. 5. Lithium disilicate ceramics for CAD/CAM indirect restorations, exhibiting high flexural strength and translucency, stored in protective packaging to prevent chipping. 6. Zirconia-based ceramics offering high fracture toughness and wear resistance, requiring storage in controlled humidity and temperature environments. 7. Hybrid CAD/CAM blocks integrating ceramic and polymer matrices to balance strength, resilience, and milling efficiency, stored in original protective sleeves. 8. High-impact polymer-based restorative materials designed for occlusal stress absorption, stored away from UV exposure and heat. 9. Bulk-fill composite resins facilitating deep cavity restoration with controlled polymerization shrinkage, stored in original syringes with caps tightly sealed. 10. Adhesive bonding systems including etchants, primers, and bonding resins, essential for restoration retention and durability, stored at recommended temperatures and away from direct sunlight.

Results: In vitro testing revealed that lithium disilicate and zirconia-based ceramics had the lowest volumetric wear, with mean loss of less than 50 μm over five simulated years, while conventional composites showed moderate wear averaging 120 μm and glass ionomers exhibited the highest wear of 200 μm . Surface roughness remained minimal in ceramics, whereas composites showed gradual increase over repeated loading cycles. In vivo assessments correlated with laboratory findings; ceramic restorations maintained occlusal morphology and aesthetics, with only minor chipping in 2% of cases. Composite resins required minor adjustments due to localized wear in 15% of cases. Glass ionomer restorations demonstrated significant occlusal flattening in 25% of patients, particularly in molar regions with high masticatory forces. Kaplan–Meier survival analysis indicated 95% five-year survival for ceramics, 88% for composites, and 75% for glass ionomers, with failure modes primarily due to fracture or secondary caries. Regression analysis highlighted occlusal load, material type, cavity depth, and patient parafunctional habits as significant predictors of wear and restoration longevity.

Discussion: The study confirms that material selection is pivotal for optimizing wear resistance and long-term performance. High-strength ceramics, particularly lithium disilicate and zirconia, provide exceptional resistance to surface degradation and occlusal wear, suitable for high-stress posterior restorations. Hybrid CAD/CAM materials offer a balance between mechanical resilience and milling efficiency, demonstrating promising performance in both anterior and posterior applications. Direct composites, while aesthetically favorable, are susceptible to gradual wear influenced by filler content, curing protocol, and occlusal forces; thus, regular monitoring and maintenance are recommended. Glass ionomer-based restorations are appropriate for low-stress applications or areas benefiting from fluoride release, but clinicians must anticipate increased surface wear and potential occlusal adjustments. Clinical longevity is directly related to proper material handling, cavity preparation, and occlusal load management, emphasizing the need for patient-specific treatment planning. This study highlights that integrating in vitro simulations with long-term clinical follow-up provides a robust understanding of material behavior, guiding evidence-based restorative dentistry.

Conclusion: Contemporary dental restorative materials exhibit a spectrum of wear resistance and clinical longevity, with ceramics demonstrating superior performance under functional loads and composites showing moderate durability influenced by material composition and occlusal forces. Glass ionomer materials provide chemical adhesion and fluoride release but are more prone to surface wear under high stress. Hybrid CAD/CAM materials offer balanced mechanical properties suitable for both anterior and posterior restorations. Long-term success requires careful material selection based on occlusal demands, aesthetic requirements, and patient-specific factors, combined with meticulous clinical protocols and regular follow-up. Incorporating comprehensive wear assessment and longevity evaluation ensures optimal restoration performance, enhances patient satisfaction, and reduces the need for frequent repairs or replacements. Future studies should investigate emerging nanocomposites, bioactive restorative materials, and digital workflow integration to further improve clinical outcomes and durability.

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