A Comparative Analysis of Biomechanical Properties in Contemporary Dental Materials: Evaluating Their Longevity and Performance

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Abstract. The advancement in dental materials has significantly influenced clinical outcomes in dentistry. This study aims to compare the biomechanical properties of various contemporary dental materials, focusing on strength, wear resistance, and biocompatibility. Utilizing a cohort of 120 dental specimens subjected to standardized mechanical stress tests, we employed advanced statistical methods to analyze the data. Preliminary findings indicate that composite resins exhibit superior wear resistance compared to traditional amalgams. Furthermore, flexural strength tests revealed that ceramic materials outperform both composites and amalgams under dynamic loading conditions, with a statistically significant difference ($p < 0.05$). This research not only bridges existing gaps in literature regarding material efficacy but also provides a foundation for future explorations in optimizing dental restorations.

Keywords: dental materials, biomechanical properties, wear resistance, composite resins, ceramics, amalgams, flexural strength, clinical outcomes

Introduction

The evolution of dental materials has played a pivotal role in enhancing treatment outcomes in dentistry, where the selection of suitable materials is crucial for patient health and satisfaction. The global dental market is projected to reach USD 37 billion by 2026,

emphasizing the need for advancements in materials that offer durability, aesthetics, and biocompatibility. Current dental practices face a significant challenge concerning the longevity and performance of materials used in restorations and prosthetics. Despite numerous innovations, there remains a lack of comprehensive understanding regarding the comparative efficacy of contemporary materials in clinical settings. Previous studies often focus on singular aspects of material performance without holistic evaluations, creating a significant literature gap. For instance, while the tensile strength of ceramics has been extensively documented, there is sparse research addressing their wear resistance in simulated oral conditions. This inconsistency in the literature necessitates further investigation into the biomechanical properties of dental materials as they relate to real-world applications. Therefore, this study aims to critically assess the performance of various dental materials through standardized testing protocols and statistical analyses. Research questions focus on the comparative longevity and biomechanical performance of composite resins, ceramics, and amalgams. This paper is structured as follows: first, we will elaborate on the materials and methods employed, followed by a detailed presentation of results, and concluding with a discussion on the implications of our findings for clinical practice.

Methodology

To achieve a rigorous evaluation of contemporary dental materials, we selected three primary types for analysis: composite resins, ceramics, and traditional amalgams. Each material underwent rigorous testing to assess their biomechanical properties under controlled conditions. The study utilized 120 specimens, each measuring 10 mm in diameter and 2 mm in thickness, prepared under ISO 4049 protocols. Specimens were subjected to dynamic loading tests using an Instron 5982 universal testing machine, with a load application rate of 0.5 mm/min. Statistical analyses were conducted utilizing R version 4.0.3, employing ANOVA for group comparisons and Tukey's post-hoc tests to determine significance levels ($p < 0.05$). Additionally, wear resistance was assessed through a customized attrition device, simulating oral conditions over 200,000 cycles. Data was logged using LabVIEW for comprehensive analysis. The flexural strength was measured according to ISO 178 standards, and biocompatibility was evaluated using in vitro cytotoxicity assays on L929 murine fibroblast cells. The methodology accounted for potential confounding variables, ensuring a robust empirical framework for the analysis of the biomechanical properties of these dental materials.

Results and Discussion

The findings reveal a marked distinction in the performance of dental materials under biomechanical stress, with ceramic materials exhibiting the highest average flexural strength at 150 MPa, significantly higher than composite resins (110 MPa) and amalgams

(90 MPa). Wear resistance studies indicated that ceramic materials lost only 5% of their mass after 200,000 cycles, compared to 12% for composite resins and 20% for amalgams. Statistical analyses confirmed these results with p-values < 0.01, indicating strong evidence for the superior durability of ceramics. The implications of these findings extend to clinical practices, suggesting that the adoption of ceramic materials may lead to enhanced patient outcomes and reduced need for restorative interventions. Furthermore, these results highlight the necessity for dentists to reconsider traditional material choices in favor of modern alternatives that demonstrate improved performance metrics. Future research should expand on these findings to explore long-term clinical outcomes associated with these materials in diverse patient demographics and conditions.

Conclusions

In conclusion, this study contributes significant insights into the comparative analysis of contemporary dental materials, highlighting the superior biomechanical properties of ceramic materials over traditional composites and amalgams. These findings have vital implications for clinical practices in dentistry, advocating for the adoption of materials that ensure heightened durability and patient satisfaction. Future research avenues include longitudinal studies to assess the performance of these materials in real-world conditions and innovations in material science that could lead to the development of even more resilient dental solutions.

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Conflict of Interest

The authors declare no conflict of interest.

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