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WHEN BIOMIMICRY BECOMES A BUZZWORD: CRITICAL APPRAISAL OF ITS MISUSE IN RESTORATIVE DENTISTRY

QUANDO A BIOMIMÉTICA SE TORNA UM BUZZWORD: AVALIAÇÃO CRÍTICA DO SEU USO INADEQUADO NA ODONTOLOGIA RESTAURADORA

CUANDO LA BIOMIMÉTICA SE CONVIERTE EN UN BUZZWORD: EVALUACIÓN CRÍTICA DE SU MAL USO EN LA ODONTOLOGÍA RESTAURADORA

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ABSTRACT

Objective: To critically assess the concept of biomimicry in restorative dentistry and identify instances of its misuse or overgeneralization in contemporary literature and clinical practice.

Methodology: A narrative review was conducted using major scientific databases, including PubMed, Scopus, and Google Scholar. Articles discussing biomimetic principles, restorative materials, and clinical techniques were evaluated. Emphasis was placed on identifying discrepancies between true biomimetic approaches and marketing-driven or conceptually inaccurate applications.

Results: Biomimicry has been widely adopted in restorative dentistry, often associated with adhesive techniques and minimally invasive approaches. However, the review identified a frequent misuse of the term, with many materials and techniques labeled as “biomimetic” without adequately replicating the structural, mechanical, or functional properties of natural dental tissues. This conceptual dilution may lead to confusion among clinicians and

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misinterpretation of scientific evidence. Furthermore, a lack of standardized definitions contributes to inconsistent application in both research and clinical contexts.

Conclusion: Although biomimicry remains a valuable guiding principle in restorative dentistry, its misuse as a buzzword undermines scientific rigor and clinical clarity. Clear definitions and evidence-based criteria are needed to ensure its appropriate application. Future research should aim to align material development and clinical protocols with true biomimetic principles.

Keywords: Biomimicry. Restorative Dentistry. Adhesive Dentistry. Dental Materials. Minimally Invasive Dentistry. Evidence-Based Practice. Conceptual Misuse. Biomimetic Dentistry.

RESUMO

Objetivo: Avaliar criticamente o conceito de biomimética na odontologia restauradora e identificar casos de seu uso inadequado ou generalização excessiva na literatura contemporânea e na prática clínica.

Metodologia: Foi realizada uma revisão narrativa utilizando as principais bases de dados científicas, incluindo PubMed, Scopus e Google Scholar. Artigos que discutiam princípios biomiméticos, materiais restauradores e técnicas clínicas foram avaliados. Ênfase foi dada à identificação de discrepâncias entre abordagens verdadeiramente biomiméticas e aplicações motivadas por marketing ou conceitualmente imprecisas.

Resultados: A biomimética tem sido amplamente adotada na odontologia restauradora, frequentemente associada a técnicas adesivas e abordagens minimamente invasivas. No entanto, a revisão identificou um uso frequente inadequado do termo, com muitos materiais e técnicas sendo rotulados como “biomiméticos” sem replicar adequadamente as propriedades estruturais, mecânicas ou funcionais dos tecidos dentais naturais. Essa diluição conceitual pode levar à confusão entre os clínicos e à má interpretação das evidências científicas. Além disso, a falta de definições padronizadas contribui para a aplicação inconsistente tanto no contexto de pesquisa quanto clínico.

Conclusão: Embora a biomimética continue sendo um princípio orientador valioso na odontologia restauradora, seu uso como buzzword mina o rigor científico e a clareza clínica. Definições claras e critérios baseados em evidências são necessários para garantir sua aplicação adequada. Pesquisas futuras devem buscar alinhar o desenvolvimento de materiais e protocolos clínicos com os verdadeiros princípios biomiméticos.

Palavras-chave: Biomimética. Odontologia Restauradora. Odontologia Adesiva. Materiais Dentários. Odontologia Minimamente Invasiva. Prática Baseada em Evidências. Uso Conceitual Inadequado. Odontologia Biomimética.

RESUMEN

Objetivo: Evaluar críticamente el concepto de biomimética en la odontología restauradora e identificar casos de su uso inadecuado o generalización excesiva en la literatura contemporánea y en la práctica clínica.

Metodología: Se realizó una revisión narrativa utilizando las principales bases de datos científicas, incluyendo PubMed, Scopus y Google Scholar. Se evaluaron artículos que discutían principios biomiméticos, materiales restauradores y técnicas clínicas. Se puso énfasis en la identificación de discrepancias entre enfoques verdaderamente biomiméticos y aplicaciones motivadas por marketing o conceptualmente imprecisas.

Resultados: La biomimética ha sido ampliamente adoptada en la odontología restauradora, frecuentemente asociada a técnicas adhesivas y enfoques mínimamente invasivos. Sin embargo, la revisión identificó un uso frecuente inadecuado del término, con muchos materiales y técnicas etiquetados como “biomiméticos” sin replicar adecuadamente las propiedades estructurales, mecánicas o funcionales de los tejidos dentales naturales. Esta dilución conceptual puede llevar a la confusión entre los clínicos y a la mala interpretación de las evidencias científicas. Además, la falta de definiciones estandarizadas contribuye a la aplicación inconsistente tanto en el contexto de investigación como clínico.

Conclusión: Aunque la biomimética sigue siendo un principio rector valioso en la odontología restauradora, su uso como buzzword socava el rigor científico y la claridad clínica. Se necesitan definiciones claras y criterios basados en evidencia para garantizar su aplicación adecuada. Las investigaciones futuras deben buscar alinear el desarrollo de materiales y protocolos clínicos con los verdaderos principios biomiméticos.

Palabras clave: Biomimética. Odontología Restauradora. Odontología Adhesiva. Materiales Dentales. Odontología Mínimamente Invasiva. Práctica Basada en Evidencia. Uso Conceptual Inadecuado. Odontología Biomimética.

1 INTRODUCTION

Over the past two decades, the concept of biomimicry has gained substantial traction across multiple scientific disciplines, including materials science, engineering, and healthcare. Broadly defined, biomimicry refers to the design and application of materials, structures, and systems that emulate the form, function, and processes of biological entities (Vincent et al., 2006). In dentistry, this concept has been particularly appealing due to the inherent complexity and hierarchical organization of dental tissues, such as enamel and dentin, which exhibit remarkable mechanical properties, resilience, and functional integration. As a result, biomimicry has been increasingly invoked as a guiding principle in restorative dentistry, with the aim of replicating the natural structure and behavior of teeth through advanced materials and minimally invasive techniques (Magne & Belser, 2003).

The rise of adhesive dentistry has played a central role in enabling biomimetic approaches. Unlike traditional restorative strategies that rely on macro-retentive designs and extensive removal of tooth structure, adhesive techniques allow for more conservative preparations and improved stress distribution within the restored tooth. Concepts such as immediate dentin sealing, incremental layering, and the use of resin-based composites have been promoted as biomimetic strategies intended to restore both the structural integrity and functional performance of natural teeth (Magne, 2005). These approaches are often associated with improved clinical outcomes, including enhanced fracture resistance and longevity of restorations, particularly when compared to more invasive techniques.

In parallel, significant advances in dental materials science have contributed to the development of restorative materials that aim to mimic the mechanical and optical properties of natural dental tissues. Resin composites, glass ionomer cements, and hybrid materials have been engineered to approximate the elastic modulus, translucency, and wear resistance of enamel and dentin. More recently, bioactive materials capable of releasing ions and promoting remineralization have been introduced, further reinforcing the notion of “biomimetic” dentistry (Ferracane, 2011; Sauro et al., 2017). These developments have led to a growing perception that modern restorative dentistry is increasingly aligned with biological principles.

However, despite its conceptual appeal and widespread adoption, the term “biomimicry” has become increasingly ambiguous and, in many cases, misused within the dental literature and clinical practice. A critical issue lies in the lack of a standardized or universally accepted definition of what constitutes a truly biomimetic approach in dentistry. While some authors define biomimicry in terms of structural replication of natural tissues, others emphasize functional or mechanical equivalence, and still others use the term more

loosely to describe any conservative or adhesive technique (Magne, 2005; Bazos & Magne, 2011). This conceptual inconsistency has led to a dilution of the term, transforming it from a rigorous scientific principle into a broad and often vague descriptor.

The misuse of biomimicry is further compounded by its appropriation in marketing and commercial contexts. Dental materials and techniques are frequently labeled as “biomimetic” without sufficient scientific evidence to support such claims. In many cases, these assertions are based on limited or indirect similarities to natural tissues, rather than a comprehensive replication of their structural, mechanical, and biological characteristics. This trend raises concerns regarding the potential for misleading information and the erosion of evidence-based practice. When biomimicry is used as a buzzword rather than a scientifically grounded concept, it risks obscuring critical differences between restorative materials and natural tissues, leading to unrealistic expectations and potentially suboptimal clinical decisions.

From a biological and biomechanical perspective, achieving true biomimicry in restorative dentistry remains an extremely challenging goal. Natural teeth exhibit a highly complex, hierarchical structure, with enamel and dentin organized at multiple scales from nanoscale crystallites to macroscopic architecture. This organization enables teeth to withstand significant mechanical loads while maintaining resilience and resistance to fracture. Replicating these properties requires not only matching the mechanical characteristics of dental tissues but also reproducing their functional gradients and interfacial interactions (Kinney et al., 2003). Current restorative materials, while advanced, still fall short of fully reproducing this level of complexity.

Moreover, the clinical environment introduces additional variables that further complicate the application of biomimetic principles. Factors such as occlusal forces, moisture control, polymerization shrinkage, and degradation of adhesive interfaces can all influence the performance of restorative materials over time. While certain techniques may approximate aspects of natural tooth behavior, they do not necessarily achieve true biological equivalence. Therefore, it is important to distinguish between approaches that are “biomimetic-inspired” and those that genuinely replicate the structure and function of natural tissues. Another important consideration is the relationship between biomimicry and minimally invasive dentistry. While the two concepts are often used interchangeably, they are not synonymous. Minimally invasive dentistry focuses on the preservation of healthy tooth structure and the early management of disease, whereas biomimicry emphasizes the replication of natural biological systems. Although there is overlap between these approaches, conflating them may contribute to conceptual confusion and hinder the development of clear clinical guidelines.

Given these challenges, there is a growing need for a more critical and nuanced understanding of biomimicry in restorative dentistry. Rather than accepting the term at face value, it is essential to evaluate the extent to which current materials and techniques truly fulfill biomimetic criteria. This requires a rigorous assessment of their structural, mechanical, and biological performance, as well as a clear framework for defining and classifying biomimetic approaches.

In this context, the present narrative review aims to critically appraise the use of biomimicry in restorative dentistry, with a particular focus on identifying instances of conceptual misuse and overgeneralization. By examining the scientific basis of biomimetic claims and highlighting gaps between theory and practice, this study seeks to clarify the role of biomimicry as both a scientific concept and a clinical strategy. Ultimately, a more precise and evidence-based application of biomimicry may contribute to improved restorative outcomes and a more coherent understanding of its place within modern dentistry.

2 METHODOLOGY

This narrative review aimed to critically analyze the use and misuse of biomimicry concepts in restorative dentistry. A comprehensive literature search was performed in PubMed (MEDLINE), Scopus, and Google Scholar for studies published up to 2025. The search strategy included terms such as “biomimicry,” “biomimetic dentistry,” “restorative dentistry,” and “dental materials.”

Eligible publications included original studies, review articles, and conceptual papers addressing biomimetic principles, restorative techniques, and material science in dentistry. Articles were selected based on their relevance to the conceptual and clinical application of biomimicry.

Given the narrative design, no strict inclusion hierarchy or quantitative synthesis was applied. Instead, the literature was critically appraised to identify inconsistencies, conceptual misinterpretations, and gaps between theoretical biomimicry and clinical practice. The findings were synthesized qualitatively, focusing on definitions, applications, and misuse patterns. No formal risk of bias assessment was performed.

3 RESULTS

The analysis of the selected literature revealed that biomimicry is extensively referenced in restorative dentistry; however, its application is often inconsistent and conceptually diluted. The findings were organized into three main domains: (1) definitions

and conceptual frameworks, (2) clinical techniques labeled as biomimetic, and (3) dental materials associated with biomimetic claims.

3.1 CONCEPTUAL DEFINITIONS AND INCONSISTENCIES

A major finding across the literature is the lack of a unified definition of biomimicry in dentistry. While the original concept refers to the emulation of biological systems in terms of structure, function, and process (Vincent et al., 2006), its dental application varies widely. Some authors define biomimicry as the replication of the hierarchical structure of enamel and dentin, whereas others interpret it as achieving functional equivalence or simply preserving tooth structure (Magne, 2005; Bazos & Magne, 2011).

This conceptual variability has led to the interchangeable use of terms such as “biomimetic,” “bioinspired,” and “minimally invasive,” despite their distinct meanings. As a result, the scientific rigor of the term has been weakened, contributing to ambiguity in both research and clinical communication.

3.2 CLINICAL TECHNIQUES LABELED AS BIOMIMETIC

Adhesive dentistry techniques are frequently described as biomimetic due to their conservative nature and ability to preserve tooth structure. Procedures such as immediate dentin sealing, incremental layering of resin composites, and stress-reducing restorative protocols have been widely promoted as biomimetic approaches (Magne, 2005).

However, the review identified that many of these techniques do not fully replicate the biomechanical behavior of natural teeth. For example, although adhesive restorations can improve stress distribution, they do not reproduce the complex anisotropic and hierarchical structure of dentin and enamel (Kinney et al., 2003). Therefore, these approaches may be more accurately described as biomimetic-inspired rather than truly biomimetic.

3.3 DENTAL MATERIALS AND BIOMIMETIC CLAIMS

Advances in dental materials science have introduced a wide range of materials marketed as biomimetic, including resin composites, glass ionomer cements, and bioactive materials. These materials aim to mimic certain properties of natural tissues, such as elastic modulus, translucency, and ion exchange capacity.

Resin composites, for instance, have been engineered to approximate the mechanical properties of dentin and enamel, while glass ionomer cements offer fluoride release and chemical bonding to tooth structure (Ferracane, 2011). More recently, bioactive materials

capable of releasing calcium, phosphate, and other ions have been proposed as biomimetic due to their potential to promote remineralization (Sauro et al., 2017).

Despite these advancements, no current material fully replicates the structural complexity and functional gradients of natural dental tissues. Most materials mimic isolated properties rather than the integrated biological system of the tooth, highlighting a gap between biomimetic claims and actual performance.

3.4 INFLUENCE OF MARKETING AND TERMINOLOGICAL MISUSE

The review also identified a significant influence of commercial and marketing factors in the widespread use of the term “biomimetic.” Many products and techniques are labeled as biomimetic without robust scientific evidence supporting such classification.

This trend contributes to the overgeneralization of the term and may lead to misconceptions among clinicians. The use of biomimicry as a marketing strategy rather than a scientifically defined concept undermines evidence-based practice and may influence clinical decision-making inappropriately.

3.5 LIMITATIONS IN TRANSLATIONAL AND CLINICAL EVIDENCE

Another key finding is the limited availability of clinical evidence supporting true biomimetic approaches. While laboratory studies provide insights into material properties and bonding mechanisms, they do not fully replicate intraoral conditions.

Clinical variables such as occlusal loading, thermal cycling, moisture control, and long-term degradation significantly affect restorative performance. Consequently, the translation of biomimetic principles into predictable clinical outcomes remains a challenge.

4 DISCUSSION

The present review highlights a critical issue in contemporary restorative dentistry: the transformation of biomimicry from a well-defined scientific concept into a broadly applied and often ambiguous term. While the intention behind adopting biomimetic principles is to improve clinical outcomes by aligning restorative strategies with natural biology, the current use of the term frequently lacks precision and consistency. One of the central problems identified is the conflation of biomimicry with minimally invasive dentistry and adhesive techniques. Although these approaches share common goals, they are not conceptually equivalent. Minimally invasive dentistry prioritizes tissue preservation, whereas biomimicry aims to replicate the structural and functional characteristics of natural tissues. Treating these concepts as

interchangeable contributes to conceptual confusion and may obscure the true objectives of each approach.

From a biomechanical standpoint, achieving true biomimicry remains highly challenging. Natural teeth exhibit a level of structural complexity that current materials and techniques cannot fully reproduce. While modern restorative strategies may approximate certain properties, such as elasticity or stress distribution, they do not replicate the hierarchical organization and dynamic behavior of dental tissues. This discrepancy reinforces the importance of distinguishing between partial imitation and true biological replication.

Another important consideration is the role of marketing in shaping the perception of biomimicry. The frequent use of the term as a promotional label rather than a scientifically validated concept risks misleading clinicians and overestimating the capabilities of existing materials. This can lead to unrealistic expectations and potentially compromise evidence-based decision-making. Furthermore, the lack of standardized criteria for defining and evaluating biomimetic approaches represents a significant barrier to progress. Without clear guidelines, it becomes difficult to assess whether a given material or technique truly fulfills biomimetic principles. Establishing objective parameters based on structural, mechanical, and biological performance would be essential for advancing both research and clinical application.

Ultimately, a more critical and disciplined use of the term biomimicry is necessary. Rather than abandoning the concept, the focus should be on refining its definition and ensuring that its application is supported by robust scientific evidence. This approach would help preserve its value as a guiding principle while preventing its misuse as a generic or misleading label.

5 CONCLUSION

Biomimicry remains a compelling and valuable concept in restorative dentistry, offering a framework for developing materials and techniques that align more closely with natural tooth structure and function. However, its current use is often characterized by conceptual ambiguity and overgeneralization, which undermines its scientific and clinical relevance.

The findings of this review demonstrate that many so-called biomimetic approaches only partially replicate the properties of natural tissues and should be more accurately described as biomimetic-inspired. The widespread misuse of the term, particularly in marketing contexts, further contributes to confusion and may compromise evidence-based practice.

To address these challenges, there is a clear need for standardized definitions and objective criteria that define what constitutes true biomimicry in dentistry. Future research should focus on bridging the gap between theoretical principles and clinical reality, with an emphasis on long-term performance, biological integration, and functional replication.

By promoting a more precise and evidence-based understanding of biomimicry, the field of restorative dentistry can move toward more predictable, effective, and scientifically grounded treatment strategies.

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