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Review

Indications, Clinical Success and Failure Rate of All-Ceramic Restorations

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Abstract

All-ceramic restorations have become a cornerstone in modern restorative dentistry, offering exceptional aesthetics, biocompatibility, and durability. Their ability to mimic natural enamel and their wide range of applications, from veneers to full crowns, make them an ideal choice for both anterior and posterior teeth. Advances in material science, particularly the development of lithium disilicate and zirconia ceramics, have expanded their indications to include cases requiring both aesthetic and functional performance. Critical factors such as tooth preparation design, adhesive protocols, and material-specific properties influence their clinical success. Despite their advantages, all-ceramic restorations face challenges, including material-specific failures, biomechanical stresses, and patient-related factors. Veneered zirconia restorations, for example, are prone to chipping, while improper bonding techniques can lead to debonding, secondary caries, or microleakage. Functional failures, often linked to occlusal overloading or parafunctional habits, highlight the importance of meticulous occlusal planning and appropriate case selection. Patient-specific considerations, such as oral hygiene and habits, significantly impact the longevity of restorations, emphasizing the need for regular maintenance and follow-ups. Technological advancements, including CAD/CAM systems and monolithic ceramic designs, have enhanced the precision and reliability of all-ceramic restorations, reducing complications associated with traditional fabrication methods. However, the success of these restorations continues to rely heavily on the clinician's expertise and adherence to evidence-based practices. While innovations have addressed many limitations, continued research is essential to improve their durability and adapt them to the evolving demands of restorative dentistry. With proper case selection and attention to detail, all-ceramic restorations remain a reliable and aesthetically pleasing option for long-term dental rehabilitation.

Keywords: *All-ceramic restorations, clinical success, failure analysis, zirconia ceramics, adhesive protocols*

Introduction

All-ceramic restorations have emerged as a cornerstone in modern restorative dentistry due to their excellent aesthetics, biocompatibility, and mechanical properties. These restorations have become a preferred choice for both anterior and posterior teeth, offering a combination of durability and natural appearance. Their ability to mimic the translucency and color of natural enamel makes them superior to metal-based restorations in aesthetic zones. Over the past few decades, advancements in material science and adhesive dentistry have enhanced the clinical applicability and long-term performance of all-ceramic restorations, expanding their indications in dental practice (1).

The development of various ceramic systems, such as feldspathic ceramics, lithium disilicate, and zirconia, has broadened the scope of all-ceramic restorations. Each system offers unique properties that cater to different clinical scenarios. For instance, feldspathic ceramics are renowned for their exceptional aesthetic properties, making them ideal for veneers, whereas zirconia is celebrated for its high fracture resistance, making it suitable for posterior crowns and bridges (2). Despite these advancements, clinicians must carefully consider factors such as material selection, preparation design, and bonding protocols to achieve optimal clinical outcomes. The clinical success of all-ceramic restorations is highly dependent on material-specific properties, adhesive techniques, and patient-specific factors. Marginal adaptation, resistance to fracture, and longevity are key parameters influencing their success rate. Studies have reported survival rates of over 90% for certain ceramic systems over a 10-year period, demonstrating their reliability when used in appropriate cases (3). However, challenges such as chipping, debonding, and wear against opposing dentition remain concerns that necessitate a comprehensive understanding of their limitations.

On the other hand, failure of all-ceramic restorations is often linked to improper case selection, suboptimal material handling, or functional overloading. Occlusal stresses, parafunctional habits, and marginal integrity play significant roles in determining the longevity of these restorations. Furthermore, the choice of luting cement and adhesive strategies can significantly affect the bond strength and clinical performance of all-ceramic restorations (4). As such, a meticulous approach to diagnosis, planning, and material selection is critical to minimizing complications and enhancing long-term success. Despite their widespread application, there remains a need for continued research into improving durability and reducing the cost of all-ceramic restorations. Innovations such as high-translucency zirconia and novel surface treatments aim to bridge the gap between aesthetics and strength. These advancements have the potential to further solidify the role of all-ceramic restorations as a reliable and aesthetic option in restorative dentistry (5).

Review

All-ceramic restorations are highly regarded for their combination of aesthetics and functional performance, but their clinical success depends on multiple factors. Material selection plays a pivotal role; lithium disilicate and zirconia ceramics have demonstrated superior mechanical properties and aesthetic outcomes in various clinical scenarios. Lithium disilicate, for instance, is preferred in anterior restorations due to its translucency and natural appearance, while zirconia's high fracture resistance makes it ideal for posterior restorations subjected to significant occlusal forces (6). However, achieving success requires careful consideration of preparation design and bonding techniques, as these directly influence the longevity of the restoration.

Failures in all-ceramic restorations are often attributed to biomechanical factors, such as excessive occlusal loading and insufficient tooth reduction, leading to issues like chipping or fracture. Additionally, marginal integrity and the quality of cementation impact their long-term performance. Adhesive cementation, especially with resin-based cements, enhances retention and reduces microleakage, contributing to better clinical

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outcomes (7). While advancements in ceramic materials have addressed some limitations, such as enhancing zirconia's translucency, challenges like wear of opposing dentition and susceptibility to aging remain. Further innovations in ceramic formulations and bonding systems are essential to improving the success rates of all-ceramic restorations in diverse clinical applications.

Indications and Case Selection Criteria for All-Ceramic Restorations

The indications for all-ceramic restorations have expanded significantly due to advancements in material science and adhesive techniques. These restorations are primarily indicated in cases where aesthetic requirements are paramount, such as anterior teeth or high smile-line regions. The ability of modern ceramic materials to replicate the natural translucency, shade, and texture of enamel makes them an excellent choice for veneers, crowns, and inlays in visible areas. Lithium disilicate ceramics, for example, offer both strength and superior aesthetics, making them suitable for cases requiring minimal tooth preparation without compromising optical properties (8).

Patients with moderate functional demands also benefit from all-ceramic restorations. Full-contour zirconia crowns are particularly advantageous in posterior regions where occlusal forces are higher, yet aesthetics is still a consideration. In cases involving discolored underlying tooth structures or endodontically treated teeth, high-opacity ceramic systems can mask imperfections effectively. Additionally, these restorations are frequently chosen for patients with metal allergies, as ceramics are biocompatible and free of metallic components (9).

Case selection requires a comprehensive assessment of both patient-specific factors and clinical conditions. Tooth position, occlusal dynamics, and the presence of parafunctional habits such as bruxism play a pivotal role in determining the suitability of all-ceramic restorations. While zirconia has high fracture resistance, it may not be ideal for patients with severe bruxism due to its potential for causing wear on opposing dentition. Similarly, feldspathic ceramics, known for their unparalleled aesthetics, are best reserved for low-stress applications, such as veneers or anterior crowns, to avoid fracture risks (10).

The condition of the remaining tooth structure also influences the choice of material and design. Teeth with adequate enamel for bonding are optimal candidates, as adhesive techniques enhance the retention and longevity of the restoration. However, in cases of significant tooth structure loss, additional considerations such as reinforcement with post systems or the use of high-strength core materials may be necessary. Furthermore, the preparation design must accommodate the selected ceramic system's thickness requirements to avoid over-contouring and ensure adequate strength. For example, lithium disilicate restorations generally require a minimum thickness of 1.5-2.0 mm in functional areas to withstand occlusal forces (5).

Emerging trends in dentistry have also influenced the indications for all-ceramic restorations. The push towards minimally invasive techniques has popularized ceramics for onlays and overlays, preserving as much natural tooth structure as possible. Additionally, advances in CAD/CAM technology enable precise fabrication of restorations, allowing for predictable outcomes and reduced chair time. Digital workflows have particularly benefited patients with complex needs, as virtual planning aids in customizing the restoration to individual anatomical and functional requirements. Overall, the decision to use all-ceramic restorations should consider a balance between aesthetics, function, and material properties. Patient preferences, expectations, and budget also guide clinical decisions. Open communication between the clinician and the patient is essential to select the most appropriate restorative option, ensuring long-term satisfaction and success.

Factors Influencing Clinical Success of All-Ceramic Restorations

The clinical success of all-ceramic restorations is contingent upon a variety of factors encompassing material selection, tooth preparation, bonding

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techniques, and patient-specific considerations. Each of these factors interacts to influence the long-term performance of restorations and their ability to meet functional and aesthetic demands. Material selection remains a cornerstone of success, as different ceramics possess unique physical and optical properties. Zirconia-based ceramics, for instance, are preferred in high-stress areas due to their superior fracture toughness and resistance to wear, while lithium disilicate is ideal for anterior restorations requiring translucency and lifelike aesthetics. However, it is crucial to recognize that zirconia's opaque nature may limit its application in highly aesthetic zones unless veneered with a translucent ceramic (11). Additionally, processing methods, such as sintering and milling, can affect the material's microstructure and, consequently, its clinical performance. Tooth preparation is another critical determinant. Adequate tooth reduction is necessary to accommodate the thickness required for ceramic restorations while maintaining strength and aesthetics. Insufficient reduction can compromise the restoration's ability to withstand occlusal forces, while excessive reduction risks pulpal injury and weakens the remaining tooth structure. Furthermore, the preparation design must provide appropriate margins, with chamfer or shoulder margins being preferred to enhance fit and minimize stress concentrations (12).

Adhesive bonding techniques significantly contribute to the durability of all-ceramic restorations. The bonding process is particularly vital for ceramic systems reliant on micromechanical retention, such as etched glass ceramics. Surface treatments, including hydrofluoric acid etching and silanization, optimize the bond strength between the ceramic and resin cement. Conversely, zirconia's non-etchable surface necessitates the use of primers containing phosphate monomers, such as 10-MDP, to establish a chemical bond. Proper handling and application of these adhesives are imperative, as suboptimal bonding can lead to debonding or marginal leakage, both of which compromise restoration longevity (13). Patient-specific factors, including occlusal dynamics and oral hygiene, also play a substantial role. The presence of parafunctional habits like bruxism imposes excessive stress on restorations, increasing the risk of fracture or wear. In such cases, occlusal guards may be recommended to protect the restoration. Additionally, poor oral hygiene can accelerate marginal discoloration, caries, and periodontal issues, all of which undermine the success of ceramic restorations. Regular maintenance and patient compliance with hygiene protocols are essential to mitigate these risks (14).

The interaction between opposing dentition and the ceramic surface must also be carefully evaluated. High-strength ceramics, such as zirconia, can cause wear on natural teeth or opposing restorations if their surface finish is not appropriately polished or glazed. This underscores the importance of proper finishing protocols to achieve a smooth, non-abrasive surface while maintaining the restoration's integrity. Furthermore, the clinician must ensure precise occlusal adjustments to prevent uneven load distribution, which can lead to early failure. Advancements in digital technology have further influenced the clinical success of all-ceramic restorations. Digital workflows, including CAD/CAM systems, enhance the precision of restorations, reducing human error and improving the fit and marginal adaptation. However, the quality of digital impressions and milling accuracy depends on the skill of the operator and the technology employed, highlighting the need for adequate training and familiarity with these systems.

Common Causes and Analysis of Failure in All-Ceramic Restorations

Failures in all-ceramic restorations are multifactorial, often involving material properties, clinical protocols, and patient-related factors. Understanding the underlying causes is crucial for mitigating risks and improving the longevity of these restorations. Material-related failures are a common concern, particularly in cases of improper material selection. While zirconia is renowned for its high fracture toughness, veneered zirconia restorations are susceptible to chipping of the veneering ceramic. This issue, often referred to as cohesive failure, occurs due to mismatched

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coefficients of thermal expansion between the zirconia core and the veneering layer during fabrication (14, 15). Such failures are more prevalent in layered restorations compared to monolithic designs, which have significantly improved structural reliability.

Bonding deficiencies also play a significant role in failures. All-ceramic restorations rely heavily on adhesive cementation to enhance retention and distribute functional loads. Poor bonding can lead to debonding, secondary caries, or microleakage, which compromises the restoration's marginal integrity. For glass ceramics, inadequate surface treatment, such as insufficient etching or silanization, reduces micromechanical retention. Zirconia, on the other hand, requires specialized primers like 10-MDP to establish a durable chemical bond with resin cements. Failure to adhere to these protocols often results in premature restoration loss (15).

Mechanical stresses, particularly in posterior regions, are another primary cause of failure. Functional loads, occlusal adjustments, and parafunctional habits, such as bruxism, subject the restoration to excessive stress. Over time, this can lead to fractures, especially in thinner or inadequately supported ceramic restorations. Clinical studies have demonstrated that occlusal overloading exacerbates crack propagation, ultimately resulting in catastrophic failure. Proper occlusal equilibration and the use of splints in bruxism patients can mitigate these risks (16).

Patient-specific factors, including oral hygiene and habits, further contribute to failure. Suboptimal oral hygiene leads to plaque accumulation and secondary caries at the margins, undermining the restoration's retention. Additionally, high dietary acid intake can weaken the ceramic material through erosion, reducing its resistance to functional loads. Patients with habits like nail-biting or pen-chewing subject restorations to non-physiological forces, accelerating wear or fracture. The design and fabrication process also influence failure rates. Sharp angles or inadequate rounding of internal line angles in tooth preparations create stress concentrations within the restoration, increasing the likelihood of fractures. Similarly, insufficient ceramic thickness compromises its ability to withstand occlusal forces. Inaccurate digital impressions or errors during milling can further affect the restoration's fit and marginal adaptation, increasing the risk of debonding or microleakage over time (17).

Failures due to biological factors, such as periodontal complications, also merit consideration. Marginal discrepancies in restorations provide a niche for plaque accumulation, leading to gingival inflammation and periodontal pocket formation. Over time, these issues can compromise both the restoration and the supporting structures. Meticulous attention to marginal fit and regular follow-ups are essential to prevent such complications. Technological advancements have addressed some of these challenges. Improved CAD/CAM systems, high-strength monolithic ceramics, and enhanced adhesive protocols have reduced failure rates significantly. However, clinical success depends on the operator's skill and adherence to evidence-based practices throughout the treatment process.

Conclusion

The clinical performance of all-ceramic restorations is shaped by careful material selection, precise preparation, and adherence to adhesive protocols. Recognizing and addressing factors influencing success and failure enhances their longevity and functionality. Advancements in ceramic materials and digital workflows have reduced failure rates, yet meticulous clinical practice remains essential. Continued research and innovation are pivotal for optimizing outcomes in diverse restorative scenarios.

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Conflict of interest

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Ethical consideration

Non applicable.

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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