Perspective

Brittle dental ceramics: A challenge in dentistry

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The challenge of dental ceramic degradation necessitates innovative technology, rigorous testing and proactive dental care, demanding collaboration between researchers, dentists and patients to ensure durable and reliable dental restorations.

Dental ceramics are a groundbreaking advancement in the field of dentistry, offering not only functional dental restorations but also aesthetically pleasing solutions to patients.[1,2] However, the fatigue of dental ceramics remains a persistent challenge for dental practitioners and patients.[2,3] This phenomenon, characterized by the gradual degradation of the ceramic's properties over time, demands urgent attention from the dental community. Aging can also affect other biomaterials, such as dental composites and cements.[4,5] However, in brittle materials like ceramics, its effect can result in a reduction of the material's properties by over 50% of the original value.[6]

Dental ceramics are often considered an ideal choice for dental restorations due to their natural appearance, biocompatibility and durability.[7] They mimic the properties of natural teeth, making them an attractive option for patients seeking long-lasting dental solutions. However, the reality is far more complex. Dental ceramics are subjected to a multitude of challenging conditions within the oral environment. These include fluctuating temperatures, acidic pH levels and intense masticatory forces.[8] These factors contribute to the deterioration of ceramic restorations over time, resulting in cracks, chipping, and, in severe cases, bulk failure.[9,10]

Deterioration of dental ceramics compromises the structural integrity of the restoration, jeopardizing patients' oral health and placing a financial burden on both patients and the healthcare system. Addressing this issue requires a multifaceted approach that combines innovative research, advanced material engineering and enhanced clinical practices to repair and improve aged restorations.[11]

Dentists and researchers must collaborate to develop ceramics with improved mechanical properties and enhanced resistance to crack propagation. Incorporating nanoparticles, adjusting material composition and implementing new designs are promising innovations in nanotechnology for creating dental ceramics that can withstand the challenges of the oral environment for extended

periods.[12] Additionally, rigorous testing methodologies must be established to assess the long-term performance and durability of these materials before introducing them into clinical practice. Fatigue cycling, including accelerated life tests and the measurement of stress-life curves (S-N), are fundamental concepts in the field of biomaterials that should be encouraged to predict the fatigue life of dental ceramics.[2] In vitro tests that apply intermittent cyclic loading are essential to induce mechanical fatigue of structures. These tests should be performed to predict mechanical behavior, particularly when interactions occur between recurrent stresses from fatigue regimens and critical defects observed at the inner and outer surfaces of ceramic restorations. The literature has shown that critical defects introduced during finishing/polishing of outer surfaces or grinding of the inner surfaces significantly affect the mechanical behavior of ceramic restorations.[2–7] For instance, grinding the inner surface of ceramic restorations can markedly reduce their mechanical fatigue behavior.[7,12] Moreover, inner surface treatments are the primary factor influencing the mechanical behavior. Promoting maximum adhesion between the materials/substrates is a must to induce a better mechanical behavior.[13] Therefore, dentists are strongly encouraged to prevent the introduction of defects and/or to manage them through proper finishing, polishing and surface treatment of the ceramic surfaces. This will mitigate their deleterious effects and optimize adhesion and its positive effects.[4]

Fractography analysis and finite element analysis (FEA) are indispensable tools for the comprehensive study of the fatigue behavior of dental ceramics. They provide valuable insights that can significantly improve the validity and reliability of fatigue results (Fig. 1). The meticulous examination of fracture surfaces enables to identify specific fracture features that can indicate the correct direction of crack propagation.[13] These patterns can be used by researchers to determine the vulnerabilities of ceramics under cyclic loading, which can guide the improvements in design and composition. Moreover, identifying the primary causes of failures, such as material defects, manufacturing processes, or bonding techniques, allows for addressing these issues at their source, strengthening the durability of dental restorations.[14]

Dental professionals play a pivotal role in reducing the effects of ceramic fatigue. Education and training programs should be intensified to ensure that practitioners are well-versed in the latest advancements in dental ceramics. Computer-aided design and computer-aided manufacturing (CAD/CAM) techniques can be used to create precise ceramic restorations, which can reduce the likelihood of premature failures through topology optimization. Practitioners must emphasize the importance of regular dental check-ups and maintenance using 3D patient monitoring tools to evaluate the wear and morphological changes over time. Transillumination should be used to verify initial cracks, and static and dynamic occlusion should be monitored to avoid overloading due to excessive contact points.[15] Furthermore, it is important to continuously check the quality of the polished surface and re-polish it when necessary, in order to contribute to a better prognosis.

Clinicians must be aware of the gradual degradation that dental ceramics undergo over time due to oral conditions. Staying up-to-date with technological innovations, particularly understanding different toughness mechanisms, is vital for selecting the most appropriate ceramic resilience. Utilizing advanced CAD/CAM techniques ensures precise restorations and reduces premature failures. However, basic care, including regular dental check-ups and occlusion assessments, is equally important. Continuous education enables the implementation of best clinical practices.

In conclusion, the fatigue cycle is a significant concern that requires collaborative efforts from researchers, dental professionals and patients. By investing in research, education and preventive care, the dental community can lead the way for the development of more durable ceramic materials and ensure that patients continue to benefit

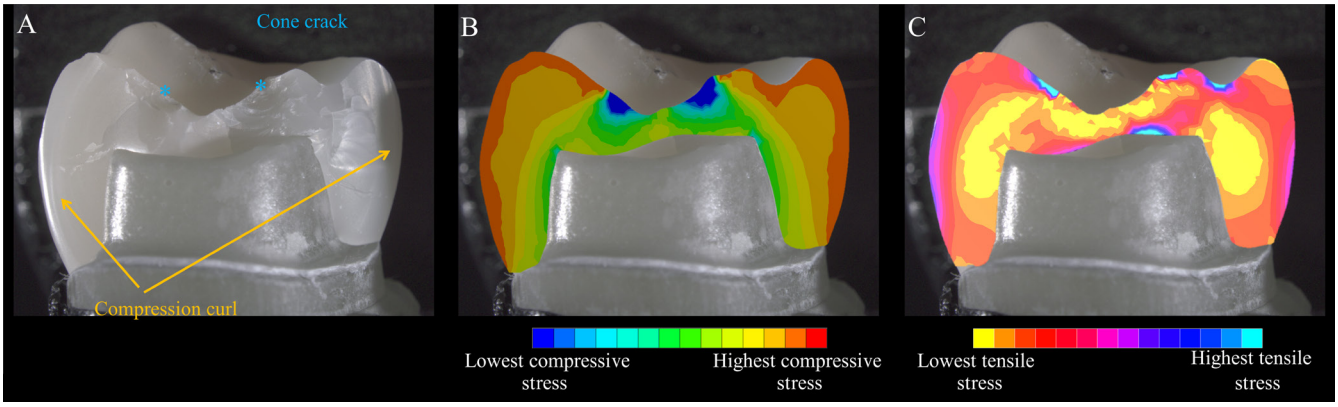

Fig. 1. Microscopy analysis of failed monolithic crown made of zirconia-reinforced lithium silicate after fatigue aging

A. Initial fractography in stereomicroscope from a fractured ceramic crown; B. Simulation showing the calculated compressive stress; C. Simulation showing the calculated tensile stress. In this example, fractography analysis was used with finite element analysis (FEA) to correlate the fracture features with the mechanical behavior during loading.

from their aesthetic and functional advantages. Together, we can address the challenges posed by ceramic fatigue and finally endorse reliable dental restorations.

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