International Journal of Biology and Biomedicine
http://www.iaras.org/iaras/journals/ijbb

Failure behavior of bilayered all-ceramic crowns

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Abstract: Based on clinical long-term data bilayered single crowns can be considered as a reliable and promising treatment option that can be recommended in the posterior region. Veneer chipping and zirconia frameworks fractures are critical issues in all-ceramic restorations. The objective of this study was to assess the failure behavior of bilayered all-ceramic molar crowns, evidenced by different type of fractures. Experiments were conducted on a right first maxillary molar. Bilayered all-ceramic crowns were obtained with a 0.5 mm thick zirconia milled framework and veneered with hot-pressed ceramics. The specimens were tested at compressive load until failure. The typical macroscopic crack pattern of all samples showed that crack propagation resulted in more broken pieces with sharp edges. Ceramic materials show considerable variation in strength due to their extreme sensitivity to cracks. Understanding the fracture behavior of dental ceramics and its relation to different materials and restorations is important from a clinical point of view.

Key-Words: bilayered crowns, molar, zirconia framework, pressed ceramic veneer, failure behavior, fracture.

1 Introduction

Due to the lower opacity and translucency of many core materials, bilayered ceramic crowns were introduced to obtain sufficient veneer support and to improve aesthetics [1]. Based on clinical long-term data bilayered single crowns can be considered as a reliable and promising treatment option that can be recommended in the anterior and posterior region [2].

It is important to know that the resultant multi-layer structure increased the complexity of stress distribution within the restorations [3]

Ceramic materials show considerable variation in strength due to their extreme sensitivity to cracks of different sizes. The unstable fracture of ceramics starts from critical flaws, which determines that fracture always propagates from the largest flaw favorably oriented to the tensile stress. The distribution of crack size, shape, and orientation differs from sample to sample, according to the material, volume of the restoration, and its strength varies according to the flaw size distribution [4-6].

Veneer chipping and zirconia frameworks fractures are critical issues in restorative dentistry. Most posterior zirconia restoration failures were reported either as minor or major chipping, with the chipping rate as high as 25% [7-16]. Fracture or chipping of veneering porcelains can be either a fracture of the porcelain itself or a fracture originating from the interfaces between the framework and the veneer [17]. The following classification of the ceramic fractures has been suggested: type 1, crack of the veneering ceramic; type 2, chipping restricted to the veneering ceramic; type 3, chipping exposing the core; and type 4, fracture of the core [18].

2 Purpose

The objective of this study was to assess the failure behavior of bilayered all-ceramic molar crowns, evidenced by different type of fractures.

3 Materials and Method

Experiments were conducted on a right first maxillary molar from a typodont model prepared for all ceramic crowns. This preparation was replicated and alloy dies were obtained by casting, using the lost-wax technique. The dies were scanned using Cercon Eye scanner and a dedicated CAD (computer aided design) software Cercon Art 3.2 (Degudent, Hanau, Germany) was used for the design of the full anatomically crowns. In order to obtain identical samples, a wax-up were milled in Cercon base cast material. This wax up was replicated in order to obtain eight identical wax-ups for veneering. Eight bilayered all-ceramic crowns were obtained with a 0.5 mm thick zirconia framework milled with Cercon Brain and veneered with hot-pressed ceramics Vita PM9 (Vita, Bad Säckingen, Germany), keeping the same external morphology. The restorations thickness was verified by periodic measurements at several locations. The crowns were glazed and conventionally cemented on the metallic dies. For fixing, a digital load was applied to the occlusal surface of each crown during setting to ensure complete seating and maintained for 24 hours before loading. The specimens were mounted into an Instron 8874 (Instron, Norwood, MA, USA) testing device and subjected to failure testing.

Each crown was positioned under a stainless steel ball with a diameter of 6 mm fixed to the upper crosshead of a universal testing machine. Due to the radius of the contact sphere, the actual contact positions were located adjacent to the central fossa. A thin rubber foil of 0.2 mm was inserted between the tested crowns and the antagonists in order to reduce peak stresses at the contact points. The vertical load was aligned with the tooth's axis. A compressive load was applied at a crosshead speed of 2 mm/min, and failure was recorded (Fig. 1). Maximal compressive loads were registered.

For each of the samples, the macroscopic fracture patterns of specimens broken in compressive test, and the number of broken pieces of all specimens at each test condition were inspected.

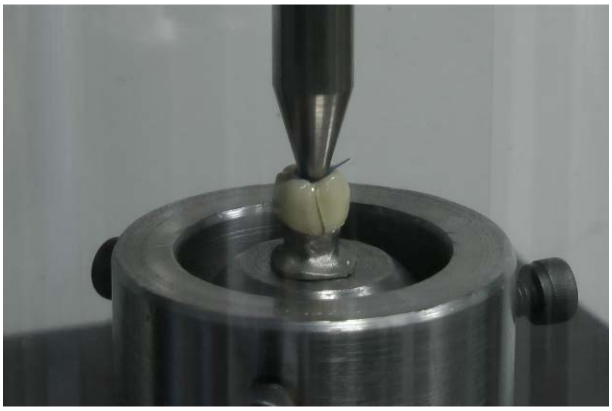

Fig. 1. Compressive loading in the testing device until fracture of the restoration.

The mean value of maximal compressive load was 3820.54 N (with variations between 2087.25 and 5115.82 N).

3 Results and Discussions

During fractographic analysis, it was possible to confirm from the cracking patterns that fracture initiated in the most cases under the loading piston (central fossa). The typical macroscopic crack pattern of all samples showed that crack propagation resulted in more broken pieces with sharp edges (Fig. 2, 4, 6). A correlation between fracture load and number of fractured pieces of the specimens was no observed (Fig. 3, 5, 7).

Fig. 2. Fracture pattern of sample 1 – type 4 - with fracture of the framework and veneering material.

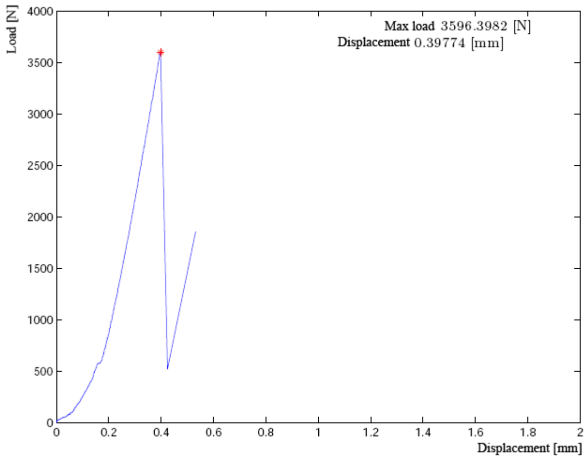

Fig. 3. Graphical representation of the load distribution over time, relative to the displacement for sample 1 (fracture type 4).

Fig. 4. Fracture pattern of sample 3 – type 3 – fracture of the veneering material, exposing the framework.

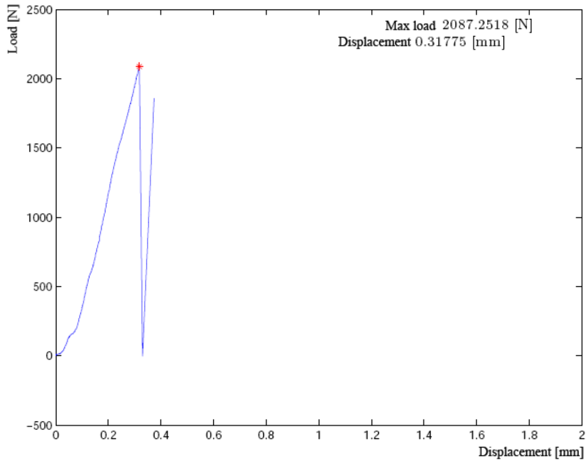

Fig. 5. Graphical representation of the load distribution over time, relative to the displacement for sample 3 (fracture type 3).

Fig. 6. Fracture pattern of sample 1 – type 4 - with fracture of the framework and veneering material in multiple pieces.

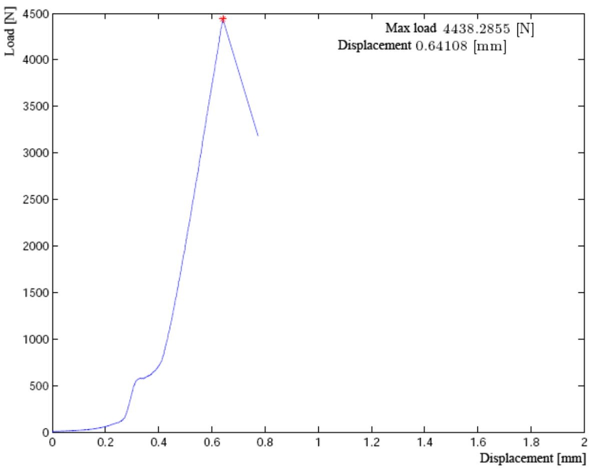

Fig. 7. Graphical representation of the load distribution over time, relative to the displacement for sample 4 (fracture type 4).

Understanding the fracture behavior of dental ceramics and its relation to different materials and restorations is important from a clinical point of view to assist the clinician in choosing the best ceramic material and design of restoration for each situation. It also can be helpful in developing new materials and technologies for dental restorations [4].

Experiments show that microstructural differences between the ceramic materials resulted in different behaviors in terms of fracture strength, structural reliability and slow crack growth. Studies suggest another approach for the improvement and development of new dental ceramics, since the crystalline phase is not the only important factor in determining the mechanical properties and especially slow crack growth susceptibility. Changes in the glassy matrix composition of veneering materials can result in better mechanical properties and greater resistance to slow crack propagation [4, 19].

4 Conclusion

Within the limitations of the present study because of the multitude of parameters involved in the failure behavior of bilayered ceramic crowns, the following conclusions can be drawn:

1. Ceramic materials show considerable variation in strength due to their extreme sensitivity to cracks.
2. Understanding the fracture behavior of dental ceramics and its relation to different materials and restorations is important from a clinical point of view.
3. Failure analyses can be helpful in developing new materials and technologies for dental all-ceramic restorations.

5 Acknowledgements

This work was supported by UEFISCDI, project number PN-II-RU-TE-2014-4-0476.

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