Fracture behaviour of hot-pressed glass ceramic dental crowns

Liliana Porojan, Sorin Porojan, Anghel Cernescu, and Cristina Savencu

***Abstract*—**New ceramic materials, like hot-pressed glass ceramics can be used to achieve monolithic full anatomic all-ceramic dental restorations even in the molar areas. Due to the fact that these materials are brittle and susceptible to fracture, the aim of the study was to reveal the fracture behaviour of hot-pressed glass ceramic molar crowns under different loading methods. For the experimental analyses anatomically first upper molar crowns were fabricated. The specimens were submitted to cyclic fatigue loading and fracture resistance testing. The mode of failure depends on the loading mode. Static loading, wide used in literature, can give an information regarding the values of fracture resistance, but are not illustrative for the long-term success of the restorations, like fatigue behaviour. The most accurate way to simulate the clinical behaviour is the cyclic loading in order to simulate a defined period of oral service. In vitro testing is important before the clinical application.

***Keywords*—** fracture, hot-pressed ceramics, loading modes, molar crowns.

I. Introduction

MODERN ceramic materials, like hot-pressed glass ceramics are indicated to achieve reliable monolithic full anatomic all-ceramic dental restorations even in the posterior areas. All-ceramic restorations are amongst the most aesthetically prosthetic restorations because they exhibit life-like appearance due to the lack of metallic substructure. A small number of studies investigated the fracture behaviour of posterior glass ceramic crowns, and the involved testing parameters are varied [1,2].

The introduction of new ceramic materials has improved some of their properties, offering a new dimension to the application of aesthetic indirect restorations [3].

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Sintered feldspathic and leucite reinforced ceramic are used for the fabrication of metal-free restorations using traditional laboratory based fabrication techniques. With the development of hot-pressed and CAD/CAM technologies, different ceramic materials can now be used for aesthetic applications. Ceramics are brittle and susceptible to fatigue fracture in repetitive function. Although occlusal loading is compressive, some tensile stresses in the restorations are inevitable. Cracks tend to follow paths where tensile stresses are greatest. Fracture during static load differ from those resulted after an extended period of lower loads [4-8].

One of the most commonly observed clinical fracture mode is the crack initiating from the contact zone at the occlusal surface. All of the cracks can result in the damage of the crowns. Through thickness fractures initiated from the occlusal surface can split the crown in two or more parts. Clinical trials reporting survival rates for several all-ceramic systems indicate vulnerabilities to these kind of fractures [4, 9-16].

II. Aim

The aim of the study was to reveal the fracture behaviour of hot-pressed glass ceramic molar crowns under different loading methods.

III. Materials and methods

For the experimental analyses anatomically first upper molar crowns were fabricated on specific prepared teeth casted from a base metal alloy. The axial undercuts were eliminated by a reduction of 1.5 mm, while the occlusal surface was reduced by 1.5-2 mm. A 1 mm deep chamfer finish line and a convergence angle of 6 degree were chosen. Finally all sharp angles were rounded. The preparations were scanned using Cercon Eye system and a dedicated CAD (computer aided design) software Cercon Art (Degudent, Hanau, Germany) was used for the design of the anatomically crowns (Fig. 1), in order to obtain identical samples, and the wax-ups were milled in Cercon base cast materials (Fig. 2). These were invested, and specific steps were covered in order to obtain heat pressed ceramic crowns using Cergo pressed ceramics (Degudent, Hanau, Germany). The crowns were glazed and conventionally cemented. For antagonists base metal alloy teeth were fabricated using the lost wax technique generated from impressions of the standardized model teeth (first and second lower molars). All specimens were mounted in a universal testing machine and subject to failure tests. 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 (Fig. 3).

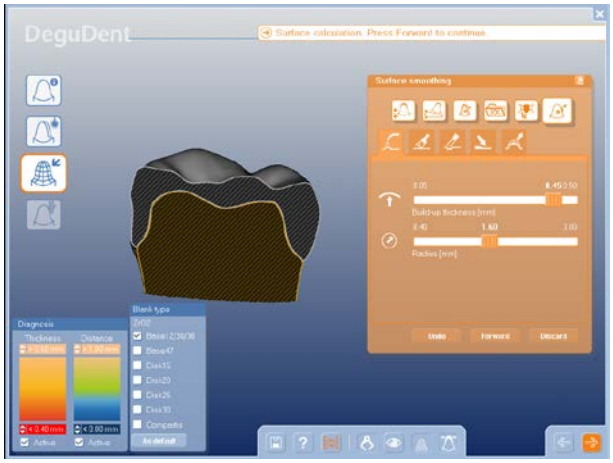

Fig. 1. CAD of the crown.

Fig. 2. Wax pattern of the crowns prepared for investing.

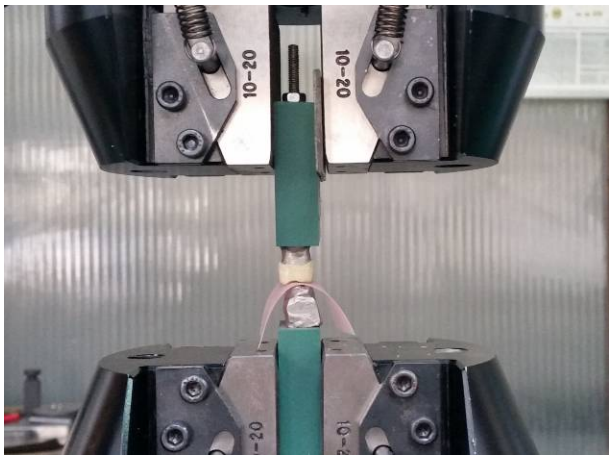

Fig. 3: Mechanical loading of the crowns.

The specimens were submitted to cyclic fatigue loading and fracture resistance testing, according to the load values, using a Dynamic Multipurpose Testing System series LFV (walter+bai ag Löhningen, Switzerland). After fractures, the specimens were visually assessed in order to determine the type of failure: cracks, chips, or fractures.

IV. Results and Discussions

The mode of failure depends on the loading mode. The cyclic loaded crowns show surface cracks and the static loaded crowns show fractures with different patterns.

The study was designed to compare the structural integrity of hot-pressed all-ceramic crowns for the posterior area, in order to determine the fracture strength under different loading modes. Besides different load values, the loading approach was different. A large variability in fracture load and patterns of the crowns was observed and compared with other literature results [24].

During static loading, at a value of 1200 N, cracks were initiated from the occlusal surface loading point, and they splitted the crown in more parts (Fig. 4, 5).

Fig. 4. Fracture lines and in the crowns initiated from the loading point, after static loading (1200 N).

Fig. 5. Section view of one fragment after static loading.

After cyclic loading, cracks are initiated also from the contact point, and penetrate slowly the crown thickness, increasing until fracture occurs (Fig. 6-9).

Fig. 6. Cracks in the crown after cyclic loading (550 N).

Fig. 7. Fractured crown after cyclic loading.

Fig. 8. Section view after cyclic loading.

Cyclic loading involves a gradual cracking, compared to the static one, which requires higher loads and occurs suddenly. The lifetime of the restorations can be simulated only by fatigue loading, by correlating the number of loading cycles.

Fig. 9. Fracture of the crown after cyclic loading (800 N).

The fracture behaviour of ceramic crowns have to be associated also with structural defects. These can arise during fabrication, and during functional and parafunctional activity [17-20]. Different modes of fracture can dominate under certain geometric conditions and at different stages in loading. Therefore fracture evolution is complex [4].

Fracture approach can be conducted by laboratory tests on different restorations by pressing down on the exposed surface with an indenter [21-23], but complex structures and the varied behaviour during functions involve comprehensive tests.

Even their many advantages, glass ceramics are brittle materials. Crack initiation and propagation can result in compromise of the restorations. The compromised structural integrity indicated by a significant reduction in fracture strength will be reflected in a poor clinical performance. Therefore the clinical significance of these results is to give an indication of the strength of hot-pressed ceramic crowns to be used in the molar areas as monolithic restorations. Further studies are required to assess the durability of such restorations before clinical use.

V. Conclusions

In vitro testing is important before the clinical application. Static loading, wide used in literature, can give an information regarding the values of fracture resistance, but are not illustrative for the long-term success of the restorations, like fatigue behaviour. The most accurate way to simulate the clinical behaviour is the cyclic loading in order to simulate a defined period of oral service.

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