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Survival of resin infiltrated ceramics under influence of fatigue

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ABSTRACT

Purpose. to evaluate influence of cyclic fatigue on two resin infiltrated ceramics and three all-ceramic crowns manufactured using CAD/CAM technology.
Materials and methods. CAD/CAM anatomically shaped crowns were manufactured using two resin infiltrated ceramics (Lava Ultimate and Vita Enamic), two reinforced glass ceramic milling blocks (^{IPS}Empress CAD and ^{IPS}e.max CAD) and a veneered zirconia core (^{IPS}Zir CAD). ^{IPS}e.max CAD and ^{IPS}Zir CAD were milled into 0.5 mm thick anatomically shaped core structure which received standardized press-on veneer ceramic. The manufactured crowns were cemented on standardized resin dies using a resin adhesive (Panavia F2.0). Initial fracture strength of half of the specimens was calculated using one cycle load to failure in a universal testing machine. The remaining crowns were subjected to 3.7 million chewing cycles (load range 50–200 N at 3 s interval) in a custom made pneumatic fatigue tester. Survival statistics were calculated and Weibull modulus was measured from fitted load-cycle-failure diagrams. Scanning electron microscopy was performed to fractographically analyze fractured surfaces. Data were analyzed using two way analysis of variance and Bonferroni post hoc tests ($\alpha = 0.05$).
Results. Dynamic fatigue resulted in significant reduction ($F = 7.54$, $P < 0.005$) of the initial fracture strength of the tested specimens. Zirconia showed the highest deterioration percent (34% reduction in strength) followed by ^{IPS}Empress (32.2%), ^{IPS}e.max (27.1%) while Lava Ultimate and Vita Enamic showed the lowest percent of reduction in strength. The two types of resin infiltrated ceramics and ^{IPS}Empress demonstrated the highest percent of fracture incidences under the influence of fatigue (35–45% splitting). None of the tested veneered zirconia restorations were fractured during testing, however, chipping of the veneer ceramics was observed in 6 crowns. The lowest percent of failure was observed for ^{IPS}e.max crowns manifested as 3 cases of minor chipping in addition to two complete fracture incidences. SEM images demonstrated the internal structure of the tested materials and detected location and size of the critical crack.
Conclusion. The internal structure of the tested materials significantly influenced their fatigue behavior. Resin infiltrated ceramics were least influenced by fatigue while the characteristic strength of zirconia prevented core fracture but failure still occurred from the weaker veneer ceramic.

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1. Introduction

Strength of dental ceramics increased significantly over time from values lower than 100 MPa for feldspathic ceramics, to 175 MPa for leucite reinforced glass ceramic [1], over 400 MPa for lithium-disilicate reinforced glass ceramics [2], up to 687 MPa for sintered alumina, and finally 1200 MPa for zirconia polycrystalline ceramics. New hybrid ceramics are currently being tested as Ceria stabilized zirconium alumina titanium composite ceramics which offer much higher mechanical properties and fracture toughness [3]. Nevertheless, during clinical service, all-ceramic restorations are subjected to complex intra-oral forces. Restorations are loaded repeatedly in the presence of water with sub-critical masticatory loads reaching at an average of 500,000 cycle/year [4]. This combination of cyclic loading in an alternating chemical and thermal conditions resulted in marked reduction of the mechanical properties of all-ceramic restorations.

Dynamic fatigue studies represent a clinically relevant approach to investigate the failure mechanism of the tested restorations and they allow accurate calculation of their survival statistics. On the contrary, one cycle load-to-failure tests, commonly known as fracture strength tests, utilize unrealistically high loads (1500–5000 N) several folds higher than the estimated forces produced by human orthognathic system [5]. These tests deliver the applied load through blunt indenters which generate Hertzian cone cracks on the surface of the brittle ceramic material leading eventually to total crushing and shattering of the tested specimen [5,6]. Unfortunately, studies concerned with long-term fatigue resistance require expensive and sophisticated appliances increasing both time and total cost of the study.

The combination of accurate digital imaging systems combined with state of the art design and milling technology (CAD/CAM) allowed fabrication of all-ceramic restoration with high reliability and success rate [7,8]. Recently, new hybrid CAD/CAM blocks were introduced to the dental field, composed of two matrices: a polymer and a ceramic networks. This dual network structure reduced brittleness and surface hardness of the material allowing easier milling in a shorter time [9]. The properties of resin-infiltrated ceramics (RIC) make them an interesting choice as interim restorations during management of and rehabilitation of complicated cases. However, not much is known about the fatigue resistance of these new materials.

The aim of this study was to evaluate fatigue resistance of two resin-infiltrated ceramics, two reinforced glass ceramics, and a polycrystalline core material under the influence of dynamic fatigue. The proposed hypothesis was that resin infiltrated ceramics would demonstrate lower fatigue resistance compared to the other tested materials.

2. Materials and methods

2.1. *Preparation of the specimens*

A maxillary central incisor received a full crown preparation for an all-ceramic restoration according to the following criteria: 1.5 mm incisal reduction, 1.2 mm axial reduction and 0.9 mm uniform rounded chamfer finish line. Polyether impression was made for the finalized polished preparation (Impregum Penta, 3M ESPE, Seefeld, Germany) and resin composite duplicates were prepared by filling and packing a posterior resin composite material (Z350, 3M ESPE). Digital impressions were made for the prepared resin dies (Cerec 3D 4.0, Sirona, Germany) and 5 types of CAD/CAM blocks were used to fabricate the restorations:two types of resin infiltrated ceramics: (Enamic, Vita Zahnfabrik, Bad Säckingen, Germany) and (Lava Ultimate, (3M ESPE, St. Paul, MN, USA), two types of glass reinforced ceramics IPSEmpress CAD and IPSe.max CAD (Ivoclar-Vivadent, Schaan, Liechtenstein), and a zirconia veneered restoration (Zir CAD, Ivoclar-Vivadent).

IPSe.max CAD and Zir CAD blocks were milled into a 0.5–0.7 mm thick anatomically shaped cores which received a press-on veneer ceramic according to manufacturer instructions (IPSe.max press, Ivoclar Vivadent); Fig. 1A. All crowns were cemented on their corresponding resin dies using a resin adhesive (Panavia F 2.0, Kuraray, Osaka, Japan) applied under

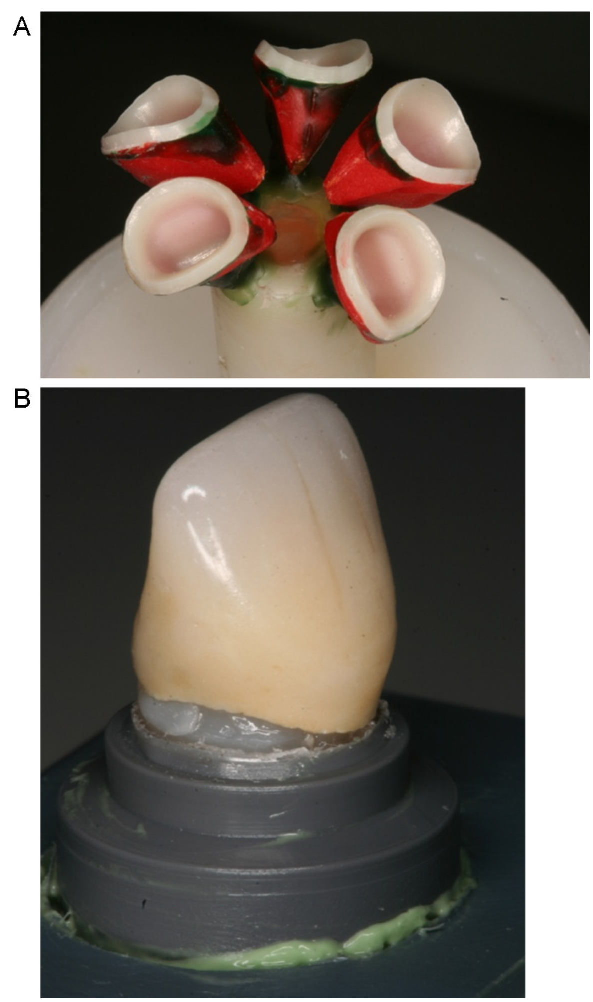

Fig. 1 – (A) Zirconia coping received identical wax superstructure and prepared for veneer pressing. (B) Veneered zirconia restorations cemented on their resin dies and fixed to the attachment unit before application of cyclic loading.