<u>Fracture strength of hybrid ceramic occlusal veneers using two preparation designs on different dental substrates</u>

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Introduction

Excessive loss of coronal tooth structure or severe tooth wear is not uncommon in the general population.[1]The multifactorial etiology of tooth wear is associated with dietary habits, medical conditions, and/or oral habits that lead to attrition, abrasion, and erosion of the enamel and dentin[2].The destruction of tooth structure has been a significant concern as it affects musculoskeletal harmony, occlusal stability, oral comfort, esthetics, and overall the patients' satisfaction with their dentition.[3]

Traditionally treating for erosive lesion and severely worn dentition includes extensive tooth preparation required for conventional crowns.[4]

Ceramic materials have the desired esthetics and durability. However, the feasibility of their application in thin conservative preparations depends on their fabrication options and fracture properties. Recent advances in (computer-aided design/computer-aided manufacturing) CAD/CAM technology and materials are offering new options for restoration of severely worn dentition where space is limited.[5] A new CAD/CAM ceramic hybrid material has been developed by infiltration of a polymer into a porous ceramic network.[6] This polymer-infiltrated ceramic network material is clamied to have a microstructure similar to a natural tooth and has mechanical properties that fall between those of porcelains and resin composites.[7] It can be milled at thin thicknesses to accommodate conservative tooth preparation.[5]

Adhesion is the primary requirement so that restorative materials can be bonded to enamel or dentin and without the need of extensive tooth preparation. It is very important to focus on the mineral component of enamel. The formation of resin micro and macro tags within the enamel surface constitutes the fundamental mechanism of enamel-resin adhesion. Bonding to dentin has been proven more difficult and less reliable and predictable than to enamel.[8]

Mechanical failure of ceramic materials is almost completely controlled by brittle fracture. Usually, this brittle behavior combined with surface flaws result in relatively low ceramic strengths. Increased crystalline-filler content within the glass matrix, with a more even distribution of particles and finer particle size, has yielded significant improvements in the flexural strength of ceramic materials. However, strength improvements are still limited by the inherent weakness of the glass matrix.[9]

Different preparation designs for occlusal veneers as non anatomical and anatomical designs were proposed. However, the best design is not yet revealed.

So the objective of the present study is to assess the fracture strengths of occlusal veneers fabricated from CAD/CAM hybrid ceramic with two preparation designs and bonded to enamel or dentin under vertical compressive loading after thermocycling.

Review of literature

Enamel as the outer barrier is designed to resist the wide array of aggressions from the oral environment (thermal, biological, chemical) for one's entire life. The progressive reduction of enamel thickness is a biological condition resulting from the aging process[10] or a pathological condition as dietary and oral habits which cause abrasion of enamel and dentin.[11] As mineral loss is sluggish, slow and usually trouble-free, dental erosion is frequently overlooked.[12] It is usually diagnosed at a progressive stage, once a significant loss of enamel has occurred.[13, 14]

The management of dental erosion must be concentrated on the cause and inhibition of additional damage. The restorative phase requires a careful approach, depending on the degree of damage. Incipient lesions call for a clinical follow-up (for example standardized photographs and accurate periodic impressions), noninvasive dentin sealing with a filled dentin bonding agent, or conservative direct composite resin restorations.[15]

However, treatment of patients with severe generalized erosion, wear and attrition is more complex. The major challenges are restoring the shape and anatomy of the dentition often involves reducing sound dental tissues and there is a wide range in the amount of reduction required by the different restorative approaches.[16] Considering the often regular pattern of structural loss often seen in cases of long-term bruxism and acid erosion, restoring such worn teeth with occlusal veneers can be relatively non-invasive, requiring little additional tooth reduction.[17]

Occlusal veneer:

The benefits of decreasing retentive features of tooth preparations could be increased by the application of concepts used in treatment with anterior laminate veneers, hence the proposal for posterior "occlusal veneers" (thin onlay/overlay with non-retentive design). Such restorations could compete with gold onlays/overlays. Occlusal veneers are extra coronal restorations demanding a simple preparation lead by anatomical considerations and occlusal clearance.[18] Occlusal veneers have been demonstrated as a conservative alternative to traditional onlays.[19]

The main advantage of the occlusal veneers is conservation of tooth structure, as they require little tooth reduction. Before long-term clinical studies are available to support their longevity, occlusal veneers can be viewed as provisional restorations. More often than not, patients are in need of prolonging their oral rehabilitation period due to financial issues. Occlusal veneers could maintain vertical dimensions to allow a patient to prolong their treatment and secure necessary funds through a rehabilitative process. The occlusal veneers can also be used to assess a patient's ability to withstand an increased vertical dimension. Many patients with severely worn dentition have lost the vertical dimension, and vertical dimension opening can be extremely challenging. Occlusal veneers could serve as a reversible method of evaluating one's vertical dimension opening. The clinical durability of the minimal invasive ultrathin occlusal veneers has yet to be proven, but their ease of fabrication and practicality may help protect vital tooth structure while maintaining vertical dimensions throughout rehabilitative treatments, at least as interim restorations.[20]

The usual recommendation for porcelain thickness is 1.5 to 2.0mm.[21, 22] However, given the development of stronger materials in combination with CAD/CAM techniques and innovative adhesive technology; more conservative approaches should be considered.[23-24] Several thicknesses of occlusal veneer restorations were used in previous researches: (0.3, 0.6, 1, 1.2mm).[25]

There are different designs for occlusal veneer preparation:

- For anatomical occlusal preparation: The teeth can be prepared by keeping the cuspal inclination as constant as possible by maintaining the buccal and palatal margins at approximately 5.5mm from the CEJ. Anatomical preparation with 150 º angle is prepared between cusps is recommended by **Sasse et al[25] and Clausen JO et al.**[26]

- For flat occulsal preparation: The entire coronal tooth structure is sectioned perpendicular to the long axis of the tooth leaving a flat area of exposed dentin and peripheral enamel. The flat design is recommended by **Johnson[17] et al and Eegbert et al.**[20]

Recent advances in CAD/CAM (computer-aided design/computer-aided manufacturing) technology and materials are offering new options for restoration of severely worn dentition where space is limited. They are considered more conservative restoration which applied in thin thickness, required minimum reduction and allowed better and finer reproduction of detail in machine-milled restorations.[27] Hybrid ceramic, nano resin ceramic and zirconia reinforced lithium disilicate, new composite have been introduced. Many tests were carried out to asses and evaluate the occlusal veneers with various materials.

Material used for the construction of occlusal veneers:

The choice of restorative material is considered to be one of the most crucial factors for success; reliability and long term prognosis of any restorative system.[28] Recent trends in esthetic dentistry include the reduction or elimination of metals and increasing use of CAD/CAM technology.[29] These trends have led to increased usage of ceramic and composite materials and have contributed to the growth of the CAD/CAM market.[30]

Ceramics as dental materials have desirable characteristics such as chemical stability, biocompatibility, high compressive strength and a coefficient of thermal expansion similar to that of tooth structure.[28] In addition, dental ceramic have esthetic properties that simulate the appearance of natural dentition; however, they are susceptible to fracture, which is a result of material characteristics and surface and bulk defects.[31] Advantages of ceramics are a high flexural strength and great color stability, while disadvantages are high antagonistic tooth wear and loss of tooth structure due to a minimum thickness of 1.5 to 2.0 mm. These two parameters are better for composite resins, but the wear of the materials itself is higher.[32]The development of novel dental esthetic materials has switched to more polymer based resin-composites. However, traditional dental composites are compromised by their curing shrinkage, low mechanical properties and poor wear resistance. Thus there is an urgent need to develop a new composite system to support the emerging indirect restorative material market. There have been some developments in this area with the release of Paradigm TM MZ100 Block for inlay, onlay, veneer and full crown.[33] The performance of composite resins has improved during the last decade, [34, 35] through a superior bond between the different phases (enabling appropriate stress transfer) [36, 37] and various post-polymerization treatments.[38,39] Key properties of composite resin restorations include their low abrasiveness to antagonistic teeth (enamel preservation)[40] and low elastic modulus, allowing more absorption of functional stresses through deformation.[41] These parameters show that there always a need for a materials that combines, the advantages of ceramic with those of composites. Ultrastructure, physical and mechanical properties of available CAD/CAM materials vary widely, and, accordingly, their mechanical behavior in the tooth restoration complex is expected to vary as well.[42]

The ongoing research for such a biomimetic materials with physico-mechanical properties similar to those of natural tooth tissues led to the development of a new generation of hybrid blocks for CAD/CAM processing (**Hybrid Ceramic**).

Magne et al (2012)[19] compared stresses within bonded porcelain and composite resin ultra-thin occlusal veneers to restore advanced erosive lesions (finite study). A sound maxillary molar was digitized with a micro-CT scanner. The 2D image data were converted in a 3D model using an interactive medical image processing software (Mimics). Standard triangle language files (STL files) of enamel and dentin surfaces were then exported to the software 3-matic to execute design and meshing operations. Solid 3-dimensional (3-D) models acquired in a finite element software(Marc/Mentat) were subjected to nonlinear contact analysis to simulate occlusal loading at 200N and 800N. There were marked differences in stress distributions both at 200N (maximum peak values of 21.59, 28.63, 31.04 MPa) and 800N (96.16, 115.73, 134.90 MPa) for all restorative materials (MZ100, Empress CAD and e.max CAD, respectively). High tensile stresses (measured in the central groove) were found at 800N with the ceramic occlusal veneers showing occlusal stress peaks 17–29% higher than composite resin. The estimated risk of fracture was decreased for ultrathin composite resin occlusal veneers, which correlated with theexisting validation data.

Jonhson et al (2014)[17] evaluated the effect of material type and restoration thickness on the fracture strength of posterior occlusal veneers made from computer-milled composite

(Paradigm MZ100) and composite-ceramic (Lava Ultimate) materials (in vitro study). Molars were prepared and restored with CAD/CAM occlusal veneer restorations fabricated from either Paradigm MZ100 or Lava Ultimate blocks at minimal occlusal thicknesses of 0.3, 0.6, and 1.0 mm and subjected to vertical compressive loading. Results revealed that no significant difference existed among the various restoration thicknesses in terms of fracture strength and the material type was found to be influential. The maximum load at fracture (N) for Lava Ultimate averaged over all thicknesses (2111± 500N) was significantly higher than that of the Paradigm MZ100 (1826±564N).

Schlichting et al (2015)[43] assessed the influence of CAD/CAM restorative material (ceramic vs. composite resin) on fatigue resistance of ultra-thin occlusal veneers. All teeth were restored with a 0.6 mm-thick occlusal veneer(in vitro study). Reinforced ceramics and composite resinere used to mill the restorations. Cyclic isometric loading was applied at 5 Hz, beginning with a load of 200N (x 5,000), followed by stages of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each. Specimens were loaded until catastrophic failure (lost restoration fragment) or to a maximum of 185,000 cycles. Results showed that composite resins increased the fatigue of ultra thin occlusal veneers when compared to ceramics.

Vita Enamic:

In early 2013 VITA introduced ENAMIC. The new polymer infiltrated ceramic and polymer (Vita Enamic) combines the properties of ceramic and polymer. According to manufacture claimes, Vita Enamic consists of "a hybrid structure with two interpenetrating networks of dominating ceramic and a reinforcing composite forming what's called double network hybrid ceramic material.[44]The pores in the structure-sintered ceramic matrix are filled with a polymer material. The mass percentage is 86wt% and 14wt% for the inorganic ceramic part and the organic polymer part respectively.[45,46] Compositional analysis of the dominant ceramic network revealed a major leucite –based phase of feldspar origin and a minor crystalline phase of zirconia, which could function as a strengthening component. Great amount of a carbon was found on the polymer based network, which the manufacture described as a surface modified PMMA (polmethylmethacrylate) free from MMA (methylmetacrylate).The microstructure, polymer infiltrated ceramic network is reflected on the material properties having mechanical properties between porcelains and resin based composites.[7]

One of the main advantages of Vita Enamic is reasonable brittleness index with proper fracture toughness which makes the material a suitable candidate for CAD/ CAM technology. Unlike partially sintered CAD/CAM materials which require additional firing, the one-step manipulation of this material helps ensure a high degree of dimensional accuracy of the final products. The material also show lower hardness compared with traditional veneering porcelains which may better protect the opposing teeth from excessive wear and should enable more rapid machining in CAD/CAM machines. Similar creep response as enamel and low hardness endows the material with lower contact stresses and good stress redistribution ability when used as a dental restorative.[33]The modulus of elasticity of the material influences the susceptibility to fracture of a cemented ceramic restoration since materials with more compatible elastic moduli, like Vita Enamic polymer infiltrated ceramic and lava Ultimate resin nanoceramic, tend to bend under load and distribute stresses more evenly, while rigid materials with different elastic moduli, such as lithium disilicate, produce stress concentration at critical areas that might cause catastrophic failures.[47]

Egbert et al (2015) [20] compared the fracture strengths and failure modes of ultrathin (0.3-mm) occlusal composite or hybrid ceramic veneers.60 extracted maxillary molars were sectioned to remove the entire coronal structure 4mm occlusal to the CEJ leaving a flat area of exposed dentin and peripheral enamel. Standardized occlusal veneers with a central fossa