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ORIGINAL ARTICLE

Fracture resistance of porcelain veneered zirconia crowns with exposed lingual zirconia for anterior teeth after thermal cycling: An in vitro study

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Abstract *Statement of problem:* In some clinical conditions minimally invasive complete crown tooth preparations are indicated. This is especially true when gross removal of tooth structure would weaken the remaining tooth or violate the vitality of the dental pulp.

Objective: The purpose of this study was to investigate the influence of (1) exposed lingual zirconia with veneered zirconia crowns, and (2) reduced lingual thickness of monolithic lithium disilicate crowns on the fracture resistance of the crowns after cyclic loading. Metal-ceramic crowns with exposed lingual metal served as controls.

Materials and methods: Twenty-four maxillary central incisor crowns were fabricated in identical shape on metal testing dies in 3 groups: metal-ceramic crowns (MC, $n = 8$), veneered zirconia crowns (VZ, $n = 8$), and monolithic lithium disilicate crowns (MO, $n = 8$). A conservative preparation design with 0.75 mm lingual clearance was used for each crown system. All crowns were cemented to their corresponding crown preparations with self-adhesive resin cement (Multilink Automix). The crowns were subjected to 1000 cycles of thermal cycling, then cyclic loading of 111 N by means of a stainless steel ball, and 50,000 cycles of loading were applied for the fatigue test. Fatigue loading was followed by a continuously increasing compressive load, at a crosshead

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speed of 1 mm/min until failure. The compressive load (N) required to cause failure was recorded. Means were calculated and analyzed with one-way ANOVA and the Tukey HSD test ($\alpha = .05$).

Results: There was a significant difference between MO vs. MC ($P = .0001$), MO vs. VZ ($P = .0001$), and VZ vs. MC ($P = .012$).

Conclusions: There was a significant difference in the mean fracture resistance of MC, VZ, and MO crowns in this in vitro study. The MC group recorded the highest mean fracture strength.

1. Introduction

Three fundamental criteria traditionally considered in the selection of materials for complete-coverage restorations include: strength, esthetics, and fit. Clinical longevity is a critical outcome measure related to these selection criteria (Abbate et al., 1989; Vahidi et al., 1991).

Metal-ceramic restorations have been available for over 50 years. During this period, substantial improvement in alloy substrates and veneering porcelains has resulted in widespread acceptance of metal-ceramic restorations, and continued research efforts have led to a more detailed, practical understanding of metal-ceramic systems (Kelly et al., 1996). Dental ceramic technology is a rapidly advancing area of dental materials research and development (Anusavice and Phillips, 2003). Dental ceramics have the potential to reproduce the depth of translucency, depth of color and texture of natural teeth (O'Brien et al., 1985).

Dental crowns fabricated as multilayered structures may have different stress distributions and load-bearing ability when compared with monolithic restorations. Therefore, differences in mechanical behavior and incidence of fracture could be expected (Santana et al., 2009). The ultimate aim of using all-ceramic systems is to provide crowns with sufficient mechanical strength to resist occlusal forces while maintaining excellent esthetics and biocompatible properties.

Metal-ceramic restorations are reputed to be the gold standard in dentistry, offering acceptable esthetics and long-term structural performance (Donovan, 2009; Napankangas and Raustia, 2008). Over the past 60 years, different designs and techniques for the fabrication of metal-ceramic restorations have been developed and improved (Warpeha and Goodkind, 1976; Shelby, 1962; Straussberg et al., 1966; Shoher and Whiteman, 1983; Brecker, 1956; Goodacre et al., 1977). Materials proposed as an alternative must be as reliable as metal-ceramics, particularly with regard to fracture rate and marginal adaptation (Pilathadka and Vahalova, 2007; Heintze and Rousson, 2010). A survey of several dental laboratories indicated that metal-ceramic restorations fabricated with high gold or high noble alloys are more expensive than zirconia-substructure crowns (Donovan, 2009).

Patients' demands for tooth-colored crowns without a metal substructure have driven substantial efforts toward increasing the strength and reliability of dental ceramic systems (Raigrodski, 2006). Fracture-strength studies of crown systems, within their limits, provide data relative to the load-bearing capacity of crowns in simulated clinical situations (Ku et al., 2002). Different in vitro and in vivo studies have been conducted, attempting to evaluate the reliability and fracture resistance of alternative dental ceramic systems and to define the factors that affect the longevity of these restorations. Al-Dohan et al. (2004) tested the shear bond strength of 4 veneering porcelains to the corresponding all-ceramic substructure materials, with metal-ceramic crowns serving as the control, and reported no statistically significant difference for 3 of the porcelain systems when compared to the control group. Coelho et al. (2009a,b) and Guess et al. (2009) fatigue tested zirconia-substructure, porcelain-veneered crowns using different testing methods, different veneering techniques, and different crown systems. Single load-to-failure tests conducted by Coelho et al. (2009a) resulted in fractures through the zirconia core. Fatigue testing that resembled occlusal loading (Coelho et al., 2009a,b) (Guess et al., 2009) resulted in surface damage to the zirconia veneering ceramics with chipping. To develop a clinically relevant testing method, a variety of clinically important variables, such as type of luting agent, bonding technique, the presence of water, substructure material, and preparation design must be considered (Friedlander et al., 1990; Kelly et al., 2010). Clinical follow-up of zirconia porcelain-veneered crowns has suggested a promising alternative to metal-ceramic crowns (Ortorp et al., 2009; Sailer et al., 2006, 2007).

Preservation of tooth structure is essential, especially for situations where gross removal of tooth structure would weaken the remaining tooth or violate the vitality of the dental pulp, for example teeth that are thin facio-lingually. When palatal clearance is limited, the use of a veneered zirconia-substructure crown with the palatal surface only in zirconia might be an option for all-ceramic crowns. Although the commonly recommended minimal thickness for a lithium disilicate monolithic crown is 1 mm, the absolute minimal allowable thickness of lithium disilicate monolithic crowns has not been studied scientifically as an option for certain clinical circumstances where palatal clearance is limited.

The aim of this study was to investigate the influence of (1) exposed lingual zirconia with zirconia porcelain-veneered crowns and (2) reduced lingual thickness of monolithic lithium disilicate crowns on fracture resistance of the crowns after thermal cycling and cyclic loading. The null hypothesis was that there would be no difference in the mean fracture resistance of zirconia veneered crowns with exposed lingual zirconia, monolithic lithium disilicate crowns, and metal-ceramic crowns with a metal lingual surface.

2. Materials and methods

2.1. Tooth preparation

A maxillary central incisor resin tooth (Ivorine tooth; Columbia Dentoform, Long Island City, NY, USA) was fixed in a plaster block, with the plaster 1 mm below the cemento-enamel