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The effect of margin thickness, degree of convergence and bonding interlayer on the marginal failure of glass-simulated all-ceramic crowns

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A B S T R A C T

The objectives of this study were to identify the effect of design parameters, namely marginal thickness, degree of convergence and the different interfacial conditions, on the initial failure load that induces cracking from the margin in glass-simulated dental crowns. Crown-like glass cylinders were prepared to simulate posterior all-ceramic crowns with two different marginal thicknesses (0.8 or 1.2 mm) and degrees of convergence (6° or 12°). A three-step bonding system was used complementarily with a silane coupling agent to adhesively bond the specimens to resin dies. The crowns were subjected to an axial applied load to generate hoop tensile stress at the crown margin. The entire loading and fracture processes were recorded by video camera. The loading data were compared with the other two interfacial treatments (Vaseline grease and directly poured uncured resin on glass). The Weibull distribution was used to statistically analyze the characteristic failure load and the mean values. The fracture surfaces were fractographically analyzed along with the load–displacement curves, and the degrees of crack stability for each parameter were also identified. It was found that there is no difference in the initial failure load between the different marginal thicknesses in all interfacial conditions. The bonded crowns present more resistance to crack propagation. The higher convergence crown preparation can reduce the initial failure load at the crowns' margin, which can be resisted by a strongly bonded interface. Clear interactions between margin design parameters and their effects on the stress development and crack propagation are necessary to develop an appropriate design of all-ceramic crowns.
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1. Introduction

Ceramic coatings have great versatility and have been used in many fields [1–4] because of their satisfactory physical properties and improved functionality. In dentistry, all-ceramic restorations have become more popular as a restorative option; they can sustain multidirectional chewing forces, reduce plaque accumulation and importantly provide excellent esthetic outcomes. However, due to their brittleness, all-ceramic prostheses are usually susceptible to tensile stress, especially in the area where the bulk of the material is not sufficient. For a single crown, the potential sites are primarily the occlusal or the marginal areas, where the space is quite limited by the position of the opposing or adjacent tooth, the remaining tooth structure and the risk of invading pulp vitality. Consequently, the design of all-ceramic crowns, especially for posterior teeth, undoubtedly raises critical concerns regarding both stress distribution and the vitality of the remnant tooth structure.

The situation is even more complicated when monolithic ceramic crowns are supported by dentin forming a complex bilayer or trilayer structure, especially when a tough but opaque ceramic coping is additionally introduced as a crown's substructure aiming to provide support for veneering porcelain. In addition, clinical crown failure origins have been variably reported (such as the occlusal contact area or wear facet [5,6] and coping–veneer interface for bilayer crowns [7,8]; these are sometimes considered to have multiple origins [9]) and may be affected by competing fracture modes that can be dominant under certain conditions. For these reasons, perfect design preparations for all-ceramic restorations have not been developed. Despite this, studies of a hard contact on the failure of flat glass bilayer or trilayer specimens have brought considerable understanding of the failure from radial cracking or cone cracking and have been useful to explain chipping, impact fracture of the veneering porcelain or catastrophic failure of the monolithic crown. The test has some limitations regarding the behavior of clinically failed crowns because of the simpler shape of the tested specimens and the dominant role of local contact failure.

Crown fracture resistance tests undertaken by applying an axial or non-axial force on anatomical crowns monotonically [10–14] or cyclically [15,16] until the crowns fracture or the first sign of

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