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Influence of interface surface conditions on indentation failure of simulated bonded ceramic onlays

Nancy L. Clelland[a,*], Nicholas Warchol[b], Ronald E. Kerby[a], Noriko Katsube[c], Robert R. Seghi[a]

[a]*Department of Restorative and Prosthetic Dentistry, College of Dentistry, The Ohio State University, 305 West 12th Ave., #191, P.O. Box 182357, Columbus, OH 43218-2357, USA*
[b]*Department of Materials Science and Engineering, College of Dentistry, The Ohio State University, 305 West 12th Ave., #191, P.O. Box 182357, Columbus, OH 43218-2357, USA*
[c]*Department of Mechanical Engineering, College of Dentistry, The Ohio State University, 305 West 12th Ave., #191, P.O. Box 182357, Columbus, OH 43218-2357, USA*

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Summary *Objective*. This study aims to evaluate the influence of surface roughness and acid etching on interfacial failure load and fracture initiation site for simulated resin bonded ceramic restorations.
Methods. Layered disks were fabricated using soda lime glass to simulate porcelain and fiberglass to represent dentin. These materials were selected due to their approximate elastic modulus to porcelain or dentin. In addition, soda lime glass allowed for visualization of crack initiation. Glass microscope slides (1.2 mm thick) were sectioned into 1-mm^2 specimens. The frosted portions of the slides were used as the rough or sandblasted group and the clear areas were used as the smooth or polished group. All surfaces were either cleaned or etched. Prepared surfaces were divided into eight groups and bonded to the substrates using Optibond Solo Plus (SDS Kerr, Orange, CA) and Nexus resin cement (SDS Kerr). Support substrates were made from 5-mm slices of fiberglass rods (1/2 in. diameter). Vertical loads were applied to the layered disks with a 20-mm spherical indenter at a cross-head speed of 0.05 mm/min. Observations were made using 10× magnification with a video monitor. Load magnitudes were recorded at the time of crack initiation. Weibull parametric survival analysis and the effect likelihood ratio test were performed on the failure initiation load data to determine significant differences at the 0.05 level.
Results. Mean failure initiation loads ranged from 273.6 to 341.9 N for the rough specimens and from 1056.5 to 2980.2 N for the smooth samples. According to the Weibull parametric survival analysis and the effect likelihood ratio test, surface

* Corresponding author. Tel.: +1 614 292 3015; fax: +1 614 292 9422.
E-mail address: clelland.1@osu.edu (N.L. Clelland).

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roughness and surface etch significantly influenced failure initiation loads. Smoother surfaces tolerated much greater contact loads before failure initiation.
Significance. The clinical performance of all-ceramic restorations may be improved with smoother internal surfaces. Etching significantly increases survival for restorations with smooth internal surfaces.

Introduction

All-ceramic restorations are growing in popularity due to the high esthetic demands of patients and the clinicians concerns with the esthetic limitations of metal–ceramic crowns. However, there is some professional concern regarding the clinical longevity of these restorations [1]. Metal–ceramic restorations have demonstrated relatively low failure rates [2–5], whereas fractures have been a relatively frequent reason for all-ceramic restoration replacement, particularly for molar teeth [6–10]. In an effort to improve clinical performance, researchers are investigating the influence of various parameters such as material strength, fracture toughness, luting agents, thermocycling, core substructures and surface treatments on failure characteristics.

For glass–ceramic materials, the influence of the internal surface characteristics remains an area of particular interest. Fractographic analysis of clinically failed all-ceramic crowns has shown that a majority of the fractures were initiated from the internal surface of the restoration rather than from the outer contact surface [11,12]. This information has led several investigators to focus their efforts on evaluating factors that influence the strength of the ceramic surface.

The physical surface of glass may be altered by sandblasting or acid etching. Both methods have been used in dental ceramics to improve surface adherence. Several in vitro studies have shown that sandblasting or air-abrading porcelain surfaces improve its shear bond strength to resin [13–16]. The effect of abrasion on porcelain strength, however, was not evaluated in these studies.

The effect of surface finishing procedures on the strength of ceramic materials has been assessed by several investigators. Kosmac et al. [17] found that surface grinding and sandblasting produced opposite effects. Surface grinding with a coarse diamond burr using high speed rotation decreased the mean strength, whereas sandblasting increased the strength. De Jager et al. [18] found that porcelain samples with smoother outside surfaces generally exhibited greater strength than those with rougher surfaces. They concluded that grinding restorations into occlusion may introduce surface roughness and flaws that may propagate cracks and decrease the longevity of restorations.

The glass and ceramic industry has reported that chemical etching can strengthen commercially produced glass [19–21]. It has been explained that the etching process acts to remove or smoothen glass surface flaws reducing stress concentrations and improving overall strength [22,23]. However, defect-free glass may react less favorably or actually weaken from etching [24]. Reports are mixed regarding the effect of etching on dental porcelain strength in the dental literature. Hussain et al. [25] found that the strength of aluminous porcelain jacket crowns decreased after etching. In a more recent study, the flexural strength of laminate veneers was not statistically different for etched or non-etched groups [26]. The flexural strengths of the feldspathic and castable glass ceramics used were slightly lower for the etched specimens [26]. It was uncertain whether these lower values would affect the clinical longevity of porcelain veneers.

Although few clinical studies have reported data relating internal surface treatments to clinical success, one significant long-term clinical study followed 417 patients with a total of 1444 Dicor single-tooth restorations for 16 years [27]. The effect of acid etching on the internal ceramic surface was among the factors evaluated. The reported failure risk for the non-etched restorations was over twice that of the acid-etched restorations. The data for this study included restorations that were luted with zinc phosphate and glass ionomer as well as composite resin [28]. Clinical and in vitro studies have demonstrated higher survival rates for bonded ceramics following chemical etching [26,27]. Information regarding the mode of failure and the relationship of surface roughness, coupling agent and aging on the final restoration strength would also be helpful. A simple bi-layered glass model has been used in materials research to provide direct visualization of crack initiation using a camera arranged below the surface [29]. This study aims to use a similar model to determine the effect of various surface