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Original article

Evaluation of shear bond strength of veneering ceramics and zirconia fabricated by the digital veneering method

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ABSTRACT

Purpose: The purpose of this study was to evaluate the shear bond strength (SBS) of veneering ceramic and zirconia fabricated by the digital veneering method.

Methods: A total of 50 specimens were fabricated, i.e., 10 specimens each for the metal-ceramic (control) group and the four zirconia groups. The zirconia groups comprised specimens fabricated by the digital veneering method, the heat pressing method, and hand layering method for two groups, respectively. Furthermore, the shear bond strength was measured with a universal testing machine (Model 3345, Instron, Canton, MA, USA) and statistically analyzed using one-way ANOVA set at a significance level of $P < 0.05$. The corresponding mode of failure was determined from Scanning Electron Microscope (FESEM JSM 6701F, Jeol Ltd., Japan) observations.

Results: One-way analysis of variance (ANOVA) revealed that the metal-ceramic group had the highest SBS (43.62 MPa), followed by the digital veneering method (28.29 MPa), the heat pressing method (18.89 MPa), and the layering method (18.65, 17.21 MPa). The samples fabricated by digital veneering had a significantly higher SBS than the other zirconia samples ($P < 0.05$). All of the samples exhibited mixed failure.

Conclusions: Veneering ceramic with a zirconia core that was fabricated via the digital veneering method is believed to be effective in clinical use since, its shear bond strength is significantly higher than that resulting from the conventional method.

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1. Introduction

Porcelain fused to metal (PFM) has been used extensively in the last 40 years for fixed partial dentures (FPDs) and is still widely used [1–3]. However, owing to the internal metal core, the esthetics of natural teeth cannot be completely re-created with metal-ceramic restorations [4].

Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), which was introduced in the early 1990s, has been widely used in the fabrication of all-ceramic crowns with CAD/CAM zirconia cores owing to its color, which is similar to that of natural teeth, its excellent biocompatibility, and its physical and mechanical properties [5–8]. However, in the last 3 years, delamination and chip-off in these crowns have resulted in a 25% clinical failure rate of the corresponding restorations [9]. This failure rate is significantly higher than that reported [10,11] for metal-ceramic restorations (2.7–5.5%).

Failure of all-ceramic crowns with zirconia cores has been attributed to low bonding strength between the zirconia core and the upper porcelain [12], design of the zirconia core [13], stress concentration resulting from the difference between the coefficient of thermal expansion of the zirconia core and that of the veneering ceramic [14], structural defect of zirconia from the zirconia coloring pigment [15], and flaws resulting from the production processes [16].

Previous studies revealed that the CAD/CAM technique applied to the production of ceramic prostheses reduced the porosity and flaws that accelerate failure of the upper porcelain. This technique also resulted in a uniform zirconia core; the all-ceramic crown with a zirconia core fabricated by the CAD/CAM veneering method exhibited significantly less chipping and failure than that fabricated by other methods [7,17]. In addition, the bond strength varied with the production method of the upper porcelain [12].

Most all-ceramic crowns with zirconia cores are fabricated by forming the upper porcelain on top of the zirconia core via layering [18,19] and a heat pressing method [18]. The Digital Veneering System (DVS) (Lava™; 3M ESPE, Seefeld, Germany), which was introduced as a CAD/CAM veneering method, can reduce both the time required for fabrication and the flaws resulting from the production process. DVS produces all-ceramic crowns by combining the upper porcelain and the zirconia core through firing; this firing is performed after veneering the fusion powder between the upper porcelain and the zirconia core, which were fabricated by milling the glass ceramic block and by using the CAD/CAM technique, respectively. By conducting this procedure, a zirconia all-ceramic restoration that closely replicated the shape and color of the natural teeth could be fabricated with minimum firing.

There are several available test methods to evaluate the bond strength between dental materials. The shear, tensile, three-point flexure, and four-point flexure tests are commonly used. The bond strength between a metal core and veneering porcelain has been investigated using flexure tests. Although the flexure test may be appropriate for metal-ceramic materials, it is not suitable for all ceramic system because of the brittle character of the ceramic core [20]. Some researchers prefer the tensile test. However, it has been reported that the tensile test results are greatly influenced by the geometry of the specimen, and non-uniform stress distributions arise during load application [21].

The shear bond strength test was selected for this study for certain important reasons, i.e., the result is not influenced by the Young's modulus of the substrate, and it allows simple specimen fabrication procedure and easy to perform the test with rapid acquisition of the results [20,22,23].

Numerous studies have been conducted on the bonding strength of the veneering ceramic and zirconia; however, studies on the shear bond strengths produced by different veneering methods, including the digital veneering method, are rare.

The goal of the present study was to evaluate the effective clinical use of zirconia-core all-ceramic crowns that were fabricated by the digital veneering method. This evaluation was made by comparing the shear bond strength (SBS) of all-ceramic crowns with zirconia framework fabricated by digital veneering and also by conventional methods, with the SBS of metal-ceramic restorations.

The null hypotheses were that the shear bond strength of an all-ceramic crown with zirconia would not be significantly different from that of a metal-ceramic crown and the digital veneering method would not affect the shear bond strength between the zirconia and ceramic.

2. Materials and methods

A metal-ceramic (MC) was used as the control group. Specimens with their upper porcelain fabricated by the layering method and digital veneering method on top of the Lava zirconia (3M ESPE, Seefeld, Germany) core were defined as LZL (Lava zirconia layering method) and LZD (Lava zirconia digital veneering method), respectively. In addition, specimens with their upper porcelain fabricated by layering and by heat pressing method on top of the IPS e.max zirconia (Ivoclar-Vivadent, Schaan, Leichtenstein) core were referred to as IZL (IPS zirconia layering method) and IZP (IPS zirconia heat pressing method), respectively. A total of 50 specimens (i.e., 10 specimens each for the metal-ceramic group and the four zirconia groups) were fabricated (Table 1).

2.1. *Preparation of the metal-ceramic specimens*

A silicone mold (blue eco, Detax GmbH, Ettlingen, Germany) was used to fabricate wax in the shape of a rectangular parallelepiped; the hardened wax pattern was removed from the mold and replicated as a metal casting by a traditional investment and burn out process. The metal specimens (Bellabond plus, BEGO, Bremen, Germany) were polished to sizes of 5 mm (length) × 5 mm (width) × 10 mm (height) using a stone point (carborundum point #11, SC, Korea), wheel (carborundum wheel #301, SC, Korea), and technical carbide bur (TC-cutter, Edenta, Switzerland). A 10 mm distance of the surface of the cast was blasted for 20 s with 110 μm aluminum oxide at a pressure of 2.5 bar and then cleaned ultrasonically with distilled water for 10 min. Porcelain (Vita VM13; Vita Zahnfabrik, Bad Sackingen, Germany) was veneered in a separable silicone mold located on top of the metal casting in which degassing and opaque (Vita VM13; Vita Zahnfabrik, Bad