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Influences of multiple firings and aging on surface roughness, strength and hardness of veneering ceramics for zirconia frameworks

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ABSTRACT

Objectives: To evaluate the effects of multiple firings and aging on surface roughness, strength, and hardness of veneering ceramics for zirconia frameworks.

Methods: Five different veneering ceramics for zirconia frameworks were used: Vintage ZR (ZR), Cerabien ZR (CZR), VitaVM9 (VM9), Cercon ceram KISS (KISS), and IPS e.max ceram (e.max). Specimens were fired 2 or 10 times in order to accelerate aging. Surface roughness was evaluated using laser profilometry. Flexural strength and Vickers hardness were also measured. Surface topography was observed using scanning electron microscopy.

Results: After accelerated aging, the surface roughness of all specimens fired 10 times was significantly lower than that of the same specimens fired 2 times ($P = 0.000$). Except for VM9, the flexural strength of all specimens fired 10 times was greater than that of the same specimens fired 2 times, and the differences were significant for ZR and CZR ($P < 0.01$). The flexural strength of VM9 fired 10 times was significantly lower than that of VM9 fired 2 times ($P = 0.034$). The Vickers hardness of ZR and VM9 fired 10 times was significantly higher than that of the same specimens fired 2 times ($P < 0.05$), but that of KISS fired 10 times was significantly lower than that of KISS fired 2 times ($P = 0.000$).

Conclusions: Multiple firings had a positive effect on the surface roughness of all aged veneering ceramics used for zirconia restorations and on the strength and hardness of many aged veneering ceramics used for zirconia restorations.

1. Introduction

Metal-based restorations are a time-tested means of producing satisfying results in dentistry. Zirconia-based are the most recent restorations in the dental ceramics family and they have been rapidly adopted for a wide range of applications because of their superior strength, fracture toughness, which is caused by an inherent transformation toughening mechanism, and biocompatibility [1–4]. Currently, the zirconia used in dental restorations is mainly tetragonal zirconia polycrystalline (TZP), which contains dopants such as yttrium and cerium. Numerous veneering ceramics matching the frameworks of these zirconias have appeared on the dental market.

In clinical practice, in either metal-based restorations or zirconia-based restorations, the materials directly exposed to the oral environment are primarily veneering ceramics. The oral environment is very harsh being affected by many factors, such as humidity, mechanical load, changes in temperature, shifts in pH, oral bacteria, and others. For this reason, the durability of veneering ceramics is especially important for maintenance of the mechanical properties, esthetics, and longevity of the restorations and similar matters [5–13].

Water is the primary chemical species in the humid oral environment. It can dissolve the glass component by hydration, hydrolysis, and ion-exchange reactions, give rise to selective leaching of alkali ions from ceramic materials, and cause changes in the surface characteristics, microstructure, and mechanical

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properties of those materials [14–17]. The chemical durability of ceramic materials is influenced by a variety of factors, such as their composition and microstructure, chemical character of the exposure medium, duration of exposure, and temperature [13,17–22].

Traditional dental ceramics are mainly multiphased silicate glass phase ceramics, glass ceramics, monophased glasses containing various crystal phases, densely sintered alumina, and zirconia. They all exhibit compositional and microstructural differences, depending on the type of ceramic. Although low-temperature degradation of zirconia, the chipping of veneering ceramics, the design of the framework, and the fit of the prosthesis have attracted extensive attention from the researchers, there have not been many studies concerning the aging of these veneering ceramics [23–32].

Previous studies on the effects of multiple firings and aging on the mechanical properties and microstructure of veneering ceramics used with zirconia frameworks have been evaluated [2,8]. The results indicated that multiple firings could improve the densification and the hardness, and had a positive effect on flexural strength. However, aging had a negative effect on surface roughness and hardness.

The purpose of this study was to evaluate the effects of multiple firings and aging on surface roughness, strength and hardness of veneering ceramics for zirconia frameworks. The null hypothesis to be tested is that multiple firings and aging have no effect on the surface roughness, strength, or hardness of veneering ceramics for zirconia frameworks.

2. Materials and methods

Five types of commercial veneering ceramics in a dentine (body) color for zirconia-based systems were used in this study (Table 1).

2.1. Specimen preparation

Forty specimens of each type of veneering ceramic were fabricated. Ceramic powder and an appropriate amount of the indicated liquid were mixed in a vacuum to form a slurry. This was then poured into a rectangular silicon mold with internal dimensions of 30 mm × 6 mm × 4 mm. After vibration–condensation, these specimens were fired twice according to the manufacturers' instructions, and 20 specimens were selected at random and removed. The remaining 20 specimens received 8 additional firings in the same manner. Firing was performed in a vacuum porcelain furnace (Twin Mat, Shofu, Kyoto, Japan). The schedules for firing the veneering ceramics are listed in Table 2. After firing, the specimens were ground to final dimensions of 4.0 ± 0.2 mm in width, 1.2 ± 0.2 mm in thickness and at least 20 mm in length using diamond discs, following the guidelines of ISO 6872:2008 (three-point flexural strength) [33]. Twenty specimens in the groups fired twice or 10 times were randomly divided into two groups for each type of veneering ceramic. The accelerated aging test was performed on 10 specimens (aged group), and the other ten specimens served as controls (unaged group).

2.2. Accelerated aging test

An accelerated aging test was performed with an electric drying oven (DRA330DA, Advantec, Tokyo, Japan) and a decomposition container consisting of an inner Teflon vessel and an outer stainless steel vessel. Specimens were washed 3 times with ethyl alcohol, dried, and sealed in the Teflon vessel. Inside this vessel, the specimens were supported by a Teflon support screen and immersed in distilled water. The specimens were treated at 2 atm and 200 °C for 5 h. To reduce the risk of micro-crack formation, the temperature of the electric drying oven was slowly increased to a storage temperature of 200 °C. Guideline ISO 13356:2008 is referenced in this study [34].

2.3. Surface roughness

After the accelerated aging test, the specimens were removed from the Teflon jars, cleaned ultrasonically in distilled water for 10 min, and dried in air. The average roughness (Ra) for the aged and unaged specimens was evaluated by laser profilometry using a confocal laser scanner profilometer (LEXT OLS4000, Olympus, Tokyo, Japan). The diameter of the laser beam was 0.2 μm. Four separate areas were measured on each specimen. The measured area was 256 μm × 256 μm and the distance between separate scans was more than 3 μm. The resolution used in the *X*, *Y*, and *Z* directions was 0.02, 0.02, and 0.01 μm, respectively.

2.4. Flexural strength

Flexural strength ($n = 10$ for 2 firings or 10 firings) was measured using the three-point bending test. The test was performed using a universal testing machine (Autograph AG-5000B, Shimadzu, Kyoto, Japan), resting on a self-aligning fixture with a span of 14 mm. Tests were conducted at a crosshead speed

Table 1
Veneering ceramics used in the investigation.

Veneering ceramic	Code	Shade	Manufacturer	Composition[a]
Vintage ZR	ZR	A2	Shofu, Kyoto, Japan	Aluminosilicate glass, leucite, etc.
Cerabien ZR	CZR	A2	Noritake, Nagoya, Japan	Potassium aluminosilicate glass, leucite, etc.
Vita VM9	VM9	2M2	Vita, Zahnfabrik, Bad Säckingen, Germany	Feldspar, alumina, cerium oxide, etc.
Cercon ceram KISS	KISS	A2	DeguDent, Hanau, Germany	Silicon dioxide, alumina, etc.
IPS e.max ceram	e.max	A2	Ivoclar-Vivadent, Schaan, Liechtenstein	Nanofluorapatite, etc.

[a] Composition as given by manufacturers.

Table 2
Firing schedules of the specimens.

Veneering ceramic	Pre-drying temperature (°C)	Pre-drying time (min)	Heating rate (°C/min)	Firing temperature (°C)	Holding time (min)
ZR	650	6	55	910	1
CZR	600	10	45	935	1
VM9	500	6	55	910	1
KISS	450	5	55	830	1.5
e.max	403	8	50	750	1

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