Assessment of Two Surface Treatment Protocols on Monolithic Zirconia at Pre-sintered and Post-sintered Stages

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Dedication

This work is dedicated to

My dear parents,

Precious sister,

Beloved wife,

and lovely son

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Al_2O_3: Aluminum trioxide

BFS: Biaxial flexural strength

CAD: Computer aided design

CAM: Computer aided manufacturing

FDP: Fixed dental prosthesis

LTD: Low temperature degradation

MDP: 10-methacryloxydecyl dihydrogen phosphate

Ra: Surface roughness

SBS: Shear bond strength

TBS: Tensile bond strength

XPS: X-ray photoelectron spectroscopy

XRD: X-ray diffraction

ZrO_2: Zirconium dioxide

Introduction

The increased popularity of all-ceramic materials as an alternative to metal-ceramic restorations is mainly due to their excellent esthetics, chemical stability and biocompatibility. However, the brittleness and low tensile strength of conventional glass ceramics limit their long-term clinical application.[(1)] Several glass ceramics have been introduced such as high alumina-content glass-infiltrated ceramic material and lithium disilicate glass-ceramic which has been successfully used for crowns, anterior fixed dental prostheses (FDPs) and three-unit FDPs replacing the first premolar.[(2)] However, these materials do not have sufficient strength to allow reliable use for FDPs, especially in the molar region.[(3)]

Recently, the development of advanced dental ceramics has led to the application of partially stabilized zirconia in restorative dentistry which can be produced using a computer aided design/computer-aided manufacture (CAD/CAM) systems. The use of zirconia-based ceramics for dental restorations became more popular due to their superior fracture strength and toughness when compared to other dental ceramic systems.[(4-6)]

Nowadays, the application of zirconia in the production of all-ceramic restorations has become one of the most focused on topics in dental research. Such increase in the interest is mainly due to its high mechanical strength and exceptional biocompatibility.[(7, 8)] The success of zirconia-based all-ceramic restorations is highly dependent on the establishment of a strong adhesion between zirconia and the luting cement. Compared with traditional luting cements, resin cement has some irreplaceable advantages including higher mechanical strength and better esthetic properties.[(9)] However, without any surface treatment, the resin zirconia integration was found to be susceptible to aging conditions.[(10)] Meanwhile, the conventional bonding approaches, such as acid etching followed by the application of silane coupling agents, could not effectively improve the bond strength between zirconia and resin cement due to the chemical inertness of zirconia and the absence of a glass content.[11, 12] Thus, zirconia ceramics cannot be etched with commonly used acids, such as hydrofluoric (HF) and phosphoric (H_3PO_4) acids for adding the surface roughness. Furthermore, it is also very cumbersome to form a strong chemical integration between zirconia and resin cement by using solely the conventional silane coupling agents.[13-15]

Air-abrasion with alumina particles followed by an appropriate chemical bonding process was recommended to achieve long-term retention to zirconia.[13] The incorporation of 10-methacryloxydecyl dihydrogen phosphate (MDP) in primers or resin cements was a major factor in producing durable resin zirconia bonding which has already been confirmed in the related clinical trials.[16, 17] Other surface treatments, such as the tribochemical silica coating, selective infiltration etching, heating with a hot etching solution, laser surface treatment, plasma treatment and surface fluorination, have been developed to enhance resin zirconia bonding.[18] The tribochemical method has been proven not only to increase the values of surface roughness, but also to add silica content on zirconia surface. Silica content is vital for activating the functions of silane coupling agents. Both mechanical interlocking and chemical integration between resin cement and zirconia have thus been enhanced.[19]

However, there are still concerns about the influence of air abrasion and tribochemical silica coating on the mechanical properties and long-term stability of zirconia ceramic since it has been reported that they induce some flaws and phase transformation on the surface, thus promoting low temperature degradation.[20] The generation of such flaws and transformation might produce some detrimental effects on the liability of zirconia ceramic.[21]

There are also some concerns about the durability of the bond strength to silica-coated zirconia ceramic as many laboratory studies showed that it decreased significantly after a few months of artificial aging.[22, 23, 13, 15, 24]