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A review on repair of fracture porcelain

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ABSTRACT

Because of their high esthetic qualities and mechanical stability in the oral environment, ceramic restorations are commonly used in daily dental practice. Due to the inherently brittle nature of porcelain restorative materials, failure of metal ceramic restorations under intraoral conditions is not uncommon. The majority (65%) of failures are observed in the anterior region (60% in labial, 27% in buccal, 50% in incisal and 80% in occlusal regions). Clinical studies show failure rates upto 90% for ceramic veneers. Because it is arduous to remove the ceramic restorations from the mouth, they are repaired intraorally, using a bonding system and composite resins. It is necessary to know the possible causes of fracture of porcelain, the various bonding systems and the composites resins used for repairing. The current review takes into account the majority of papers published in the last few decades concerning the issue of bonding composite resins to porcelains.

Key Words: Porcelain fracture, bonding agent, ceramic repair, composite.

INTRODUCTION

Since 1728, when Fauchard [1] first suggested the use of porcelain, the art and science of ceramics in restorative dentistry has evolved into a revolutionary method for aesthetically treating dental needs of a wide variety. Porcelain inlays and crowns as well as the use of porcelain facial veneers are reported several decades ago.[2-4]Although aesthetically satisfactory, the brittle nature of the early porcelain restorations limited their wider application.[5]

In the 1960's gold was used as a reinforcing under structure. [6], followed by MacLean's application of high aluminous ceramic substructure for fixed partial dentures. Because of their high aesthetic qualities and mechanical stability in the oral environment porcelain fused to metal restorations are commonly used in daily dental practice.[7] It is to be expected that with increased application of this technique the number of failures also will increase.[8] Clinically failures often begin as porcelain fractures that may be caused by inappropriate coping design, poor abutment preparation, technical errors, contamination, physical trauma or premature occlusion.[9] These fractures are mainly in the maxilla [75%] and predominantly at the labial surface.[10] It is necessary to assess the possible cause of fracture so that the most suitable treatment can be recommended. Depending on the extent of the area to be restored, cost and time available treatment may range from making a new prosthesis, faceting or overcastting to resin composite repairs.[11] Replacement of a failed restoration is not necessarily the most practical solution for obvious economic reasons and because of the complex nature of the restoration.[12] Because it is arduous to remove these restorations from the mouth ceramic restorations are repaired intra-orally.[10]

With development of the composite restorative materials and the introduction of organosilanes by Bowen [13] in 1962; solutions

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to the repair problem were possible. Two types of bond, metal-resin and porcelain-resin are involved in the repair process of ceramo-metal restorations. Surface configuration, reactivity of the bonding surface and the use of adhesive resins are important for metal-resin and porcelain-resin bond. [14] To achieve a satisfactory bond between porcelain and composite resin several mechanical and chemical retention systems were developed. Mechanical roughening of porcelain surfaces with a coarse diamond, Air-abrasion (sandblasting) and acid etching with hydrofluoric acid[15], acidulated phosphate fluoride[16], Ammonium biflouride [17] or phosphoric acid[18] are some of the commonly used methods to achieve retentive porcelain surface texture. The organosilane repair materials enhance the adhesions of the repair resin to the porcelain surface.[19,20] Within the last few years, several types of porcelain repair systems have been developed for use by the dental profession. The purpose of this article is to review the treatment pertaining to the various porcelain repair systems.

THE EVOLUTION OF PORCELAIN REPAIR SYSTEMS

Historically, intraoral repair of fractured porcelain restorations has required roughening of the porcelain surface with a rotary abrasive, application of silane fallowed by composite to replace the contour of the restoration.[21,22] Early in the 1960s manufacturers' reinforced plastics with particles of glass treated with silane bonding agents, Bowen (1962)[13] used these materials in the development of composite resins that were reported to the dental profession in 1963.[23]

Paffenbarger et al 1967[24] bonded porcelain teeth to acrylic resin using silane solution as the coupling agent. In 1968, Semmelman and Kulp [25] reported results of bonding porcelain denture teeth to acrylic resin with a silane coupling agent. The study indicated that failure occurred not at the tooth resin interface, but within the body of the porcelain indicating a true bonding. In 1969 Myerson [26] concluded from his experiments that cold-cured resins produced a stronger bond than mechanically retained porcelain teeth, but that thermal cycling was detrimental to the bond. A study of porcelain teeth in cold-cured dentures by Duhaney HN[27] in 1970 indicated that retention by bonding with silane solution was as satisfactory as mechanical retention.

Jochen and Caputo [28] reported that the abrasion of the surface of porcelain with a diamond rotary instrument increased the retention of the repair material. In 1978, Eames et al [29] evaluated the composite resins utilizing silane coupling agents for repair of porcelain. Porcelain denture teeth were used in this study and acceptable bond strength for temporary repairs was reported. In 1978, Newburg and Pameijer [8] also studied the bond strength of composite resin to porcelain denture teeth utilizing a silane coupling agent, and reported that the samples produced a reliable bond. Highton et al [30] 1979 also studied the effects of silane coupling agents on the composite resin/porcelain bond. The study indicated that the repair system using a bonding agent with acrylic resin was significantly stronger than the repair system using a composite resin.

Nowlin et al[31] reported that fusion plus concise (3M Co. Dent products Div., st. Paul Minn) was superior to Dent-mat and 18% of the original porcelain strength was regained.

In 1983, Ferrando et al[32] concluded that Enamalite (Lee pharmaceuticals, South El Monte, Calif.) was superior to Fusion plus Adaptic (Johnson and Johnson Dental products co., East Windsor, N.J.), Adaptic, Dent-mat porcelain repair kit and cyano-veneer (Ellman International Manufacturing Inc., Hewlet., N.Y) in tensile strength and had the least leakage at the resin-porcelain interface.

The adhesion of resin to dental porcelain was enhanced by etching the porcelain surface with hydrofluoric acid (Horn 1983[33]; Calamia 1983[34]) and using silane coupling agents (Calamia and Simonsen, 1984).[35] Combination of hydrofluoric acid etching and the application of silane coupling agent was shown to be an effective method for improving the adhesion of resin. (Stangel et al 1987; Shetch et al 1988[5]; Aida et al 1990)

As an alternative to hydrofluoric acid, acidulated phosphate fluoride (Lacy et al[25] 1988) or phosphoric acid (Newburg and Pameijer[8] 1987; Okamoto et al[36] 1989; Matsumara et al[37] 1989) were investigated. However, neither etching with hydrofluoric acid nor adding silane resulted in an adequate resin bond to some new high-strength ceramics.[38] High-alumina[39] or Zirconia-reinforced ceramics[40] cannot be roughened by hydrofluoric acid etching since such ceramics do not contain a silicon dioxide (silica) phase.

For this reason, special conditioning systems are indicated for these newer types of ceramics. Modern surface conditioning methods utilize air-particle abrasion for achieving sufficient bond strength between the resins and high strength ceramics that are reinforced either with alumina or Zirconia.[40] In this technique the surfaces are air abraded with aluminium oxide particles modified with silicic acid with different particle sizes ranging from 30 to 250µm.[40] The blasting pressure results in the embedding of silica particles on the ceramic surface, rendering the silica-modified surface chemically more reactive to the resin through silane coupling agents.[41]

THE BOND BETWEEN PORCELAIN AND THE RESIN COMPOSITE

Bonding of resin to a ceramic surface is based on the combined effect of micromechanical interlocking and chemical bonding. The bond strength of composite to porcelain is affected by the surface preparation and the type of bonding agent.[42]

Mechanical roughening of porcelain surfaces with coarse diamond has demonstrated improved repair strength. [28,32] Sandblasting with aluminium oxide (Al_2O_5) is another method of surface roughening[15] and porcelain can also be etched with hydrofluoric acid, ammonium biflouride, phosphoric acid or acidulated phosphate fluoride gel to facilitate micromechanical retention of resin composite.[42] The mechanical bonding always poses an inherent disadvantage of microleakage.[43]

Chemical bonding to ceramic surface is achieved by silanization with a bifunctional coupling agent.[44] Silane coupling agents can improve the bonding of composite resin to porcelain by approximately 25%.[5] Silane coupling agents possess the general chemical structure X-$(CH_2)_3$ Si-$(OR)_3$ and have ability to bond chemically to both organic and inorganic surfaces.[45] The coupling agent at one end chemically bonds to the hydrolyzed silicon dioxide of the ceramic surface and a methacrylate group at the other end polymerizes with the adhesive resin.[44] The type of resin composite also effects of bond strength to porcelain. It is assumed that larger particle size resin composites or hybrid.[16]

THE MATERIALS AND THE TESTING METHODS USED FOR THE BOND TEST

Material selection and clinical recommendation of resin bonding to ceramics are based on mechanical laboratory tests that show great variability in materials and methods.[7,46] Many methods of measuring the in-vitro bond strength affected by porcelain repair systems have been described. These include torsion, flexural,[19] tensile and shear bond strength tests.[47] The most commonly employed is the shear bond strength test. The crosshead speed used for testing the samples range from 0.5 mm/min to 5 mm/min. But as yet there is no universally accepted bond strength tests for resin composite bonded to ceramic.

The ceramic-composite bond is susceptible to chemical, [48] thermal,[49] and mechanical[50] influences under intraoral conditions. A notable feature of some studies [51] is the observation that, the failure mode is often cohesive within the ceramic bases rather than at the adhesive interface. On the basis of which it has been suggested that the bond strength exceeds the cohesive strength of the ceramic. But this ignores the nature of the stresses generated and their distribution within the adhesive zone which can have a profound influence on the mode of failure. Finite element stress analysis (FEA) has been used to study the sensitivity of bond strengths to specimen design and changes in testing conditions. [52] These studies show that there is need for a more critical approach on the design of appropriate tests for evaluating the bond strength of resin composite to ceramic if the design for a standardized test procedure is to be achieved.

RECENT DEVELOPMENTS

Bonding to traditional silica based ceramics is a predictable procedure yielding durable results when certain guidelines are followed.[45] The physical properties and composition of high strength ceramic materials like aluminium oxide-based[40,53] and Zirconium oxide-based ceramics [41] differ substantially from silica based ceramics and require alternative bonding techniques to achieve a strong, long term and durable resin bond.[40]

Modern surface conditioning methods require airborne particle abrasion of the surface before bonding in order to achieve high bond strengths. One such system is silica coating. In this technique the surfaces are air abraded with aluminium oxide particles modified with silisic acid. [54] The blasting pressure results in the embedding of silica particles on the ceramic surface, tending the silica modified surface chemically more reactive to the resin through silane coupling agents. Silane molecules after being hydrolyzed to silanol can form polysiloxane network or hydroxyl groups cover the silica surface. Monomeric ends of the silane molecules react with the methacrylate groups of the adhesive resins by free radical polymerization process, when a ceramic exhibits chemical states of silicone and oxygen. The siloxane bond will be achieved as these represent the bonding sites for the coupling agent to the ceramic surface.[55]

The phosphate modified resin cement after airborne particle abrasion provide a long-term durable resin bond to zirconium oxide ceramic[56] The equipments for airborne particle abrasion are recently simplified and brought to the chairside.[41]

DISCUSSION

Intraoral repair of fractured porcelain restorations with resin composite presents a substantial challenge for clinicians. Newer generation multipurpose adhesive systems involve several treatment steps and agents for porcelain repair with resin composite.[57] Several studies focus on mechanical retention, chemical agents and the combination of these two methods.[10,51,42] Because of the insufficient bonding characteristics of the chemical agents, physical alteration of the porcelain surface must be used together with these agents to promote adhesion. Wolf et al[45] concluded that sandblasting with Al_2O_3 or roughening by burs achieve satisfactory bond strength but when more durable and higher bond strength is desired, hydrofluoric acid etching is the most significant step in the surface treatment because of deep acid penetration.

The silane coupling agents achieve a chemical link between the resin composite and porcelain; moreover they promote wetting of the porcelain surface so that it enhances the flow of the low-viscosity resin composites. They improve the bond of resin composite to porcelain by approximately 25%.[22] Aluminium oxide and Zirconium oxide-based ceramics require the use of special resin cement along with airborne article abrasion. Compared with silica-based ceramics, the number of in vitro studies on the resin bond to high-strength ceramics is small. Further controlled clinical trials are required to test specific treatment modalities and their long-term durability.

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