

Review Article**AS GOOD AS NEW: REPAIR OF FRACTURED PORCELAIN FUSED TO METAL RESTORATIONS**

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ABSTRACT

Statement of problem: Metal ceramic restorations continue to be widely used in dental practice, as they combine esthetics with superior mechanical properties. Unfortunately they are prone to fracture due to their brittle nature. **Purpose:** Direct intraoral repair of fractured porcelain traditionally relied on mechanical roughening of the fractured surface, followed by application of a silane coupling agent to enhance the resin-to-porcelain bond. The primary advantages of using composites for repair are less chair time, lower cost, and ease of use. Indirect repair techniques that use porcelain require clinical and laboratory procedures but are advantageous because of the esthetic ability of porcelain to match the remaining ceramic units. This review article describes the repair of fractured porcelain fused to metal restorations. **Conclusion:** Shear bond strength studies using direct as well as indirect repair methods show promising results. However some improvements in the bonding techniques are still needed.

INTRODUCTION

Metal-ceramic restorations are still considered a good option for oral rehabilitation³ due to their mechanical strength, despite the development and growing use of all ceramic.^{1,2} Their mechanical properties allow for the fabrication of restorations with greater rigidity and less thickness.⁴

Unfortunately, metal-ceramic restorations have the tendency to fracture.¹ Although fractures of such restorations do not necessarily mean failure of the restoration, they pose an aesthetic and functional dilemma to both the patient and the clinician.⁵ Porcelain failures have been reported as the second greatest cause for the replacement of restorations after

dental caries.⁶ The causes of such fractures are varied, and include impact and fatigue load, occlusal forces, incompatible thermal expansion coefficients between the ceramic and metal substructure, use of metal with low elastic modulus, seating force during trial insertion or cementation, improper design, micro defects within the material, and trauma.^{5,7}

Ideally, replacing the broken prosthesis is the best treatment, but this may not be within the patient's financial means. This becomes more costly with long-span prostheses. Moreover, it may be desirable to repair the broken prostheses, rather than removing and possibly destroying restorations underneath and damaging the abutment teeth.^{7,8} Factors such as

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elevated cost, possible trauma to the restored tooth, lack of time, and difficulty of removing the restorations may occasionally delay the replacement of a fractured metal-ceramic restoration.⁹ Thus, when a fractured restoration continues to fulfil the requirements for preserving dental-periodontal health and replacement is not feasible for some reason, repair may be indicated.^{3, 9,10}

Traditionally, repair techniques may be classified into two types: the direct method and the indirect method. Direct repairs include techniques that use light-cured composite resin applied directly to the fractured restoration^{1,3,9} and indirect repairs include those that use ceramic prepared in the laboratory and bonded to the fractured restoration.¹¹

The earlier repair systems generally used two component silane coupling agents (silane and acid) designed to chemically bond composite to the silica (SiO₂) component of ceramic, but had low shear bond strength. The recently introduced repair systems contain 10-methacryloyloxydecyl dihydrogen phosphate (MDP), which recommends physical alteration of ceramic and metal substrates in conjunction with chemical agents such as metal primer, ceramic primer and improved silane coupling agents to promote adhesion of resin to fractured metal ceramic restorations.¹²

In general, conditioning of dental material surfaces is the treatment by which the critical surface energy will be increased. Treatments may be used that enhance chemical adhesion, such as salinization and the application of adhesive primers. In addition, these may also be the treatments that promote micromechanical retention, such as airborne-particle abrasion with aluminium oxide, roughening with a diamond rotary cutting instrument, and etching with

hydrofluoric acid, phosphoric acid, or with acidulated phosphate fluoride.^{13,14,15,16} Finally, treatments that enhance mechanical retention as well as chemical adhesion may also be considered, such as the deposition of silica by conventional airborne-particle abrasion or by the use of specific equipment and tin electroplating.^{17,18,19,20}

METHODS

This review is based on a literature survey in which the PubMed data base and other literature sources have been utilized. The purpose of this article is to throw some light on repair methods related to porcelain fused to metal restorations and present the underlying chemistry so as to help the dentist operate in a better way when situation permits.

RESULTS

DENTAL CERAMICS

In clinical conditions, the dentist should be aware of which ceramics the fractured crown has been manufactured. Recently numerous new dental ceramic materials have been introduced, like high-aluminium trioxide (alumina) ceramics, leucite reinforced feldspathic ceramics, castable glass-ceramics, and novel machining and CAD/CAM ceramic systems

SURFACE CONDITIONING

The chemical bonds between ceramic and resin composite should be durable and reliable.

This is because of the extensive use of resin composites, resin-bonded restorations and porcelain repair system kits.

The bond between ceramic surface and resin composite can be created via:

i) micro-mechanical bonding by grit-blasting or acid etching with HF and

ii) silane coupling agent

For a successful bonding (luting) cement some requirements are:

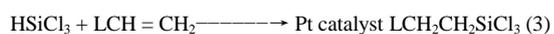
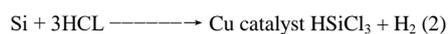
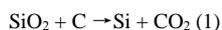
i) adequate micromechanical retention, when clinical adhesion is less

ii) adequate wetting of the substrate by the bonding agent

(iii) resistance to fatigue, stress, erosion, and stress relief 21,22,23

CHEMISTRY OF SILANE COUPLING AGENTS

Organosilanes are synthesized from SiO₂, silica (silicon dioxide) is one of the most abundant materials in the earth. Silica is reduced to silicon which reacts with hydrogen chloride to yield trichlorosilane, HSiCl₃. Then, trichlorosilane reacts with alkene and finally followed by alcoholysis, i.e., reaction with alcohol, to form the functional silanes :



A silane coupling agent, which is a trialkoxysilane, contains two functional groups at the ends of its molecular back bone, and which connect an unpolymerized resin matrix and an inorganic substrate (surface). Organofunctional trialkoxy silanes, silane esters, of the general formula R'-Y-SiX₃, where R' is a non-hydrolysable organic group, Y a linker (usually a propylene link) and X a hydrolysable group.25

At ambient temperature, silane is activated or hydrolysed by acid (acetic acid) to form silanol (SiOH) before they can bond to the inorganic substrate. The

adhesion strength of silane varies with different materials. 26

There are the two important steps of resin substrate bonding formation with silane coupling agents:

(1) silane and substrate bond formation which is activated by acid,

(2) resin and silane bond formation which is polymerised by light curing.26

Silane is activated by acid to form silanol groups which react with the substrate surface hydroxyl (OH) groups by a condensation reaction (Si-OH + HO substrate ⇒ Si-O substrate) when it is applied onto a surface treated, e.g. a silica coated substrate. The reaction between the organofunctional groups of silane (with a C-C bond), and functional groups of the resin monomers containing C-C bond is induced by the reactive free radicals generated by photo-activation of initiator components in the resin matrix. As a result, resin composite and the substrate surface are connected by the silane coupling agent.27

Usually for intraoral repair or for the commonly washed off etchable ceramic surfaces after chemical etching, the exposed ceramic surface is hydrated from the surface adsorbed water. A major problem in chair-side silanization is to remove the excess surface adsorbed water.

COMMERCIAL SILANES

The most commonly used silane in dentistry is 3-methacryloxypropyltrimethoxysilane (MPS).

VARIOUS SURFACE TREATMENTS

GRIT BLASTING

Grit-blasting cleans any greasy substances from ceramic surfaces and creates micromechanical

bonding.²⁸ However microabrasion has been shown to cause casting distortion (plastic deformation), affecting the quality of fit. Possible care for microabrasion use include substituting techniques that require less microabrasion, the selection of a particle with less mass, increased distance from the handpiece to the sample, and shorter exposure times. Using a bur for micromechanical bonding is not reliable.²⁸

These findings are in agreement with the previous studies^{29,30} who reported that higher bond strengths of intraoral repair systems to ceramic and metal were achieved with air abrasion than the roughening with diamond bur. However, these results are in disagreement with Jochen and Caputo³¹ and Suliman et al. 1993, who stated that higher bond strength of intraoral repair systems were obtained with roughening with diamond bur and etching with hydrofluoric acid than air abrasion alone.

CHEMICAL TREATMENTS

Etching generates a micromechanically retentive surface, but also promotes hydroxyl group formation on the ceramic surface. HF can be used for dissolution of the ceramic glass phase surface by reacting with silicon dioxide.³² The chemical reaction depends on the breaking of the siloxane bonds in $\equiv \text{Si-O-Si} \equiv$ network structure. The main factors influencing reaction rate include temperature, composition and concentration of reactive species in HF acid, and also the structure of porcelain. However HF is hazardous and too corrosive hence other substitutes like APF gels and various concentrations of phosphoric acid are used.³³

PYROCHEMICAL SILICA COATING

Pyrochemical means relating to or designating chemical activity at elevated temperature. In this case the silica coating is done by passing coating solution through a special flame. The Silicoater MD and Siloc systems are based on a colloidal silica and chromiumtrioxide application at high temperature, 320 C.³⁴ When the silica-coated surface has cooled down to room temperature, it is then silanized with a silane coupling agent. After that an opaquer is light-cured and then the veneering resin composite is built on.^{35,36}

TRIBOCHEMICAL SILICA COATING:

Tribochemical silica coating implies the chemical reaction which is caused by rubbing the silica particles on the metal or ceramic substrates. Example of tribochemical silica coating is the cojet intraoral repair system. The first step here is to coat the metal or ceramic substrate with the cojet sand (silica coated aluminium oxide particles). After that silanization and further applications of opaquer and veneering resins are done.³⁷

INDIRECT TECHNIQUE OF CERAMIC REPAIR:

Indirect repair techniques include the following:

- (1) fabrication of a pin onlay with a porcelain veneer cemented to the labial surface
- (2) fabrication of a pin-retained casting with a fused porcelain veneer and
- (3) fabrication of a new "overlay" metal-ceramic crown.

The fractured abutment is evaluated clinically and radiographically to ensure adequate metal substructure to prepare the framework for an overlay metal-ceramic

casting. All remaining facial and lingual ceramic is removed by use of a diamond rotary cutting instrument under copious irrigation. Care is taken interproximally to avoid chipping the adjacent ceramic and the connector area of the original restoration. A chamfer finish line is created on the lingual aspect of the original crown, in the cervical area, and the metal along the facial chamfer was made thin or removed to simplify finishing and to prevent a cement line. All the "overlay" crowns are fabricated with sufficient thickness (0.2 mm to 0.3 mm) to ensure adequate strength and rigidity. The completed metal-ceramic crowns are luted using resin luting agent.^{4,11}

DIRECT TECHNIQUE OF CERAMIC REPAIR:

Here the fractured abutment is examined and reason for fracture is evaluated. A specific protocol regarding the method and the material used for direct ceramic repair cannot be given. However various repair systems are available which use a silane coupling, a bonding agent, an opaque and composite resin. These systems have been combined with a prior surface treatment.³

Results obtained by using both the above techniques are acceptable according to various studies. However according to Aristidis A. Galiatsatos the indirect method may be more predictable than the direct-repair method using composites, especially for situations in which a large portion of ceramic material is missing.¹¹

DISCUSSION

As introduced above fracture of porcelain may not always be considered as a failure of the treatment. Reason for the fracture must be detected, analysed and handled prior to restoring the fracture with composite resin.

According to some studies the silane coupling agent was effective in establishing a strong and durable bond between composite and dental porcelain. Silane coupling agents used in conjunction with acid-etching of porcelain surfaces may create a bond stronger than a cohesive strength of the porcelain. The use of a fluoroalkylethyl silane in dental ceramics has been found to reduce stress-corrosion at the bonding interface. A study investigating the composite resin repair of porcelain using different bonding system materials inferred that the shear bond strength of composite resin to porcelain was significantly higher for porcelain bonded surfaces using a dentin bonding agent than that of other materials tested.³⁸

The APF gels of 1.23% can be substituted for 9.5% HF gels to etch porcelain before bonding of composite, but the lower concentration of HF may require prolonged etching.

According to Ji young yoo et al and Santos et al the cojet system of ceramic repair obtained a good bond strength and was more beneficial when the repair surface consisted of a metal substrate. The other repair systems were better used when the repair surface is a porcelain.^{3,39}

Ashish Kalra et al conducted a study with the objective being to evaluate the shear bond strength of two intraoral porcelain repair systems. They concluded that prior mechanical alteration is beneficial for a better bond strength. Also 40% phosphoric acid can be used instead of HF for etching the metal or ceramic repair surface.¹²

Mutlu Ozcan et al inferred that all the surface conditioning methods namely treatment with HF and air abrasion followed by salinization did not differ from each other significantly. Also they inferred that use of two layers of fiber reinforced composite

between the framework of crown and repair composite can be beneficial.¹⁰

R C prat et al suggested that Porcelain repair products are significantly affected by aging. Of the products evaluated, 3M's Porcelain repair kit produced the strongest shear bond after 3 months. Also according to Mutlu ozcan et al the repair showed significant degradation with long term thermal ageing. However the Cojet system showed better bond strength than the other systems even after ageing procedure.⁴⁰

Some studies inferred that the presence of porcelain autoglaze significantly decreased the bond strengths of the other systems. Nonglazed surfaces provided variable results over time.

The veneering composite used also contributes to the better bond strength. Some studies have shown that fractures could be minimized if a (submicron) hybrid composite resin is used.⁴¹

An in vitro study has been carried out on the effect of contamination on etched and silanized porcelain surfaces and the shear bond strength of dual-cured resin composite luting cement onto them. It has been concluded that in clinical work the contamination caused by saliva and latex gloves did not significantly affect the shear bond strength. However, die stone contamination had reduced the bond strength and cleaning had not restored it. Cleaning the surfaces with acetone has significantly reduced the shear bond strength under experimental conditions.

CONCLUSION

Various surface pretreatments and silanization belong to routine dental laboratory and clinical practice resulting in direct as well as indirect restorations. Shear bond strength studies show promising results. However some improvements in the bonding

techniques are still needed. The main concern is longterm resin bond hydrolytic stability. Development of new functional silane coupling agents and novel surface treatment methods to address the problem is in progress.

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