Review
Evaluation of alternative intra-oral repair techniques for fractured ceramic-fused-to-metal restorations

M. ÖZCAN Marmara University, Dentistry Faculty, Department of Prosthodontics, Büyükçeklik Sok., Nişantaşı, Istanbul, Turkey

SUMMARY Ceramic fractures are serious and costly problems in dentistry. Moreover, they pose an aesthetic and functional dilemma both for the patient and the dentist. This problem has created demand for the development of practical repair options which do not necessitate the removal and remake of the entire restoration. Published literature on repair techniques for fractured fixed partial dentures, concentrating on the data obtained both from in vitro and in vivo studies, reveals that the repair techniques based on sandblasting and silanization are the most durable in terms of adhesive and cohesive failures compared with those using different etching agents.

KEYWORDS: fracture, ceramics, intra-oral repair

Introduction
Despite the increased effort to improve the bond strength between the ceramic and the metal substrate, on occasion, fractures of ceramic veneers still occur under clinical conditions. Clinical studies indicated that the prevalence of ceramic fractures ranged from between 5 and 10% over 10 years of use (Coornaert, Adrians & de Boever, 1984).

Although fractures of such restorations do not necessarily mean the failure of the restoration, the renewal process is both costly and time consuming and therefore remains a clinical problem. Fractures in the anterior region pose an aesthetic problem but when they are in the posterior region, chewing function could also be affected. The published literature reveals that the reasons for failures cover a wide spectrum from iatrogenic causes to laboratory mistakes, or related to the inherent structure of the ceramics or simply because of trauma.

It is well recognized that many factors are involved in the success rate assessments of fixed partial dentures limiting the longevity of the restorations.

Need for an intra-oral repair technique
Fracture of porcelain is often considered an emergency treatment and the restoration process can present difficult challenges to the dentist. Because of the nature of the porcelain processing, new porcelain cannot be added to an existing restoration intra-orally. The manual fabrication of metal frameworks and porcelain veneers is time consuming and requires a high level of skill (Freilich et al., 1998). It is an unpleasant experience for the patient and arduous for the dentist to remove these restorations from the mouth. Replacement of a failed restoration is not necessarily the most practical solution because of the obviously substantial costs and the complex nature of the restoration (Fan, 1991).

Besides some economic and technical reasons, it was reported that the cracks or crazing in the fractured area might become a haven for microorganisms and plaque accompanied by staining (Walton, Gardner & Agar, 1986). On the basis of previous studies, a consensus was reached that the repeated firing cycles cause distortion of the ceramic restorations. Deformation or most of the distortion was found to occur especially during the initial oxidation of the alloys but small changes from 30 to 99.6 µm were also examined at the margins of the restoration during the subsequent heating and ceramic applications (Van Rensburg & Strating, 1984; Richter-Snapp et al., 1988).

Intra-oral repair options provide the possibility of repairing the veneer in the patient’s mouth preventing replacement of the complete restoration. Aesthetic
and functional repair, wherever possible, has many advantages over time consuming and expensive remakes of crowns or bridges. Given these problems and concerns, it is desirable to repair the fixed restorations in the mouth so that the service time can be increased in a more conservative approach. Various intra-oral repair alternatives for metal–ceramic restorations have been the subject of numerous studies.

**Previous intra-oral repair trials**

The clinical success of the ceramic repair system is almost entirely dependent on the integrity of the bond between the ceramic and the composite resin. This integrity is achieved either by chemical or mechanical bonds. Many of the previously advocated techniques were dependent on mechanical retention but the results of these earlier repairs were unsatisfactory because of aesthetic and mechanical limitations. Various repair techniques have been suggested in the literature, many of which are considered interim but are still preferable as it is important to salvage an extensive restoration for even a few years. Three conditions for the repair of ceramic fractures were suggested (Chung & Hwang, 1997):

1. Fracture in ceramic only
2. Fracture with both ceramic and metal exposed
3. Fracture with substantial metal exposure

**Hydrofluoric acid**

Intra-oral repair systems based on topical acid application have become very popular in bonding resin to ceramic. The greatest advantage of these systems is that chair-side application is very simple. Furthermore the restoration can be re-etched in the case of failure without the need for sophisticated laboratory procedures. The most often cited etching agent for the ceramic surface has been hydrofluoric acid.

It has been postulated that acid concentrations and etching times should be adjusted with specific ceramics to optimize bond strength (Calamia & Simonsen, 1984). Furthermore, the bond strength of composite resin to alumina ceramic was found to be inferior to that of feldspathic porcelain. In principle, chemical etching agents dissolve the glass matrix selectively and cause physical alteration to promote adhesion of composite-resin to the porous surface of fractured ceramic (Calamia et al., 1985; Sheth, Jensen & Tolliver, 1988; Thurmond, Barkmeier & Wilwerding, 1994).

Ceramics etched with hydrofluoric acid demonstrate a microstructure that appeared most conducive to the development of high strength as a function of the number of large porosities within its amorphous surface. Resin penetration of these spaces enhance micromechanical retention (Stangel, Nathanson & Hsu, 1987) and produces greater roughness on the ceramic surface than other acid agents (Aida, Hayakawa & Mizukawa, 1995).

Alumina content of the ceramic materials plays a significant role on the effect of hydrofluoric acid. It was stated that reducing the etching time to <3 min dissolved less of the glass matrix (Tjan & Nemetz, 1988). Sorenson et al. (1991) observed that etching feldspatic porcelain with 20% hydrofluoric acid for 3 min significantly increased its bond strength to composite resin. Although many commercially available porcelains are similar in chemical formula, there are distinct differences in constituents, crystalline structure, particle size, sintering behaviour and microtopography which effect the etched surface. Alumina increases the strength of the ceramic but it is highly resistant to chemical attack and therefore does not etch well. Higher bond strength after etching and a high percentage of cohesive failures in Vita ceramics containing 10% alumina has been observed.

Lacy et al. (1988) observed that etching the ceramic surface without using a silane coupling agent did not provide greater bond strength to the composite resin than mechanical roughening with a fine diamond bur. Llobell et al. (1992) found significantly higher bond strengths with hydrofluoric acid compared with phosphoric acid and advised use of hydrofluoric acid for mechanical retention and silane coupling agents for chemical retention. While some studies showed enhanced bond strength with the application of silane to the etched ceramic surface (Lacy et al., 1988), others exhibited significant variation in bond strengths between proprietary brands of silane. On the other hand, especially after hydrofluoric acid treatment, the use of silane coupling solutions promoted good results (O’Kray, Suchak & Stanford, 1987; Nicholls, 1988; Bailey, 1989).

From a clinical point of view, hydrofluoric acid application alone was considered inadequate when preparing a ceramic surface for composite resin bonding (Pameijer, Louw & Fischer, 1996). Matsumara et al. (1989) concluded that acid treatment might only be useful, in practice, to remove the smears from the
ceramic. In another study, increased incidence of cohesive failures were observed in samples pre-treated with 9.5% hydrofluoric acid because of deep acid penetration but 5 min of hydrofluoric acid application to be too long (Wolf, Powers & O’Keefe, 1992). Durability of bonding between composite resin and ceramic formed with chemical agents was markedly inferior to alteration of the ceramic surface with either aluminium oxide (Al₂O₃) air abrasion, hydrofluoric acid or a combination of both (Thurmond et al., 1994).

Although new chemical etching systems claimed to provide adequate retention, the study by Tylka and Stewart (1994) indicated that these chemical etchants unfortunately produce a shallower etch pattern on metal. They also reported that even though an optimal bond could be achieved with either etchant or in conjunction with an organosilane, the intra-oral use of dangerous hydrofluoric acid should be seriously questioned.

The hazards of hydrofluoric acid are well recognized. Despite its effectiveness, hydrofluoric acid presents severe hazards to human tissue and advised more reasonable repair alternatives (Chung & Hwang, 1997). Practitioners were warned, indicating that the problem is particularly acute when adequate rubber dam isolation is not possible, such as repair cases of fixed partial dentures where a tight cervical seal cannot be attained.

There has been only one clinical study conducted using etching gel for the repair process (Creugers, Snoek & Käyser, 1992). In this study, in order to study the effect of 37% phosphoric acid application, the surfaces of 20 ceramic crowns were fractured on purpose. Twelve of them included metal exposure and eight of them had fractures with no metal exposure. Crowns were cemented and the patients were recalled at 2 weeks, 3, 6 and 12 months after the repair. The failure rate was found to be 50% after 12 months. Failures were mostly observed at the bonding interface between the crown and the repair resin with no cohesive failures. The survival rate was noted to be 59% at the end of 12 months of the evaluation period. Because of the low survival rate, this method was not recommended for use, especially in occlusal repair of metal–ceramic crowns.

Although hydrofluoric acid is considered to be a dangerous, harmful, an irritating compound and categorized as a poisonous reagent (Llobell et al., 1992), both laboratory evaluations and clinical procedures concerning its use for intra-oral porcelain repair have been reported. Etching with hydrofluoric acid may not be practicable because of the biological risks in vivo. It still seems intra-oral repair options with acid agents are effective on an interim basis. Moreover, acid etching is a method which could be used in ceramic fractures with no metal exposure.

The studies on the use of hydrofluoric acid have significant findings. Concentration of the acid and the application period are apparently important factors to note. Considering the vast range of ceramics in today’s dental practice, the choice of suitable acid etching process clearly needs further research in order to avoid misleading information for the practitioners.

**Acidulated phosphate fluoride**

The hazards, extreme caustic effects to soft tissues and the danger for clinical use of hydrofluoric acids are well known. For this reason some studies questioned whether 1-23% acidulated phosphate fluoride gels might serve as a safe and effective substitute for etching ceramic surfaces to bond composite resin because of the reduced risk it presents. Some studies demonstrated that the bond strength of composite resin to silanized ceramic after being etched by acidulated phosphate fluoride was comparable with that of hydrofluoric acid etching (Sposetti, Shen & Levin, 1986; Wunderich & Yaman, 1986; Abbasi et al., 1988).

Lacy et al. (1988) reported that ceramic surfaces could be etched with 1-23% acidulated phosphate fluoride gels in relatively short periods of time. It was concluded that 1-23% acidulated phosphate fluoride gels can be substituted for hydrofluoric acid etching by acidulated phosphate fluoride was comparable with that of hydrofluoric acid etching (Sposetti, Shen & Levin, 1986; Wunderich & Yaman, 1986; Abbasi et al., 1988).

Lacy et al. (1988) reported that ceramic surfaces could be etched with 1-23% acidulated phosphate fluoride gels in relatively short periods of time. It was concluded that 1-23% acidulated phosphate fluoride gels can be substituted for hydrofluoric acid etching by acidulated phosphate fluoride was comparable with that of hydrofluoric acid etching (Sposetti, Shen & Levin, 1986; Wunderich & Yaman, 1986; Abbasi et al., 1988).

Remarkable differences in the etched ceramic surface morphology were observed in visual comparisons. Application of 1-23% Acidulated phosphate fluoride gel was found to create smooth, homogenous surfaces on the exposed ceramic, whereas hydrofluoric acid produced a porous, amorphous surface. The widely accepted theory that hydrofluoric acid enhances the composite resin bond to ceramic more than an acidulated phosphate fluoride was not substantiated (Senda, Suzuki & Jordan, 1989; Tylka & Stewart, 1994). The SEM findings showed that etching by acidulated phosphate fluoride gel might not be adequate (Nelson & Barghi, 1989).
No significant difference was found between the tensile bond strengths for specimens etched with 9-6% hydrofluoric acid and those of specimens etched with 4% acidulated phosphate fluoride gel in the data obtained by Della Bona and Van Noort (1995). However, the group etched with 4% acidulated phosphate fluoride gel, showed a wider statistical spread than the one etched with 9-6% hydrofluoric acid. This suggested that hydrofluoric acid etching might well produce a more reliable and consistent result but this has not been confirmed, as the sample size was too small.

This literature review led to the conclusion that intra-oral use of acid agents appears to be unwarranted.

**Micromechanical roughening**

Some practitioners have relied on mechanical retention such as grooves or undercuts to retain the composite resin to ceramic or metal. Owing to microleakage and humid intra-oral conditions, this type of repair was considered as an interim procedure. It was reported that the use of fine and coarse diamond burs increases crack initiation and propagation through the ceramic which could result in failure (Wood et al., 1992). These trials did not give long lasting, predictable results in ceramic repair.

**Air abrasion with Al₂O₃**

One easy method for intra-oral repair is roughening the surface by air abrasion with Al₂O₃, thereby increasing the surface area for bonding and decreasing the surface tension. This technique was based on direct sandblasting of the surfaces by an intra-oral device. Air abrasion (or sandblasting) promotes micromechanical retention. Physical alteration of the ceramic surface with Al₂O₃ was mostly achieved using a particle size of 50 μm. Air abrasion improves the retention between the metal and resin by cleaning oxides or any greasy materials from metal surfaces, creating very fine roughness enhancing mechanical and chemical bonding between some resins and metals. When Al₂O₃ treatment was performed on the alloy, microscopically cleaned and roughened surfaces were observed which allowed efficient wetting by resins and stronger composite-alloy bonds (Schneider, Powers & Pierpoint, 1992).

Higher bond values with Al₂O₃ were obtained than those with typical silane application on etched ceramic surface and advised its use in lieu of fluoride etching (Lacy et al., 1988).

A variety of treatment regimens including medium diamond bur, air abrasion with 50 μm Al₂O₃, hydrofluoric acid, phosphoric acid, silane and bonding agent were compared. The shear test results revealed that the most durable bond values were obtained with physical alteration of the ceramic using Al₂O₃ air abrasion followed by hydrofluoric acid (Thurmond et al., 1994).

Sandblasting was described as the most effective surface treatment for the fractured metal–ceramic restorations no matter whether the surface was simplified with metal, porcelain, or a combination of the two. Sufficient bond strength was obtained with Al₂O₃ air, eliminating the use of caustic and potentially harmful acid agents (Chung & Hwang, 1997). However the compulsory use of silane together with Al₂O₃ was advised in order to avoid changes in retention (Shahverdi et al., 1998).

Combined data from the literature reveal that sandblasting with Al₂O₃ is an effective surface treatment regardless of whether the fracture was metal, porcelain, or a combined exposure. It was also stressed that air abrasion does not expose patients to the risk of severe acid burns. Controversial reports on the effect of whether Al₂O₃ should be used alone, followed by silane application or together with hydrofluoric acid, needs to be identified. Furthermore, concerns on the mechanism of each treatment regimen should also be clarified.

**Combined surface treatments**

Some trials combined the above-mentioned methods in order to obtain better bond strengths.

Combined use of silane with hydrofluoric acid or air abrasion demonstrated better results with Al₂O₃ air abrasion than those with etched ceramic surfaces (Bertolotti, Lacy & Watanabe, 1989). Llobell et al. (1992) observed that silane and hydrofluoric acid combinations did not affect the bond strengths positively.

Various surface treatments including air abrasion with Al₂O₃ of 50 μm, roughening with a diamond, etching with 9-6% hydrofluoric acid and a combination of the latter two methods were evaluated (Suliman, Swift & Perdigao, 1993). Shear tests revealed that the most effective surface treatment combinations were: mechanical roughening with diamond burs and then chemical etching with hydrofluoric. In another study, it was advised to acidify the surface with 32% phosphoric
Acid in combination with Al₃O₃ air abrasion or roughen with a diamond instrument to alter the ceramic surface. It was also found that the durability of bonds between composite and ceramic formed with chemical agents was markedly inferior to alteration of the ceramic surface with either Al₂O₃ air abrasion and hydrofluoric acid or a combination of both (Thurmond et al., 1994).

Castellani et al. (1994) roughened the exposed metal and ceramic surfaces with a diamond bur and created mechanically retentive areas on the metal surface. The best results were obtained with the use of 50 μm Al₂O₃ sandblasting on the etched surface of the metal. Pameijer et al. (1996) obtained the best results in their study with the combined use of sandblasting and hydrofluoric acid application. Shahverdi et al. (1998) found that the combination of chemical and mechanical retention techniques seem promising for improved bond strength. In their study, the samples treated first with air abrasion, then with hydrofluoric acid and silane exhibited the highest shear bond values compared with air abrasion, then with hydrofluoric acid and silane.

Although the data appear to document the efficacy of air abrasion, it appears that optimum protocol for the treatment of either ceramic or metal using these methods is yet to be defined.

**Air abrasion with SiOₓ**

Although satisfactory bonding between ceramic and metal is achieved in current dental practice, many attempts have been made to develop better techniques for bonding composite resin materials to dental alloys. The nature of the metal–resin junction is critical; therefore, the strength of the bonding system, its resistance to microleakage, and the minimum space required for the system are very important. As an alternative to the conventional mechanical retention systems, chemical retention systems aim to develop a bond between metal and resin. This has led to the development of various surface conditioning techniques.

Guggenberger (1989) introduced the Rocatec® System*, which presented a new kind of acrylic–metal bonding system. The principle is tribochemical application of a silica layer by means of sandblasting. According to the extra-oral use of the Rocatec® System, samples are blasted with 110 μm grain size aluminum oxide particles modified with silicic acid, the so called, Rocatec® Plus*. The blowing pressure results in the embedding of silica particles on the metal surface rendering the surface chemically more reactive to resin via silane. The Rocatec® System was proclaimed to be a novel acrylic/metal bonding system. Shear, compression and tensile tests revealed increased bond strength values with this system compared with those obtained from mechanical bead retention, even after thermocycling and storage in water for 1 year.

Edelhoff and Marx (1995) conducted a study in which different surface conditioning methods were used for ceramic surfaces including diamond roughening, sandblasting, silica coating, and acid etching. The results obtained by silica coating showed significantly higher bond strengths of resin on ceramic surfaces compared with other systems. Best results were obtained when the nozzle of the intra-oral sandblaster was held perpendicular to the surface at a distance of approximately 10 mm. Depending on the size of the fracturing, it was advised that the surface be sandblasted for approximately 13 s (Proano et al., 1998).

In another study which was performed on disc samples, removing the debris layer with SiOₓ of 30 μm particle size resulted in higher bond strengths of resins to ceramic surfaces with no metal exposures. Mostly cohesive failures were observed and use of particles of 110 μm grain size was found to decrease the bond strengths compared with the etching technique after 24 h of water storage at 37 °C (Sindel, Gehrlicher & Petschelt, 1996). The same research group compared 5% hydrofluoric acid etching with use of SiOₓ of 30 and 110 μm particle size. In that study, 30 μm silica coating showed significantly higher bond strength values with cohesive failure modes than those obtained with acid etching after 24 h of storage in distilled water without thermocycling (Sindel, Gehrlicher & Petschelt, 1997). This study has significant findings but it could be criticized on the grounds that storage period was too short.

In a subsequent study, bond strengths using two different coating methods were evaluated. After storage in distilled water at 37 °C for 30, 90, 150 and 360 days without thermocycling, the test samples were subjected to tensile loads until they fractured. Significant differences in bond strength were obtained especially after an interval of 360-day period. The tensile bond strength for the intra-oral silica coating technique using SiOₓ of

---

*ESPE, Seefeld, Germany.
110 μm grain size showed better results than that of 30 μm SiO_x and Al_2O_3 after 60 s of application on NiCr alloys (Edelhoff, Marx & Spiekermann, 1998). The outcome of this study is in contrast with the findings of Sindel et al. (1997).

Some aspects of silane pre-treatment

The system of bonding composite resin to dental porcelain using silane solutions produced reliable bonds. It was thought to be an effective method for intra-oral repair of fractured or chipped ceramic restorations. However, this method, reported in the 1970s by Newburg and Pameijer, suffered from difficulties at first because of the instability of the silane solutions used to prepare the ceramic surface. Silane coupling agents have been steadily improved, producing higher bond strengths. For an effective bond of resin to feldspathic porcelain and metal, the use of silane in combination with a surface treatment is compulsory. Silane promotes adhesion between the fractured ceramic and the repair resin. Recent advances in silane coupling agents appear to enhance bond strength by promoting a chemical bond between the composite resin and the porcelain (Calamia et al., 1985; Tjan & Nemetz, 1988; Hayakawa et al., 1992; Mueller, Olsson & Söderholm, 1997).

Eames et al. (1977) evaluated various organosilanes to establish their bonding to ceramic or metal and observed that they did not bond to the metal surface as they had with the ceramic. In other studies, silane coupling agents were found to improve the bonding of composite resin to ceramic by approximately 25%. These studies demonstrated the use of silane or its degraded solutions to be completely ineffective when used on a glazed ceramic surface (Newburg & Pameijer, 1978; Lacy et al., 1988; Diaz-Arnold, Schneider & Aquilino, 1989).

Rapid increase in the amount of water absorbed by the composite material causes hydrolysis and degradation of the silane. Water storage and thermocycling were described as detrimental for the silane–ceramic bond (Roulet, 1987). Reuter and Brose (1984) reported that silanized interfaces appear to be unstable in humid conditions and the silane bond was found to deteriorate under atmospheric moisture. As the resins are permeable to water, the bond between silane and composite resin was expected to deteriorate by hydrolysis over time. It was concluded that in humid conditions this may lead to stress corrosion and subcritical crack growth.

In other studies, it was indicated that the use of silane is a must but different composite systems yield different values. It was noted that there is little information on the bond strength between organosilane and ceramic repair materials (O’Kray et al., 1987; Bailey, 1989).

The use of the Rocatec® System (SiO_x) increased the bond strength effectively because of the increase in silica content, which provided a basis for the silanes to enhance the bonding with the resin. For a better clinical success, Guggenberger (1989) advised the use of silane coupling agents as crucial ingredients in creating long-term bonds of resin to ceramic or metal.

A study conducted by Shahverdi et al. (1998) concluded that although silane coupling agents are capable of forming bonds with both inorganic and organic surfaces, silane itself was not found to help in bonding. Therefore, its use in combination with silica coating was recommended. In this study, in the cases where silane was not used, the bond strengths were less after water storage for 30 days. The data showed that when only silane was applied on the ceramic surfaces, the bond strength did not improve because of insufficient mechanical retention.

Studies indicated that silane coupling agents are important in the adhesion of composite resin to ceramic. The main contribution to the obtained values was made, not by the mechanical interlocking of the composite resin, but by the formation of siloxane bonds via silane (Pleuddemann, 1982; Söderholm et al., 1984).

The implication found in these studies was that silane coupling agents improve wettability and contribute to covalent bond formation between the ceramic and the resin composite. Literature supports silanization of ceramics, which provides a more reliable bond than etching with hydrofluoric acid only but little is known about the hydrolytic stability of the silanes especially in humid conditions.

Repair composite-resins

Composite resins are commonly used for the repair of ceramic fractures. If there is a small part missing, composite resins of appropriate shade have been the material of choice for aesthetic appearance and ease of manipulation.
In order to withstand the functional loads, the bond between the repair material and the restoration must be sufficiently strong. The repair material which ensures this bond should have a minimal coefficient of thermal expansion and minimal polymerization shrinkage. The type of composite resin also affects its bond strength to ceramic. Larger particle size composite resins or hybrid type resins at the ceramic interface result in higher bond strength than those of microfilled composite resins (Gregory & Moss, 1990). For repair purposes, use of the hybrid composite resins was advised as the most suitable ones (Lutz & Phillips, 1983). Bond strengths are also dependent on the type of the composite resin used. Hybrid composite resin was found to increase strength and decrease stress compared with a microfilled one (Simonsen & Calamia, 1983; Stangel et al., 1987). The problems of wear and surface changes are not related to the repair system but to the use of the microfilled composite resin which could be minimized if a hybrid composite resin is used. It is also recommended to be used where fatigue loading is of consideration (Creugers et al., 1992; Llobell et al., 1992).

A large number of studies investigated the effect of surface treatment regimens on the bond strength of composite resins to ceramic surfaces. The data from these studies should be interpreted cautiously as the type of the repair resins used in these studies exhibit different structures.

**Effect of thermocycling**

The durability of the bond values under the stresses of the oral environment is important for clinical predictability of dental materials. Usually, dental materials are subject to mechanical, thermal and chemical stresses in the mouth during oral functions. Thermocycling and water storage in vitro is a common way of testing dental materials to establish their suitability for in vivo use. Exposing the specimens to thermocycling speeds up the diffusion of water in between the composite resin and the metal or ceramic. Changing the temperature creates stress at the interface of the two materials because of different coefficients of thermal expansion. Most of the studies with repair process involved different thermocycling times but the common consensus was that the thermocycling decreased the bond strength as it weakens the resin structure (Cochran et al., 1988).

Water storage and thermocycling are detrimental to the silane–ceramic bond as well. However, it was not clarified whether the silane was broken down by the water storage or thermocycling (Cochran et al., 1988; Pratt et al., 1989).

With the use of silica coating, Peutzfeldt and Asmusen (1988) found no statistical decline in the adhesive strength from the initial bonding results obtained after 20 h of water storage at 36 °C plus 6 h thermocycling repeated 180 times between 15 and 70 °C and those after 1 year water storage and repeated 900 times thermocycling between 15 and 70 °C. However in another study, thermocycling caused decreased bond strengths values for samples sandblasted with 50 μm Al₂O₃ (Wolf et al., 1992).

A comparative study was performed by Kern and Thompson (1993) between five different resin-bonding systems to cobalt–chromium alloys. The samples were stored in artificial saliva for 150 days at 37 °C and every second day they were subjected to 1000 thermocycles in a temperature range of 5–55 °C for 75 000 cycles. Samples were tested after 24 h, 10, 30 and 90 days, and after 150 days of water storage. The results indicated that, in contrast to the micromechanical bonding systems, silica coating showed no significant change in the tensile bond strength during this observation period. The system was recommended as suitable for cobalt–chromium alloys used in resin-bonded restorations.

The relevance of the studies in which thermocycling was applied for a shorter period of time should be questioned. There seems to be a lack of agreement that water storage and thermocycling have decreasing effects on the resin–ceramic bond. The main reason for this could be attributed to various thermocycling times in the experiments.

**Conclusion**

Successful intra-oral repair of fixed partial dentures has been a great problem especially when the metal substructure is exposed (Chung & Hwang, 1997). From the previously introduced intra-oral repair techniques, organosilane coupling agents are not able to bond to metal surfaces as they do to dental ceramics (Bailey, 1989). Hydrofluoric acid and acidulated phosphate fluoride facilitate micromechanical retention but these chemical agents are not applicable to the fractures where metal is exposed and they are also hazardous to
soft tissues. Mechanical roughening of the metal or ceramic with fine and coarse diamond burs however, are reported to provoke crack initiation and propagation through the ceramic. Both experimental and clinical reports provided evidence of significant differences between the repair techniques but the results were not uniform, and therefore they were considered to be interim procedures.

For the repaired restoration to withstand functional loads, the bond between the repair resin and the remaining restoration must be strong and durable. Recently, the advantages of extra-oral silica coating (tribochemical coating) using the Rocatec® System were combined with the practical use of an intra-oral sandblaster in order to get a better bond strength in repairing fractured veneers in vivo. Although the intra-oral sandblasters had already been designed to be used with Al₂O₃, because of their superior advantages, SiOₓ (aluminium oxide coated SiOₓ particles) was used instead of Al₂O₃ together with silane application (Proano et al., 1998; Özcan, 1999).

At present, the minimum bond strength for retention of an adhesive to a metal–ceramic restoration in the oral environment is not known. Maximum bite force capability of each patient, the estimated biting force on specific teeth, the presence or absence of surface damage may reduce the success rate. There is however, insufficient clinical data available at this time to predict the clinical performance from in vitro studies and the performance of ceramic repairs in vivo (Özcan, Schulz & Niedermeier, 1999).

From the available literature, it could be interpreted that the innovative air abrasion technique with SiOₓ, recently called the CoJet®-System®, does not expose the patients to the risk of severe acid burns with the advantage of repairing fractures with both ceramic and metal exposure. Owing to the increasing number of composite resin materials on the market, it is still not easy to choose the best one. When the composites are used in the anterior region, more aesthetic expectations should be fulfilled and the clinician must meet both aesthetic and functional challenges. They should behave similarly to dentin and enamel with respect to the properties of reflection, refraction, scattering and transmission of light to give the illusion of natural teeth.

Before any attempt at a repair, the underlying metal substructure should first be found to be sound and that it is not the real cause of the failure. If this is the reason, instead of attempting the repair process, the restoration should be renewed.

When evaluating the current literature on ceramic repair techniques, the variables of composite resin, storage conditions and silane application should be taken into consideration.

References


THURMOND, J.W., BARKMEIER, W. & WILWERDING, T.M. (1994) Effect of porcelain surface treatments on bond strengths of...


Correspondence: Dr Mutlu Özcan, University of Groningen, Faculty of Medical Sciences, Oral Health Institute, Antonius Densinglaan 1, 9713 AV Groningen, The Netherlands.

E-mail: mutluozcan@hotmail.com