REVIEW ARTICLE

Surface Conditioning Treatments for Improving Adhesion of Fiber Posts

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ABSTRACT

The restoration of endodontically treated teeth has been studied extensively. Posts are widely used for the restoration of these teeth when there is insufficient coronal tooth structure to retain a core for the definitive restoration. Prefabricated postsystems have become more popular because they can provide satisfactory results with less chairside time. Bonding of fiber posts to composite materials relies only on the chemical interaction between the postsurface and the resin material used for luting or building-up the core.

In an attempt to maximize resin bonding to fiber posts, several surface treatments have been recently suggested. The aim of this review is to focus on these surface treatments in detail.

Keywords: Fiber post, Surface treatment, Surface conditioning, Etching, Sandblasting.

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INTRODUCTION

The restoration of endodontically treated teeth has been studied extensively. Posts are widely used for the restoration of these teeth when there is insufficient coronal tooth structure to retain a core for the definitive restoration. Prefabricated postsystems have become more popular because they can provide satisfactory results while saving chair time (with less chairside time) and reducing costs (not relevant to the review). Passive and tapered prefabricated posts have a configuration that is consistent with the tapered root canal and allow for optimal preservation of radicular tooth structure, especially in the apical region. Bonding of fiber posts to composite materials relies only on the chemical interaction between the post surface and the resin material used for luting or building-up the core.

In an attempt to maximize resin bonding to fiber posts, several surface treatments have been recently suggested. These procedures may be divided into three categories:

1. Silanization and/or adhesive application.
2. Acid etching, sandblasting and silica coating (i.e. Co-Jet®).
3. Alternative etching techniques (treatments that combine both a micromechanical and a chemical component).

All the articles published till date are based on *in vitro* investigations and have been mainly performed using bond strength tests *viz* microtensile and push-out in combination with microscopic analysis. Few of them include aging procedures like thermocycling and/or water storage in their experimental design.

The search was conducted using the terms 'fiber post' or 'surface treatment', 'surface conditioning', 'etching', 'sandblasting'.

Silanization and/or Adhesive Application

Several studies suggest the use of silane coupling agents in coating fiber posts for enhancing adhesion to composite resins. Goracci et al reported an improvement in bond strength between silanized fiber posts and flowable composite cores.[1] Similarly, Aksornmuang et al confirmed the benefit of silane application in enhancing the microtensile bond strength of a dual-cure resin core material to translucent fiber posts.[2-4] These results rely on silane capability of increasing surface wettability resulting in chemical bridges formation with OH-covered substrates, such as glass or quartz fibers. However, interfacial strength is still relatively low in terms of MPa.[5,6]

The absence of chemical union between resin composites (methacrylate-based) and the matrix of fiber posts (often made of epoxy resin) represent one possible explanation. According to some authors,[7] silane treatment did not enhance the bonding between glass fiber posts and six different resinous cements. Even if silanization proved to be significant in terms of bond strengths to FRC posts, the clinical relevance of the differences have been considered of minor importance.[7] MPS silanes are commonly applied in dentistry,[8,9] but do not bond well with the epoxy matrix of fiber posts. This lack of compatibility may exert an influence in the way silane molecules can absorb, condense or interact with a substrate.[10,11]

The chemical bond may be achieved only between the composite resin and the exposed glass fibers of the post. As a consequence, bond strength between the epoxy resin-based fiber posts and methacrylate-based resin composites could not be fully enhanced by silanization. Moreover, silane coupling is considered a technique sensitive step. Among factors influencing its efficacy, the composition *viz* pH, solvent content, molecule size, etc. and application mode are mostly involved. Solvent evaporation plays an important role since an incomplete removal may compromise coupling.[12] To optimize the chemical interaction between

silane and inorganic surfaces, the reaction may be catalyzed by acid treatment or heating.[13,14] Heat treatment of silane solutions is routinely performed in dentistry to maximize bond strength and has been proven to increase ceramic composite bond strength when repairing chipped ceramic restorations[9,15,16] or when bonding ceramics to composite resins.[14,16-18]

A similar technique has been recently proposed for improving silane coupling to translucent fiber post.[19] In the study, single-phase preactivated solutions based on different silane molecules (3-MPS and GPS, respectively) and a two-component system in which the hydrolysis occurs when mixing the silane coupler (γ-MPTS) with the acidic monomer (4-META) just before its application were tested.[20,21] The application of a warm air stream (38ºC) for air-drying the fiber post surface, seemed a clinically feasible chairside procedure to overcome some of the problems related to silane composition and/or application.[13,14,18]

Some authors and manufacturers have proposed adhesive systems as a possible alternative to silane solutions in fiber postcouplings.[22] The use of silane couplings and the consecutive application of a bonding agent have been recently evaluated with controversial results. Ferrari et al[23] reported no substantial improvement in bond strength by separately applying silane and different dentin adhesives on methacrylate-based quartz fiber posts: The formation of a thick multiphase coupling layer in which flaws may (be) easily produced during each separate phase of application possibly explain these outcomes.

Some recently marketed coupling agents rely on the combination of a silane/primer solution and a bonding agent. In these two-component systems for 'on-demand' hydrolysis, the silane is rapidly hydrolyzed by the acidic phosphate monomers present in the water-containing dentin adhesives, enabling the fresh silanes to perform more efficiently than completely prehydrolyzed solutions.[24] Satisfactory results have been reported both on zirconia and epoxy resin-based translucent fiber posts.[2,3,25] These combined silane/bonding agents have the (an) advantage of (x the x) simultaneous formation of siloxane bonds and polymerization of functional groups in the resin.

The selection of the bonding agent represents a possible limitation of this technique. Recently marketed adhesive systems include large amounts of water and organic solvents, acidic monomers or 2-hydroxyethyl methacrylate.[25] Due to their composition simplified one-step self-etch adhesives are prone to phase separation during solvent evaporation, creating a nonuniform adhesive interface. This aspect may expedite the post/composite interface degradative phenomena, rendering their use with silane coupling agents as questionable. Conversely, the inclusion of a separate hydrophobic resin coating applied after the silane/adhesive primer solution created a more reliable seal of the bond with the postsurface.

Acid Etching, Sandblasting and Silica Coating

Surface treatments are common methods to improve the general adhesion properties of a material, by facilitating chemical and micromechanical retention between different constituents.[26] In adhesive dentistry, surface conditioning techniques have been developed for natural substrates (i.e. enamel, dentine)[27] as well as restorative materials. Nontreated fiber posts have a relatively smooth surface which limits mechanical interlocking with resin cements and purely adhesive failure modes are commonly recorded at the post/composite interfaces.

Since chemical adhesion alone may not guarantee a strong and durable fiber post-to-composite bond, different conditioning procedures initially proposed for ceramics have also been tested on fiber posts. Ceramic etching with hydrofluoric acid is able to create a rough surface that allows for micromechanical interlocking with the resinous cement. This methodology has been recently proposed for etching glass fiber posts.[28-31] The acid effect was time-dependent and influenced by the postcomposition (type of matrix and/or fibers). The technique produced substantial damages to the glass fibers and affected the integrity of the post.[30] This is due to the extremely corrosive effect of hydrofluoric acid on the glass phase of a ceramic matrix.[9,32]

These findings were confirmed by Vano et al[33] when hydrofluoric acid was used for conditioning methacrylate-based fiber posts: Despite of the improvement in post-to-composite bond strength, a noteworthy surface alteration ranging from microcracks to longitudinal fractures of the fiber layer was detected. Suggesting (Suggested) general guidelines for using hydrofluoric acid for surface etching of esthetic fiber posts seems not possible. It is well accepted that sandblasting with alumina particles results in an increased surface roughness and surface area.

The Co-Jet® system (Co-Jet®, 3M ESPE, St Paul, Mn, USA) for intraoral use is a modification of the Rocatec® system introduced in 1989 for laboratory use. It relies on the use of aluminum oxide particles modified by silica. As a result, a silicate layer is welded onto the treated surface by high spot heat produced by blasting pressure in a process called tribochemical coating. These procedures are followed by silanization of the pretreated surface, thus combining chemical and micromechanical retention. Several studies investigated the bonding of resinous materials to different types of fiber posts evaluating the effect of these surface treatments. Air abrasion with silica coated aluminum oxide particles creates a silica layer on the postsurface due to the high velocity impact

of the silica on the substrate, allowing a penetration of the particles of about 15 microns.[30] The treatment improved the bond strength between quartz FRC and resin cements when compared with phosphoric acid or hydrofluoric acid etching.[30] Sahafi et al evaluated the efficacy of blasting the surface of zirconia and fiber posts with silica oxide (Co-Jet® System).[5,34] Although the satisfactory bond strengths, the treatment was considered too aggressive for fiber posts with the risk of significantly modifying their shape and fit within the root canals.[35] Application time, alumina particle size and pressure may have influenced the results. On the other hand, the treatment appeared beneficial when performed onto zirconia posts. Bitter et al[7] reported a little influence of Co-Jet® treatment on the bond strength between fiber posts and resinous cements depending of the luting materials used.

More promising results were recently achieved by Balbosh and Kern[33] and Asmussen et al:[36] Epoxy resin-based fiber posts were air-born particle abraded with 50 microns alumina particles at 2.5-bar pressure for 5 seconds and a distance of 30 mm. This regimen did not produce visible changes of the shape of the post and resulted in increased surface area and mechanical interlocking with the resin cement. Similarly, Radovic et al[37] reported a significant increase in surface retention when Rocatec-Prealuminum oxide particles were used for treating FRC posts. The mechanical action of blasting probably determined the removal of the superficial layer of resinous matrix, creating microretentive spaces on the postsurface.

Alternative Etching Techniques

The lack of selectivity represents the main problem of these conditioning techniques: Both the matrix as well as the fibers of the post is affected by the treatment, resulting sometimes in the damage of the post's inner structure. To achieve optimal properties in fibers-reinforced composite materials, adhesion between fibers and composite is usually optimized through selective surface treatments.[26,38] It was of interest to verify whether and to what extent the adhesive potential of the fiber post could be improved through these treatments. Different chemicals and laboratory and industrial techniques have been evaluated in an attempt to find a possible application in dentistry.

As previously reported, the absence of chemical interaction between methacrylate-based resin composite and the epoxy resin matrix of fiber posts[9] represent the main cause of weakness in post-to-composite bonds. Different solutions and solvents are known to be effective on epoxy resin.[39,40] Surface pretreatment of the resin phase of fiber posts may be beneficial in improving their adhesion to methacrylate-based resin composites.

For industrial applications, potassium permanganate is usually applied for conditioning epoxy resin surfaces for metal plating of printed circuits boards.[41,42] This treatment, called 'desmearing' consists on the subsequent application of three chemical solutions (swelling, etching and neutralizing). It was tested on translucent fiber posts achieving interesting results.[43]

With a similar purpose, hydrogen peroxide and sodium ethoxide are commonly employed in immunological electron microscopy to partially dissolve the resin surface of epoxy resin-embedded tissue sections during immunolabeling techniques. The etching effect of these chemicals depends on partial resinous matrix dissolution, breaking epoxy resin bonds through substrate oxidation.[40,44]

A similar approach has been proposed for fiber posts surface pretreatment to increase their responsiveness to silanization, achieving satisfactory results for both the tested chemicals.[45,46] The conditioning treatment consisted on fiber posts immersion in the solutions for a relatively short period (10-20 min). By removing a surface layer of epoxy resin, a larger surface area of exposed quartz fibers is available for silanization. The spaces between these fibers provide additional sites for micromechanical retention of the resin composites. In particular, H_2O_2 etching (10% H_2O_2 for 20 min) represents an easy and clinically feasible method for enhancing interfacial strengths between fiber posts and resin composites, without employing extremely corrosive liquids in a clinical setting.[46]

Most *in vitro* and *in vivo* studies agree that fiber posts failure mode is more favorable than with metal posts and the level of success seen in short-term published clinical studies (which) is being confirmed by ongoing long-term evaluations. If certain basic principles are followed it is possible to achieve high levels of clinical success with most of the current fiber posts available in the market.[47-49]

CONCLUSION

Advances in the surface treatments of the fiber posts represent one of the most important factor which has improved the success of the esthetic postsystems over the last two decades. The possibility of combining chemical and micromechanical retention on the postsurface provides the most promising adhesion mechanism.

Clinicians should be aware of the specific indications for the treatments they can perform. However, chairside post pretreatments are still considered a technique-sensitive step. The possibility of an industrial conditioning of the fiber postsurface may be of some help in an attempt to simplify clinical procedures. Precoated epoxy-resin based fiber post has been proposed, these coating films give excellent surface

properties, thanks to the stability of their bonds and the ability to form highly hydrophobic substrates. Moreover, the epoxy resin matrix of the post is not directly involved in the adhesion mechanism, avoiding the risk of incompatibility with methacrylate-based restorative materials. Further investigations are needed to evaluate the long-term durability of these bonds through accelerated aging conditions. Long-term clinical studies supporting the benefits of one technique over the other in the future is required.

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