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The Effect of Micro-Abrasive Surface Treatments on Fiber Reinforced Posts

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Abstract

Objective: Post debonding is considered one of the major causes of failure associated with endodontic treated teeth with fiber posts. Micro-abrasive surface treatments have showed an improvement in the retention of the fiber posts. However, the effect of these treatments on the flexural strength of these posts are not clear, so the purpose of this *in vitro* study is to evaluate the effect of different micro-abrasions on shear bond strength of fiber posts to resin cement, and their effect on flexural strength of fiber posts.

Materials and Methods: One hundred twenty glass fiber posts (Rely X Posts) were used in this study. They were randomly divided into two groups; shear bond strength and flexural strength. Each group was divided into four subgroups according to the different micro-abrasive surface treatments; (no treatment (control), 30µm cojet sand, 50µm, and 110µm aluminum oxide). For shear bond testing, samples were bonded with self-adhesive cement (Rely X Unicem). After that, samples were stored in distilled water at 37°C for 24 hours. Shear bond strength and flexural strength were tested using a universal testing machine (Instron Model 5566A Norwood, MA) loaded at a crosshead speed of 1.0mm/min. The Kruskal-Wallis test was conducted to analyze data for shear bond strength. Post-hoc testing was done via the Mann-Whitney U test, while one-way ANOVA was conducted to analyze data for flexural strength.

Results: A 110µm aluminum oxide micro-abrasion showed a statistically significant improvement in the shear bond strength ($P < 0.001$) between fiber posts and resin cement

compared to the control group. All micro-abrasion surface treatment groups did not show any statistically significant reductions in the flexural strength of fiber posts ($P = .091$).

Conclusions: Under the limitations of this lab study, micro-abrasion with 110µm aluminum oxide provided a significant improvement in shear bond strength of glass fiber posts to resin cement without compromising their flexural strength.

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Introduction:

Fiber reinforced posts (FRPs) have been used as an alternative to metal posts[1] since they were introduced by Duret *et al* in 1990s.[2] The most important advantage of FRPs is that they have a modulus of elasticity close to the dentin which has been reported to reduce the possibility of root fracture.[3-6] Moreover, these nonmetal posts eliminate the chance of a corrosion reaction that is associated with some metal alloys.[1, 5] In cases of endodontic retreatment, FRPs are easy to remove, and the most effective removal method is to use a diamond bur/Peaso reamer.[7] In addition, FRPs save time by eliminating the laboratory work that is necessary for metal cast posts. Several prospective[8, 9], and retrospective[10-13] clinical studies have shown satisfactory results using fiber post. However, failures of endodontically-treated teeth using FRPs have still been reported, and post debonding is the most likely effect of using FRPs.[14, 15]

Debonding of FRPs can be due to defects in the interface between the dentin and the adhesive or between the adhesive and the posts. Camillo *et al*.[16] found that all dislodged nonmetal posts were totally free of luting agents, which means that the mode of adhesive failure is more likely to happen at post-adhesive interface. In order to overcome this failure pattern, several studies have been done to enhance the bond strength between fiber posts and the luting agents.[16-19]

Micro-abrasive technique has been used to enhance the micromechanical bond strength between fiber posts and dual polymerizing resin cements.[16-20] Its popularity comes from its ability to create a rough surface on the posts, so that the luting agents interlock mechanically with these surfaces. Yunjung *et al*.[18] found that micro-abrasion with aluminum oxide alone as a surface treatment eliminates the need for an additional surface treatment to enhance the retention of fiber posts. However, these studies used the same particle size, which was 50µm. Soares *et* *al*.[21] found that 50µm particle size of micro-abrasion did not affect the mechanical properties of fiber posts, which is important for long term use of these posts. Micro-abrasion with 110µm particle size of aluminum oxide was found to enhance the bond strength between methacrylate-based glass posts and the luting agent. However, the authors were not sure about the volume loss from these posts after this treatment, and they were also not sure about the effect of this treatment on the mechanical properties of the posts.[22]

The cojet system is another micro-abrasive surface treatment used in dentistry. It is an intra-oral modification of the Rocate system for laboratory use in 1989.[23] This system consists of 30µm aluminum oxide particle size coated with silica. When these modified particles are used, the silicate layer welded on to the post surface using high heat which is produced by blasting pressure in a process called tribochemical coating. This surface treatment has been found to be superior to phosphoric acid or hydrofluoric acid etching to improve the bond strength between quartz fiber posts and resin cement.[24] In addition, this surface treatment has been found to be efficient to both fiber and zirconia posts.[25]

The performance of micro-abrasive powders depends on the hardness, size, and shape of the particles.[26]Aluminum oxide has an angular surface that produces more roughness to the treated surfaces, but in the same time it might affect the mechanical properties of the treated surfaces and it might lead to more damages.

Historical Background

Previous restorations, dental caries, and root canal preparation for the endodontically treated teeth increase the risk for substantial tooth structure loss, so the treatment of these teeth must provide strengthening, support for the remaining tooth structure, and retention to the overlying prosthetic restoration. The main purpose of introducing the posts in the restorative dentistry is to hold the overlying restorations and prevent dislodgment.[27, 28]

Using the dental posts is not current. Japanese for a long time ago used wooden restoration to act as the modern posts.[29] Pierre Fauchard illustrated in his book" *The surgeon-dentist*" in 1728 a method by which a silver or gold posts screwed into the root to retain the overlying restorations.[30]Today posts were named a pivot, which is fabricated by adapting wooden posts inside the root canal and permanently fixed to the artificial crown. The pivot was made to be adequately adapted to the canal because moisture would swell the wood and render its removal difficult. In addition, it resulted in increase the episodes of abuses and root fracture.[31] In 1876, The Richmond Porcelain which was post retained crown with a porcelain facing was introduced and was modified through the years to become a one-piece dowel and crown.[32, 33] Root facture and other difficulties associated with one piece posts and crowns leaded to the development of two-pieces casted posts and cores which are continued to be used until today despite of time consuming at the lab work because of a good marginal adaptation

Recently, in response to a need for tooth-colored posts, several nonmetallic posts such as zirconium, carbon fiber epoxy resin, glass fiber epoxy resin, and ultra-high polyethylene fiber reinforced posts have become available.

Literature Review

Fiber Reinforced Posts

With the increase in demand for tooth-colored restorations, fiber posts have become the most popular posts used since they were introduced by Duret in 1990s.[2] Besides the esthetic advantage of these posts, they eliminate the corrosive problem that might be associated with metal posts.[1, 5] Furthermore, fiber posts reduce the possibility of root fracture which is considered to be the most serious endodontic treatment failure.[3- 5]

Fiber Posts Composition

Fiber reinforced posts are a composite material that is a combination of two or more different components to get a new enhanced material. They consist of carbon, glass, or quartz fibers embedded in a matrix of either epoxy or methacrylate resin. Silanization is considered as the proper way to enhance the adhesion between fibers and resin matrix before embedding. This treatment is an important part in the reinforced process as the strong bond between the fibers and resin matrix enables the transfer of stress from the matrix to the fibers.[34, 35] along with silanization, orientation, quantity, type, and properties of the fibers also affect the reinforced process of fiber posts.

Fiber Orientation and Position

Fiber direction may affect the physical properties of fiber posts. Unidirectional fibers give fiber posts stronger and stiffer characteristics then the diagonal orientated fibers.[36, 37] However, bidirectional fibers may act as crack stoppers when the direction of the load is unknown.[37] Regardless of the bond strength of fiber posts to the tooth structures, Tezvergil *et* *al*.[38] found that fiber orientation did not show any significant changes in the bond strength value compared to the control group. However, it might change the crack propagation at the interface area.

Fiber Quantity

Fiber quantity in the polymer matrix can be defined as a volume percent of these fibers, and it has been reported between 45% and 65%.[37] Several studies have concentrated on the relationship between fiber quantity in the matrix and the improvement in flexural, transverse, and impact strength of fiber posts. It was concluded that there was a linear increase in the mechanical properties of fiber posts with an increase in the fiber quantity.[39]

Types of Fibers

Glass Fibers

Glass fibers are formed by heating sand, kaolin, limestone and calumniate at 1600°C. Then they draw into filaments of 10-24μm in diameter. Glass fibers can be categorized according to their chemical composition into A (alkali), C (chemically resistant), D (dielectric), E (electrical), R (resistant) and S (high strength), and thus differ in mechanical and chemical resistance properties. The most commonly used glass fibers in reinforced plastics are E-glass, which have good tensile and compressive strength, as well as electrical properties and a relatively low cost.[37]

Carbon Fibers

The bulk of carbon fibers are made from polyacrylonitrile by heating it in the air at 200◦C to 250◦C and then in an inert atmosphere at 1200◦C. This process removes hydrogen, nitrogen, and oxygen, leaving a chain of carbon atoms and forming carbon fibers.[40]These fibers exhibit favorable mechanical properties of high strength in tension and compression, high corrosion, creep and fatigue resistance, and a low coefficient of thermal expansion.[41] However, the major disadvantage is the black color of these fibers, as well as difficulties associated with their manufacturing and handling.[37]

Polyethylene Fibers

Polyethylene fibers are made of ultrahigh molecular weight polyethylene-woven fiber ribbon. They are almost invisible in a resin matrix. Even though they have several significant properties, their clinical use is limited. The possible explanation is that these fibers have the problems of the fiber bonding to the matrix polymer.[37]

Success and Failure Mode of Fiber Reinforced Posts

Carbon Fiber Posts

Several clinical studies have shown a wide range of failure percentage regardless of the use of carbon fiber posts after a different follow up time. One long term retrospective study was done by Segerstrom, and reported a 35% failure rate after a mean time of 6.7 years of using carbon fiber posts. This study concluded that this particular post system had a shorter survival time than those of previously documented cast posts.[14] Conversely, another retrospective study was done by Ferrari *et al*.[5] Which showed a lesser failure rate using carbon fiber posts which was about 2% after 4 years of clinical service, and they concluded that carbon fiber posts were superior to the conventional cast posts. These results have been supported by another study.[10] Moreover, in a retrospective study of 236 patients their teeth were restored with carbon fiber posts, and there was 2% reported failure rate after 2-3 years and the causes of the failure were not related to carbon fiber posts.[12]

A prospective study with an average follow up period of 2.3 years found that the success rate of carbon fiber posts for restoration of anterior teeth was 89.6% and this study emphasized that this post system is one of the most reliable systems available.[42] There were several reasons for endodontic failure reported by the above mentioned studies including periapical pathology, root fracture, crown debonding, and secondary caries. However, post debonding was the most reported one in several studies.[14, 15]

Glass Fiber Posts

Glass fiber reinforced posts have been studied extensively and several reports of good clinical results have been published.[13,43- 45] These post systems like the other fiber posts, have a modulus of elasticity close to the dentine, and therefore this gives them the advantage of reduced risk of root fracture.[46- 48] However, failure occurs with glass fiber posts. The most reported of which is debonding between fiber-resin and resin-root canal interface due to improper bond strength.[49]

Factors Affecting the Retention of the Posts

1-Post Length

Post length is an important factor that affects the retention of the dental posts in the root canal. Increasing the post length is associated with a significant enhancement in the post retention, [50- 52]while keeping in mind maintaining of 4mm to 5mm of the gatta perch seal.[53] However, in case of curved root canals where the desired length may not be achieved, the high in depth insertion into the root canals is not necessary to enhance the retention of the fiber posts.[51]

The determination of the appropriate post length and the remaining root canal filling after preparation has been studied extensively. Some studies recommended that the post should be longer than the crown length, half way between the root apex and the crest of the alveolar bone.[54- 59] Leary *et al*.[60] Suggests that posts with three quarters the length of the root less likely to debond.

2-Post Diameter

Maintaining the remaining tooth structure is an important task while restoring endodontically treated teeth. However, an increase in post diameter may result in more reduction of the root dentin. At the same time, some studies did not find any significant increases in the post retention by using a large post diameter.[61, 62, 50]

One study has suggested that the post diameter should not be more than one third of the root diameter at any locations, and at the post tip the diameter of post should be 1mm or less.[62] Another study suggested that the post should be surrounded by 1mm of sound dentin.[63]

3-Post Design

Post design can be classified according to two categories: shape and surface configuration. According to the shape, there are parallel-sided and tapered posts. According to the surface configuration, there are threaded, serrated, cross hatched and smooth surface posts. One clinical study found that parallel-sided, serrated posts have more retention than tapered and smooth posts. Standlee and Caputo in their study reported that endodontic posts with transverse serrations or crosshatching were retained well than with longitudinal threads.[64] However, another study indicated that threaded posts are the most retentive.[65]This is due to the fact that they engage into the root dentin comparison to the smooth surface posts which depend mainly on the cement for their retention.

Even though tapered posts produce less tooth reduction, they create a wedging effect that might be responsible for their less retention.[66, 67] Another study done by Yang *et al* .[68] reported that parallel-sided dowels distributed stress widely in the dentine leading to more stable restoration in contrast to tapered posts, which showed the greatest stress concentration and displacement under the horizontal force. However, the threads in these actively fitting posts may produce a high stress during the placement resulting to root fracture, [69, 70] and that is why most of the recent studies, the authors become more interested to the smooth surface posts ,and they try to enhance the cement to reach the required post retention.[71- 74]

4-Types of Luting Cements

There are five major categories of dental cements for luting dental restorations including zinc phosphate, zinc polycarboxylate, glass ionomer, zinc oxide and eugenol, and resin cement. The retention of these luting cements can be achieved by mechanical interlocking, chemical interaction with dental tissue, dental restoration, or both.

Zinc phosphate cement is the oldest luting cement, which was introduced in the 1800s. It is used frequently in the dental field because of its easy handling, [75, 76]and a good clinical success.[77] Two undesirable properties are associated with zinc phosphate cements, which are pulp irritation and solubility in oral fluid.[78, 79] Authors have suggested that pulp irritation may be resulted from a residual film of debris containing bacteria and a poor bond between the cement and dentin.[80]

Zinc polycarboxylate cement has become popular since it was introduced in 1968 by Smith as the first cement to chemically adhere to the tooth structure .[81] In contrast to zinc phosphate cement; this cement does not irritate the pulpal tissue and has a good biocompatibility.[77] However, it still has the disadvantage of microleakage.

Glass ionomer cement was introduced in 1969 by Wilson and Kent. It has high strength, retention, fluoride release, [82]and low solubility.[79, 75, 76] However, hypersensitivity is still the main disadvantage of this cement.[83] Resin modified glass ionomer was introduced in 1980s by adding polymerizing resin into the conversional glass ionomer to enhance its toughness and water solubility.[84]

Resin cements, which were introduced in 1952, are methyl methacrylate-, Bis-GMA dimethacrylate, or urethane dimethacrylatebased, with fillers of colloidal silica or barium glass 20 to 80 percent in weight.[85] They are available in different forms, such as self, dual, or light cure. These resin cements micromechanically bond to the tooth structure. In contrast to zinc phosphate cements, resin cements significantly improve the posts retention with both parallel as well as tapered short posts.[86] Resin cements require several clinical steps in their application, which include: the removal of smear layer, acid demineralization, and the application of the bonding agent or primer which may result to post-operative sensitivity due to complete acid etching. Even though using self-etching resin is less invasive, [87]it may offer less adhesion to the root canal dentin than the other approaches.[88] Another disadvantage associated with resin cement is that it is affected by improper canal preparation.[89]

Since fiber reinforced posts are passively acting posts, they depend mainly on the luting cements as part of several factors affecting their retention and over all clinical success. The current studies show that the most reliable outcome in fiber post cementation can be obtained from etch-and-rinse adhesives in combination with dual-cure resin cements.[90, 91]

These three steps in the cementation procedure are time consuming and quite complex. Therefore, the newest self-adhesive resin cement combined all these steps as one simple step for cementing fiber posts. However, self-adhesive cements which depend on acidic monomers for demineralization and infiltration may produce less bond strength to the tooth structures than etch-and-rinse luting agents.[92, 93] Conversely, another *in vitro* study reported that bond strength of self-adhesive cements to the dentin and the restorative surface is comparable to the conversional resin cements.[23]

5-The Effect of Smear Layer

In 1975 the smear layer was first described by McComb and Smoth as an amorphous layer of debris composed of dentin, pulp and bacteria debris. This layer is the result of both hand and rotating instruments.[94] Conflicts still remain regarding removal or leaving the smear layer before root canal filling.[95] Therefore, more clinical studies are required to determine whether or not to remove this layer.[96] The Smear layer may affect the post retention indirectly by decreasing the bonding capacity of some cements. It acts as a barrier for an adequate contact between luting cements and the dentinal wall. Therefore, removing this layer may result in a good cementation especially when using glass ionomer and unfilled resin cements.[97]

The recommended method for removing the smear layer is by irrigating the canal wall with Ethylenediaminetetractic (EDTA 17 percent) followed by Sodium Hypochlorite (NaOCL).[95, 98] While several studies[98, 99] have reported an increase in the bond strength between resinous materials to root dentin, others have indicated a negative result after EDTA and/or NaOCL irrigation.[100, 101]

6-Location of the Restored Tooth in the Dental Arch

The position of tooth in the dental arch decides what kind and amount of force that will be applied to the post retained restoration. Posterior teeth are subject to vertical force, so dislodgment of posts in these teeth less common then the anterior teeth which are subjecting to compressive, tensile, shear, and torqueing forces at dentin/ posts interface.[102, 103]

A Randomized controlled clinical trial done by Naumann *et al*.[104] concluded that posts retained restorations placed on the anterior teeth had three times more of a failure rate than those placed on the posterior teeth. Another clinical study reported that tooth position in the dental arch has a significant effect on post failure, and that upper posterior teeth tend to fail more than lower anterior teeth.[10] Conversely, Balkenhol *et al*.[105] reported that location of teeth in the dental arch did not have any effects on the survival rate of these teeth.

7-The Effect of the Obturation Sealer

Eugenol and non eugenol sealers are the main sealers used for root canal obturation. Even though the effect of both sealer groups on the resin-cemented posts has been studied extensively, the results are quite different. Some studies found that eugenol based sealers exhibit a significant reduction in the bond strength between resin cements and dentinal wall, [106, 107] while others concluded that eugenol and resin based sealers showed similar results.[108, 109] A possible explanation reported by Mayer *et al.*[110] is that eugenol may diffuse into the dentinal tubules and cause a modification to the polymerization of resin cements. However, using an alcohol or acid etching as intra canal irrigation may restore the effect of eugenol based sealers and increase the bond strength of resin cements to the dentinal wall.[111]

Surface Treatments of Fiber Posts

Since fiber posts have been introduced in dentistry, continuous efforts have been done to improve their retention in the root canal. Several surface conditioning treatments have been currently suggested in an attempt to enhance resin bonding to fiber posts. These surface treatments fall into two main categories:

1- Chemical surface treatment.

2- Micromechanical surface treatment.

-Chemical Surface Treatment

This type of surface conditioning is intended to enhance the chemical bonding between the cement and the fiber post. Silane coupling agents are hybrid compounds consist of organic and inorganic parts that can mediate adhesion between organic and inorganic matric. Even though the exact explanations for silane reaction mechanisms are not fully understood, the majority of clinical results indicate that silane agents might play a significant role in the adhesion processes.[112] Salinization has been investigated thoroughly in the literature to study its effect on the bond strength of fiber posts.[113] Even though silane has been proven to enhance ceramic-composite bond strength and in the repairing of ceramic restoration defects,[114] authors differ in their opinions about its efficiency for fiber post retention as this type of surface treatment is a technique sensitive procedure and there are several factors affecting its efficiency including the composition (PH, solvent content, molecular size) and the application mode. [115]

According to a study by Bitter K *et al*.[116] silane surface treatments did not cause a significant improvement in the bond strength of fiber posts to the luting cements. Conversely, Aksornmuang *et al*.[117] concluded that bond strength was enhanced using silanized fiber posts. Moreover, this result was approved when Goracci *et al*.[118] tested silanized fiber post bond strength to the composite resin core. This improvement in the bond strength of silanized fiber posts relies on the capability of the silane to increase the wettability and create a channel bond with OH-covered substrate.[118]

-Micromechanical Surface Treatment

Hydrofluoric Acid

Hydrofluoric acid, which is used as acid etching to the treated fiber post surfaces, is intended to create a roughness to these surfaces. These micromechanical roughness enable the interlocking of resin cements to the post surface and enhance its bond strength. However, the effect of this acid is time dependent and it might be extensively damaging to the fiber posts especially the glass one.[24] In addition, it might cause remarkable surface changes that can range from small cracks to longitudinal fracture when it was used to treat the methacrylate-based fiber posts.[119]

Hydrogen Peroxide

Hydrogen peroxide as a surface treatment for both quartz and glass fiber posts significantly increases the shear bond strength of these posts to the composite resin. The effect of H_2O_2 relies on its ability to partially dissolve the epoxy resin matrix of the fiber posts.[120, 119] Moreover, application of 10% potassium permanganate for 10 minutes was found to be more efficient then H_2O_2 as a surface conditioning to enhance bond strength of fiber posts. However, these procedures were thought to be time consuming.[121]

Sandblasting and Tribochemical Surface Treatment

A relatively smooth surface of fiber reinforced posts limits the mechanical interlocking of the resin cements into post surface. Micro-abrasion with different abrasive materials creates different degrees of roughness on the post surfaces to enhance the micromechanical bonding strength. There are several factors affecting the results of this surface treatment, including the particle sizes, pressure, treatment time, and the distance from the treated surface. Different studies used different regimens while they tested the effect of micro-abrasions.[17, 18, 6] Balbosh and Kern in their study used 50μm aluminum oxide particle size at 2.5 bar pressure for 5 second from a distance of 30mm. this regimen resulted in an improvement in the bond strength between fiber posts and resin cement. Nevertheless, it did not produce a visible damage to the form of the tested posts.[17] Yunjung *et al*.[18] in his *in vitro* study followed the manufacturer's recommendation for using micro-abrasion using 50μm at 2.8 bar from a distance of 1cm for 5 seconds and concluded that micro-abrasions with aluminum oxide alone as a surface treatment eliminate the need for an additional treatment to enhance the retention of FRP. While these studies used the same particle size which was 50μm, Radovic *et al* .[22] tried 110μm aluminum particle size as a surface treatment to assist the adhesion between glass methacrylate-based fiber posts and a dual-cured resin cement and found an enhancement in the bond strength between them. However, the authors were not sure about the volume lost from these posts after this treatment and the effect of this treatment on the mechanical properties of these posts.

The cojet system is another micro-abrasive surface conditioning used in dentistry. It is an intra-oral modification of the rocate system designed for laboratory use in 1989.[23] This system consists of aluminum oxide particles that are modified or coated by silica. When these modified particles are used, the silicate layer will be welded on to the post surface by high heat produced by blasting pressure in a process called Tribochemical Coating. This surface treatment has been found to be superior to phosphoric acid or hydrofluoric acid etching to improve the bond strength between quartz fiber posts and resin cements.[24] In addition, this surface treatment has been found to be efficient to both fiber and zirconia posts.[25]

Despite the satisfactory bond strength results that have been obtained from these micro-abrasive treatments, concerns were raised regarding the possibilities of post deformity and volume lost induced by aluminum oxide sandblasting or tribochemical coating treatments.[1, 22.122]

Flexural Strength

The flexural strength can be defined as a resistance of the materials to fracture, and is determined by the maximum load the materials can hold before fracture. To get the optimum outcome using fiber posts to restore endodontically treated teeth, these posts should have biomechanical properties closer to the dental tissues. All fiber post types have showed a significant reduction of their flexural strengths if they had a contact with water as water absorption may result in degradation to these posts. Therefore, it is necessary that fiber posts are protected from contact with oral fluid by doing a proper apical canal sealing and crown buildup.[123, 124] These results were supported by another study done by Lassila *et al.*[47] who concluded that thermocycling and water storage may cause reduction in the flexural strength of fiber post by 18%. Another reason for the reduction in fiber post flexural strength is the surface treatment specifically sandblasting as this surface conditioning can cause volume lost that leads to weakening of these posts.[1, 22]

Shear Bond Strength

There are wide varieties of mechanical tests available to evaluate the bond strength between materials such as pull-out, shear, tensile, or micro-tensile tests. Therefore, these laboratory tests can be considered an important factor during the measurement of the bond strength. Shear bond strength is a commonly applied method to evaluate the bond strength and has been proven to be reliable by several studies.[125, 126] Cohesive failures are discussed in some studies as a limitation of this test as a consequence of the heterogeneity of interfacial stress. However, other studies [127, 126] observed adhesive failures that mainly indicated the validity of shear bond strength tests. Shear bond strength is affected by the bonding surface area and is usually used for3-6mm (approximately 7-28mm^2). Easy of sample preparation and simple test protocol make shear bond tester continually used till today by several studies.[128, 129]

Research Hypothesis and Aim

Aim

The aim of this *in vitro* study was to investigate the efficacy of surface treatments with different micro-abrasions (30µm tribochemical coating (cojet sand), 50µm, 110µm aluminum oxide) on the shear bond strength between glass fiber posts and the resin cement (Rely X Unicem). The effect of these treatments on the flexural strength of the glass fiber posts was also evaluated.

Hypothesis

1. Surface treatment using 110µm Aluminum Oxide will show a higher value of shear bond strength between glass fiber posts and the resin cement than the control group, 30µm tribochemical coating (cojet sand), and 50µm Aluminum Oxide.

2. Flexural strength of glass fiber posts will show a lower value by using a larger size of micro-abrasions (110µm aluminum oxide surface treatment) than the control group, 30µm cojet sand, or 50µm aluminum oxide surface treatments).

Materials and Methods

- Sample Size Calculation

Two pilot studies were performed on shear bond strength and flexural strength to define the total sample sizes for each group. Power analysis was calculated using nQuery Advisor software (Version 7.0). For shear bond strength, assuming mean values of 1.2 (control), 6.0 (30µm), 6.3 (50µm), and 10.4 (110µm), as well as a common standard deviation of 3.8, a sample size of n = 15 per group is adequate to obtain a Type I error rate of 5% and a power greater than 99%. For flexural strength, assuming mean values of 805.6 (control), 783.4 (30µm), 807.4 (50µm), and 799.8 (110µm), as well as a common standard deviation of 16.9, a sample size of n = 15 per group is adequate to obtain a Type I error rate of 5% and a power of 95%.

- Preparation of the Fiber Posts for Shear Bond Strength

Sixty glass fiber reinforced posts (Relay X Posts, 3M ESPE) with a diameter of 1.9mm and a length of 20mm were used in this study. The post surfaces were cleaned with 70% ethyl alcohol, embedded in a self-acrylic resin (D. Caulk, Milford, DE, USA) up to the top surface. The top exposed surface of the posts were cleaned with 35% phosphoric acid gel (Ultra Etch, Ultradent Products Inc., USA) for 5 seconds, rinsed with distilled water for 15 seconds, and then dried with oil free compressed air for 15 seconds. After that, these posts were divided into four groups.

- Application of Micro-Abrasions for Shear Bond Strength Groups

1. Group 1- No surface treatment prior to cement application.

2. Group 2- A 30µm silica coated aluminum oxide (Cojet sand) (3M ESPE).

3. Group 3- A 50µm aluminum Oxide (Danville Materials, Inc).

4. Group 4- A 110µm aluminum Oxide (Recatec-Pre, 3M ESPE).

All of the micro abrasion processes were done using an intra-oral sandblaster (Danville Materials, Inc) at 2.8bar from distance of 1cm for 5 seconds.

-Application of the Luting Agent

Relay X Unicem (self-adhesive cement) luting material was mixed according to the manufactory instructions using mixing spatula on a paper pad for 20 seconds, then it was applied to the treated surfaces of the posts that they were wanted to measure their shear bond strength by using a metal ring with 1.9mm inner diameter for standardization of the bonding area, [18]after that, these posts were light cured for 40 seconds with a halogen polymerizing light unite ((ESPE, Elipar®, Trilight). The samples were stored in distilled water at 37c˚ for 24 hours.

-Shear Bond Strength Testing

Next, the shear bond strength between fiber posts and the resin cement was tested using a universal testing machine (Instron Model 5566A Norwood, MA) loaded at a crosshead speed of 1.0mm/min until the metal ring detach from the posts (figure 2). The shear bond strength was calculated in MPa by dividing the load at which the failure was happened over the bonding surface area.

-Preparation of the Fiber Posts for Flexural Strength Groups

Sixty glass fiber reinforced posts (Relay X Posts, 3M ESPE) with a diameter of 1.9mm and a length of 20mm were used in this study. The surfaces were wiped with alcohol and then dried with oil free compressed air for 15 seconds. The whole post surfaces were treated with the different sizes of micro-abrasions not just the top surfaces. Because of the cylindrical shape of the posts, the treatment time was 10 seconds, 5 seconds for each side. After that, samples were divided into four groups according to the surface treatments that were received:

1. Group 5- No surface treatment (control).

2. Group 6- A 30µm silica coated aluminum oxide (Cojet sand) (3M ESPE).

3. Group 7- A 50µm aluminum Oxide (Danville Materials, Inc).

4. Group 8- A 110µm aluminum Oxide (Recatec-Pre, 3M ESPE).

All of the micro abrasion processes were done by using an intra-oral sandblaster (Danville Materials, Inc) at 2.8bar from distance of 1cm for 10 seconds.

- Flexural Strength Testing

Flexural strength of fiber posts was tested using 3-point bending test in accordance to the ISO 10477 standard (10.00mm span, 1.0mm/min crosshead speed, and 1mm loading pins diameter). This test gave us the maximum flexural strength ($F_{max)}$ and deflection (D). After that, the flexural strength was calculated using this formula $\delta = 8\ F\ (_{max})\ L/\ Л\ d^3$ (Mpa). [47] Where the F_{max} is the applied load (N), (Л = 3.14), (L) is the span length, and (d) is the diameter of the specimens (figure 3).

Statistical Analysis:

All analyses, including descriptive statistics, were performed using SPSS version19. As the shear bond strength data exhibited non-normality, non-parametric testing (the Kruskal-Wallis test) was conducted to assess statistical significance for this outcome. Post-hoc testing was done via the Mann-Whitney U test. The Bonferroni correction was used to account for multiple comparisons; hence, the p-value cutoff for the Mann-Whitney U tests was $<.008$.

The flexural strength data were approximately normally distributed; therefore, one-way ANOVA was conducted to assess whether the surface treatments exhibited statistically significant differences for this outcome. The level of significance was set at $P < 0.05$.

Results

-Shear Bond Strength

The mean and standard deviation (SD) for shear bond strength of the groups are displayed in the table 2.

Micro-abrasions as surface treatments for the fiber posts prior to the cement application resulted in a higher shear bond strength compared to the control group. The highest shear bond strength was obtained by using 110µm aluminum oxide compared to the other groups. Also 50µm aluminum oxide surface treatment resulted in a second highest mean of the shear bond strength compared to the mean and 30µm cojet sand.

Statistical analysis with the Kruskal-Wallis test showed a significant difference between different surface treatment groups ($P = .001$). Post-hoc comparison using the Mann-Whitney U test indicated a statistically significant difference between the 110µm aluminum oxide surface treatment group and the control group ($P < .0001$). Moreover, 110µm aluminum oxide surface treatment showed a statistically significant enhancement on bond strength of fiber posts to resin cement compared to 30µm cojet system ($P = .005$). Although surface treatment using 30µm cojet sand and 50µm aluminum oxide did show an improvement in the bond strength compared to the control group, this improvement was not statistically significant.

-Flexural Strength

The mean and standard deviation (SD) for the flexural strength of the groups are displayed in the table 3. The highest mean was obtained from the control group compared to the other groups. The largest micro-abrasive particle (110µm aluminum oxide) did show some reductions in the mean of the flexural strength of the fiber posts, but this reduction was not a statistically significant comparing to the control group.

Statistical analysis using one-way ANOVA showed that there was not a statistically significant difference in the flexural strength between different surface treatment groups ($P = .091$)

Discussion

Debonding and loss of retention are the most likely causes of failure associated with using FRPs.[14, 15, 49] A relatively smooth surface of FRPs limits the mechanical bonding of the resin cements into the post surfaces. Micro-abrasive surface treatments have been studied thoroughly to assess their effects on the bond strength between the fiber posts and the resin cements.[17, 18] The effects of these treatments depend on the hardness, size, and shape of the particles.[26] An aluminum oxide has angular surfaces that have the ability to create a rough surface on the post, so the luting cements interlock micromechanically with the post surfaces. However, the volume lost from the fiber post surfaces might affect the mechanical properties of these posts.[1, 22] While many studies used the same particle size, which was 50µm, our study attempted to compare different particle sizes of micro-abrasions (30µm cojet system, 50µm, and 110µm aluminum oxide), and the effect of these treatments on the flexural strength of glass fiber posts.

-Micro-abrasion and Shear Bond Strength

Shear bond strength, which was used in our study, is a commonly applied method to evaluate the bond strength, and has been proven to be reliable by several studies.[125, 126] The results of our *in vitro* study partially support the research hypothesis, in that micro-abrasion surface treatments significantly improved the shear bond strength of fiber posts to the resin cement. The results showed a statistically significant difference in the shear bond strength among different surface treatment groups, and this is compatible with previous studies[17, 18, 25] which reported that micro-abrasion with aluminum oxide particles increases the surface area and enhances the bond strength between the roughed surface of fiber posts and cements.

In the present study, 110µm aluminum particle size surface treatment resulted in a significant improvement in the shear bond strength between the fiber post and the resin cement compared to the non treated posts. These results are consistent with the previous study done by Radovic *et al*.[22] who concluded that 110µm aluminum oxide size sandblasting improved the bond strength between the fiber posts and the resin cement, eliminating the need for an additional chair-side treatment. However, the authors were unsure about the volume lost that might be caused by this aggressive treatment and the effect of this treatment on the flexural strength of the fiber posts.

The lowest shear bond strength was reported in the control and the cojet system groups. The cojet system resulted in an improvement in the bond strength compared to the control group, but this improvement was not a statistically significant. These results are compatible with the outcome reported by Petra *et al*.[130] who found no significant difference in the bond strength of fiber posts when they applied the cojet system in combination with Relay X Unicom cement which was also used in our study. Conversely, our results are incompatible with the outcomes of other studies, [24, 25] which reported a significant improvement in the post retention using the cojet system. The possible explanation for these contradicting results is that in our study, we concentrated on the mechanical effect of cojet system while the other studies add the silane agent after cojet system treatment. The cojet system exposes the fibers of the fiber posts and increases the surface area available for the silane agent to form a chemical bonding with the alcoxy groups of the silane, so both the mechanical and chemical bonds will be enhanced.

A 50µm aluminum oxide particle size showed an improvement in the bond strength compared to the control group. However, according to our study, this improvement was not statistically significant. This result is consistent with the study done by Soares *et al*.[21] and inconsistent with the study done by Yunjung *et al*.[18] Yunjung *et al* used the same micro-abrasion protocol as our study regarding to the pressure, distance, and time. However, they used a different fiber post type as well as different cement, and this might explain the discrepancies in our results.

-Flexural Strength of Fiber Posts and Airborne-Abrasion

The flexural strength can be defined as the resistance of the materials to fracture. It is determined by the maximum load the materials can hold before fracture. In this study, we used a 3-point bending test in accordance to the ISO 10477 standard as this test is the most reliable test to measure the flexural strength of fiber posts.[47] The results of our *in vitro* study do not support the research hypothesis, in that the micro-abrasion surface treatments do not significantly affect the flexural strength of fiber posts, and this finding is consistent with the results reported by Soares *et al*.[21] who found that 50μm aluminum oxide micro-abrasion did not affect the mechanical properties of glass and carbon fiber posts. In addition, to our knowledge, our *in vitro* study was the first study that showed that 110μm aluminum oxide surface treatment did not cause a significant reduction in the flexural strength of glass fiber posts.

This study was an initial investigation of the use of different micro-abrasions as surface treatments of fiber posts on shear bond strength to resin cement which is limited by several laboratory factors that may affect the accuracy of the results. Further studies are suggested to assess the effects of other variables of micro-abrasions such as pressure, distance, and the treatment time to determine the optimum conditions of micro-abrasions as a surface treatment for fiber posts

Conclusion

Within the limitations of our study we can conclude that:

1) A 110µm aluminum oxide as a micro-abrasive surface treatment for glass fiber posts significantly improves the shear bond strength between fiber posts and resin cement.

2) There was not significant evidence that micro-abrasion surface treatments with different particle sizes (30µm cojet sand, 50µm, and 110µm aluminum oxide) affect the flexural strength of fiber posts.

Table 1: The Materials Were Used in this Study

Materials In Study	Manufacturer
Glass fiber posts.	Relay X Posts, 3M ESPE
50µm Aluminum oxide (AL_2O_3)	Danville Materials, Inc
110µm AL_2O_3	Recatec-Pre, 3M ESPE
Silica coated AL_2O_3 (cojet sand)	3M ESPE
Resin cement	Rely X Unicem, 3M ESPE

Figure 1: How the eight individual groups of fiber posts were categorized.

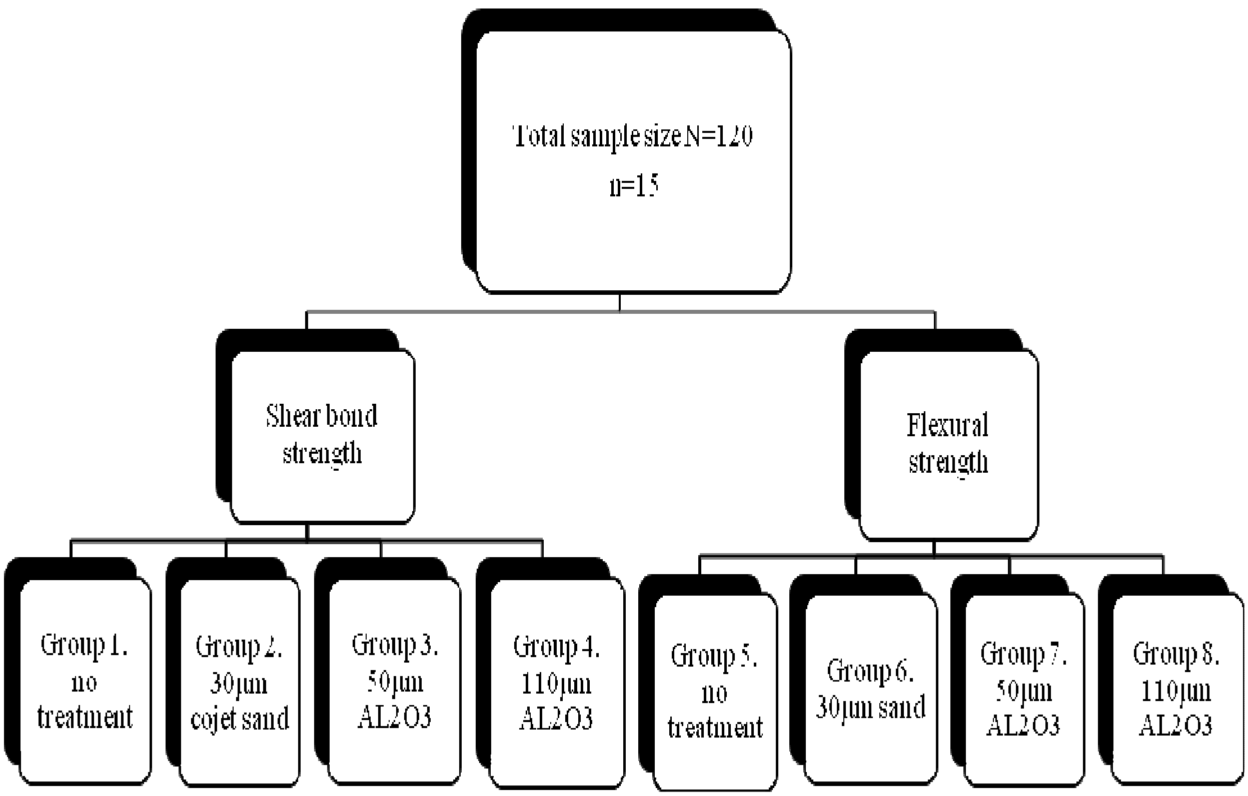

Table 2. Kruskal-Wallis test of results of shear bond strength.

Surface Treatments	n	Shear Bond Strength Mean(MPa)±(SD)	Median	Inter-Quartile Range	P-Value
No Treatment [a]	15	5.3±(2.9)	5.3	10.32	= .001
30µm Cojet Sand [a]	15	7.0±(4.2)	7.5	15.65	
50µm Aluminum Oxide [a, b]	15	9.6±(4.0)	10.0	23.81	
110µm Aluminum Oxide [b]	15	18.9±(13.6)	15.1	43.28	

* Same letters denote groups that were not significantly different (Kruskal-Wallis test and Mann-Whitney U test).

Table 3. One-way ANOVA test of the results of flexural strength

Surface Treatments	Flexural Strength Mean±(SD)	P-Value
No Treatment	807.5± (19.4)	.091
30µm Cojet Sand	781.6± (23.6)	
50µm Aluminum Oxide	776.1± (44.5)	
110µm Aluminum Oxide	780.2± (50.1)	

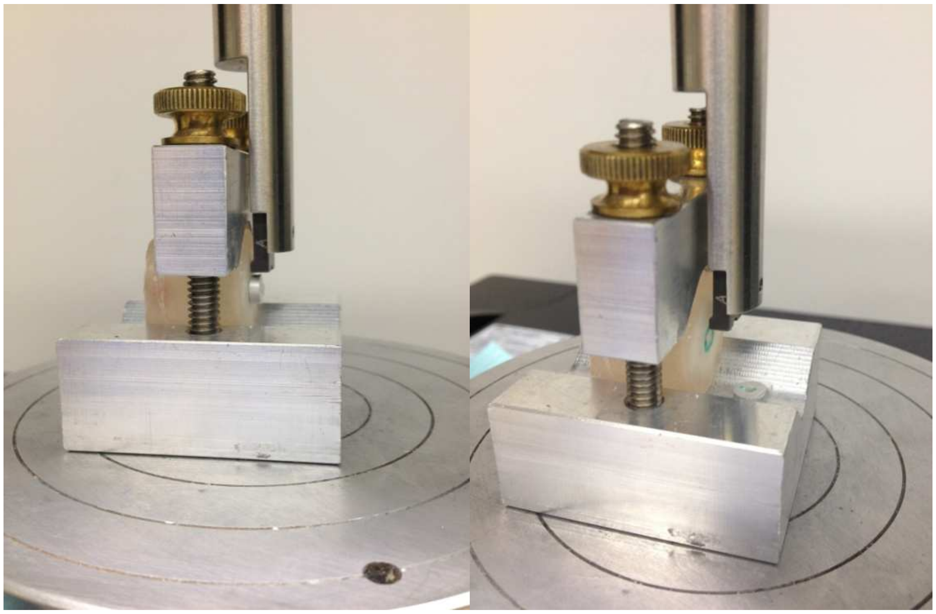

Figure 2. Shear bond strength testing

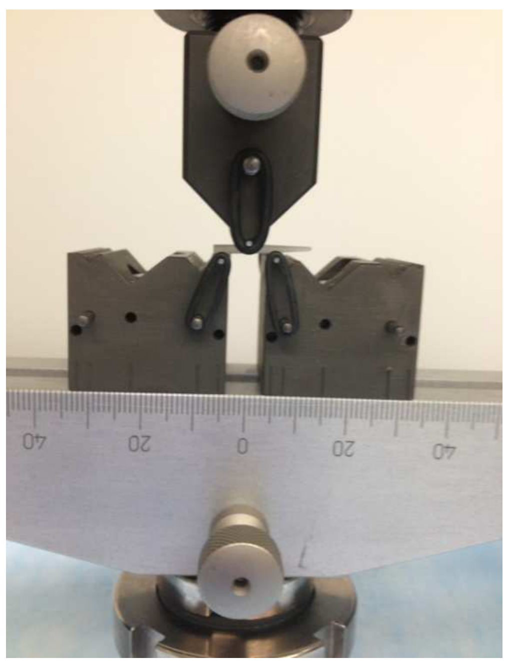

Figure 3. 3-Point bending test for the flexural strength

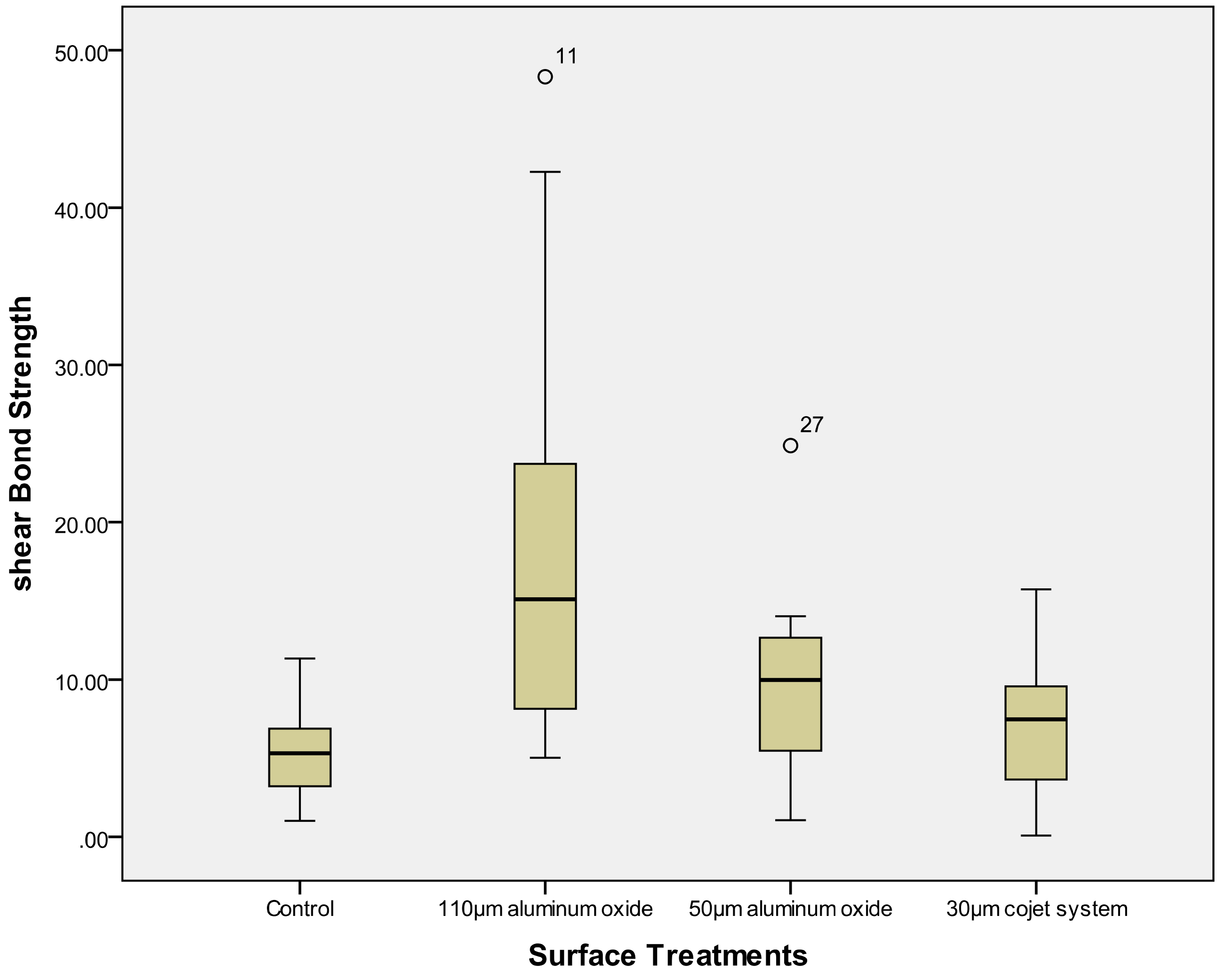

Figure 4: Box-plot for shear bond strength in each study group.

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