An S.E.M. evaluation of carbon-fiber post and core resin interface, before and after an *in vitro* test

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ABSTRACT

*Purpose: This study aims to evaluate the role of surface treatments performed on plain carbon fiber posts, compared to serrated carbon fiber posts, on the interface with composite resin core. Materials and Methods: Fifty carbon posts were divided into five groups; the first four groups contained plain carbon fiber posts and the last group contained ten serrated carbon fiber posts. Plain carbon posts received the following surface treatments: aluminum oxide spray (group A); medium grit diamond burs (group B); depth cutter diamond burs for laminate veneers (group C); coronal end modification, mechanically machined (group D). Group E consisted of carbon fiber posts serrated by manufacturer. An acrylic resin mold was developed in order to precisely fit the post, leaving a machined space to accommodate a self-curing composite core resin. After surface treatment, all posts received primer, were dried and then were fitted to the mold, then receiving a 3 mm composite core. After thermocycling and storage in distilled water for one week, tension test was performed at speed 0.5 mm.min^{-1} up to lack of adhesion or core fracture. Posts were submitted to S.E.M. evaluation at 500X magnification before and after tension load was performed. Results: After tension load, mean values were lower for Group **B** when compared to other groups; more adhesion was found in Groups **A** and **B** than in Groups with macroscopic retention (**C**, **D** and **E**). Conclusion: under S.E.M. evaluation, groups without macroscopic retention (**A** and **B**) presented greater surface of core resin adhering to carbon post when compared to groups with macroscopic retention (**C**, **D** and **E**).*

UNITERMS

Post-core; interface; composite resin, retention; pre-fabricated post.

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RESUMO

Objetivos: Esse estudo tem o propósito de avaliar o efeito de tratamentos superficiais à superfície de pinos de fibra de carbono lisos na retenção da resina de preenchimento, comparando com a retenção aos pinos de carbono de superfície serrilhada. *Materiais e Métodos*: Cinqüenta pinos de fibra de

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carbono foram divididos em cinco grupos: os primeiros quatro grupos continham pinos de fibra de carbono lisos e o último grupo, dez pinos de fbra de carbono de superfície serrilhada. Os pinos de fibra de carbono lisos receberam os seguintes tratamentos superficiais: jateamento com óxido de alumínio (grupo A); tratamento com pontas diamantadas de granulação média (grupo B); tratamento com pontas diamantadas para facetas laminadas (grupo C); usinagem da extremidade coronária (grupo D); o Grupo E consistia de pinos de fibra de carbono serrilhados pelo fabricante. Uma matriz de resina acrílica foi desenvolvida para que os pinos ficassem bem ajustados, deixando um espaço na extremidade coronária para acomodar uma resina autopolimerizável para núcleos de preenchimento. Após o tratamento superficial, foi aplicado um primer, os pinos foram secos e adaptados à matriz para receber um núcleo de resina composta com 3 mm de altura. Os espécimes receberam ciclagem térmica e foram armazenados em água destilada durante uma semana. O teste de tração foi executado em uma máquina Instron até o deslocamento ou a fratura do mesmo. Foi feita uma análise da superfície dos pinos sob microscopia eletrônica de varredura (M.E.V.) sob aumento de 500X, antes e após o teste de tração. *Resultados*: Após o teste de tração, os valores médios de retenção foram menores para o Grupo B quando comparados aos demais Grupos. A adesão foi maior para os Grupos A e B que para os Grupos com retenção macroscópica (**C**, **D** and **E**). *Conclusão*: a avaliação em M.E.V. revelou que os grupos sem retenção macroscópica (**A** and **B**) apresentaram maior superfície de adesão da resina composta de preenchimento quando comparada à retenção dos grupos com retenção macroscópica (**C**, **D** and **E**).

Unitermos

Pinos dentários, núcleos, interface; resinas compostas, retenção.

Introduction

Restoring endodontically treated teeth is a very difficult task in clinical practice. It is very well established that placement of a post and core is not obligatory (Sorensen & Martinoff[29], 1984; Sorensen[27], 1988; Gutmann[10], 1992). Resistance of pulpless teeth is more related to amount of remaining sound structure than to its "reinforcement" with posts, according to many authors (Sorensen[27], 1988; Assif et al.[2]1993; Assif & Gorfil[1], 1994, Morgano[20], 1996). Sorensen & Martinoff[2] 1984 affirmed, in a study with 1273 endodontically treated teeth, that it is advisable to recover cusps in posterior teeth in order to prevent tooth fracture; they would also stated that anterior teeth are not so prone to tooth fracture and they would only need a prosthetic approach if too much structure was lost due to caries, restorations and/or endodontic access. The relationship among dowels, posts and stress to root structures is also well known (Caputo & Standlee[3]1987). According to Gutmann[10] 1992, when a post is truly needed care must be taken regarding to:

- stability of post inside the root;
- avoiding a post system that could stress a specific type of root;
- enhancing optimal cement-to-post contact;
- considering the use of a low viscosity resinous cement;
- minimizing post stresses during insertion and function;
- establishing a ferrule effect around tooth.

It is also well known that type and form of posts can directly influence amount of functional stresses in pulpless teeth. Parallel-sided posts are less dangerous to root structure, when compared to tapered posts (Caputo & Standlee[3]1987, Sorensen[27]1988, Sorensen & Engelman[28]1990).

Over past few years, there has been a growing preoccupation about developing new restorative materials. Manufacturers have also noticed clinical concern about materials for intraradicular anchorage. Research has been developed to try to find out alternatives to metallic posts, because their *moduli* of elasticity is much higher than dentin's *modulus* of elasticity, which can induce functional stresses and lead to root fracture. Ideal material for intraradicular placement, according to Duret et al.[7] 1990, should have:

- identical shape of lost structure;
- physical-mechanical properties similar to structures to be replaced, but with higher shear strength to compensate loss of tooth structure;
- composition compatible with dentinal adhesion for better interface.

Carbon-fiber posts were introduced in 1990 by Duret et al.[7,8] Manufacturers[5] state that, as an anisotropic material, its *modulus* of elasticity depends on the angle of application of force:

- 125GPa along longitudinal direction;

- 8GPa along transverse direction;
- range from 21 to 24 at forces of 30°.

Plain carbon-fiber posts are very rigid when compared to metallic posts, because of 64% content of fibers (Purton & Love[22]1996, Purton & Payne[23]1996). There are also some studies pointing out that failures in pulpless teeth treated with this system are, most of the time, located in a reversible site for restoring the tooth again (Sidoli et al.[26]1997, Martinez-Insua et al.[19]1998). Intraradicular retention represents no problem to these posts, according to Rovatti et al.[24]1994. Main disadvantage of carbon posts is lack of retention to resin core, despite Bis-GMA matrix (Purton & Love[22]1996). Manufacturers have created a serrated version, but these posts are less rigid than plain posts (Love & Purton[17]1996). This study aims to evaluate if surface modifications on coronal end of plain carbon posts would lead to better interface to link with a resin core, and also to compare microscopic features to test results.

MATERIALS AND METHODS

Fifty carbon-fiber posts (C-Post, #3, BISCO, USA) were divided into five groups (A,B,C,D and E). Four groups contained plain posts that received modifications at coronal end before core placement. Surface alterations were performed as follows: Group A, sandblasting; Group B, medium grit diamond bur; Group C, laminate veneers diamond burs (depth cutter); Group D, head form change. Group E consisted of posts serrated by manufacturer.

In Group A, sandblasting (50mm aluminum oxide) was made at 1mm distance in 3mm height at coronal end. Posts in Group B also had 3mm height prepared with a medium grit diamond bur (Diamond Burs, number 315, Moyco, USA) parallel to their long axis. Group C received the same height preparation with a depth cutter (Diamond Series, number S4, Moyco, USA). Diamond burs were discarded after single use for each specimen in Groups B and C. Group D had their head machined as shown in Figure 1. Each group with a surface treatment was submitted to S.E.M. evaluation at 500X magnification before receiving resin core.

All posts received a double coat of Primer B (All-Bond, BISCO, USA) and were dried. A machined acrylic resin mold was developed and divided into two halves, inside which a #3 C-Post fitted exactly; at the coronal end, a 3mm space was created in order to receive a composite resin core (Figure 2). A fine brush with a thin layer of petroleum jelly lubricated the coronal end of the mold before core placement.

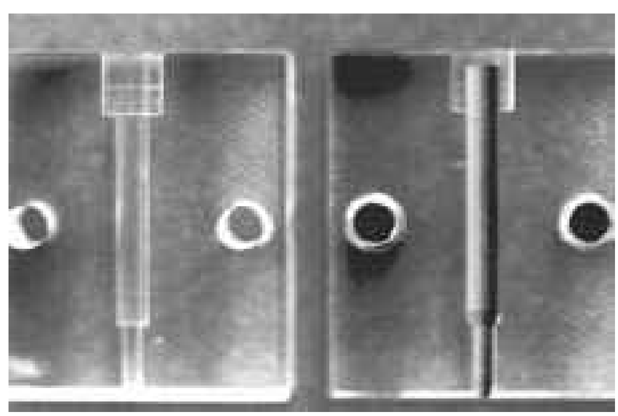


FIGURE 2 – Acrylic resin mold with carbon post in place and coronal end to composite core.

FIGURE 1 – Machined carbon-fiber post (C-Post, BISCO, USA).

After primer had dried, a composite resin specially developed for core build-up (Core-Flo, BISCO, USA) was mixed as recommended by manufacturer and then inserted in the 3mm core space. Post was then placed, both halves of mold were screwed and kept under pressure; according to Duret et al.[10]1990, pressure is essential to push composite material into post's microscopic retentions to get a chemical link to the Bis-GMA matrix. Excess of composite resin at the top of the mold was removed with a spatula before set. Any composite excess remaining was trimmed with abrasive paper discs (Mooreplastics, garnet fine, Moore) in a handpiece mandrel.

Specimens were then submitted to tension test in an Instron machine (model 4301, U.S.A.), that was adapted in order to transmit force exactly to the long axis of the samples, at 0.5 mm.min $^{-1}$ croshead speed. Test was stopped when there was core displacement or fracture.

After tension load had been performed, each group post was also observed at S.E.M. with same magnification (500X).

Results

After tension load, both Groups B and C had one specimen discarded. Test results were submitted to an analysis of variance test (ANOVA), with a 5% Confidence Interval (C.I.). There was a statistical difference among groups at a 5% level. Results were considered on a logarithmic basis.

In Figure 3, mean values are shown for experimental conditions, demonstrating a statistically significant difference between Group **B** and the other groups. There were no statistically significant differences related to core retention among Groups **A**, **C**, **D** (plain posts treated) and **E** (serrated posts).

There was also a macroscopic difference among groups: Group **B** samples presented just core dislodgment, which was a completely different result in relation to all other Groups. In 80% of specimens in Group **A**, there was core dislodgment with partial or total fracture of composite resin. In Groups **C**, **D** and **E** there was core fracture in all specimens.

However, under S.E.M. evaluation, there was more adhesion in Groups **A** and **B** than in other Groups. (Figures 4a, b, c, d and e).

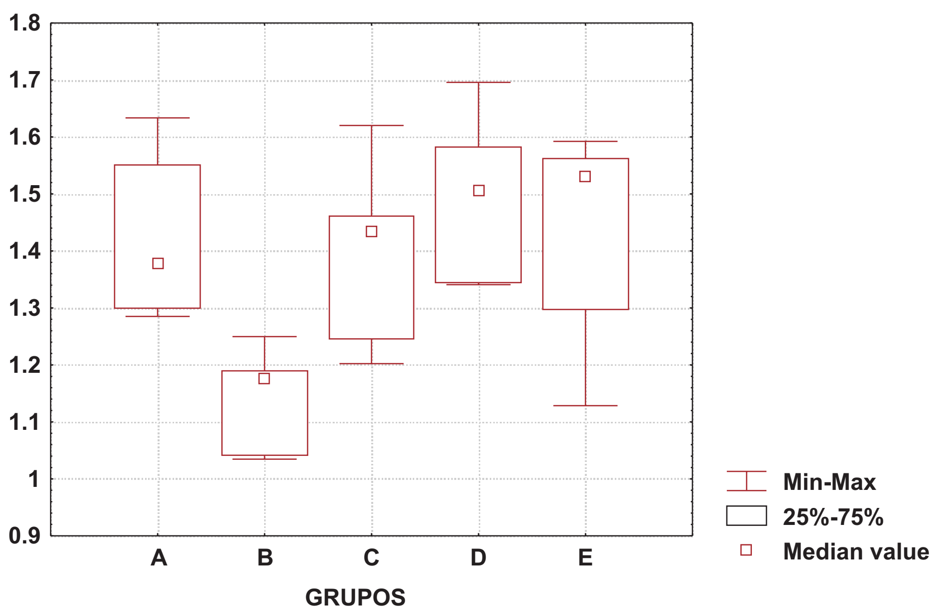
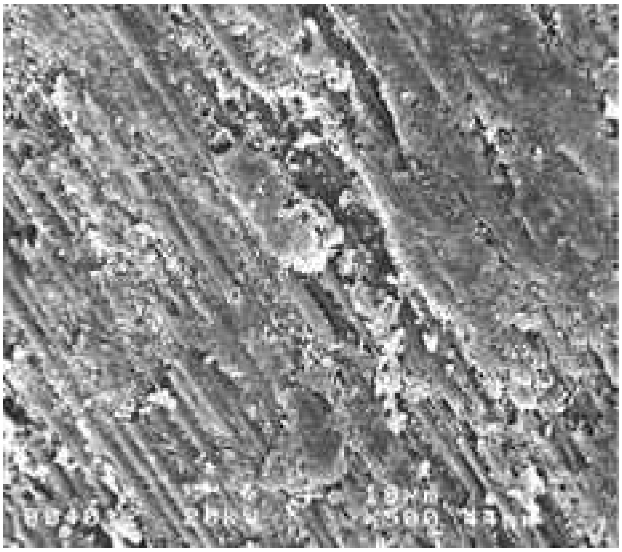
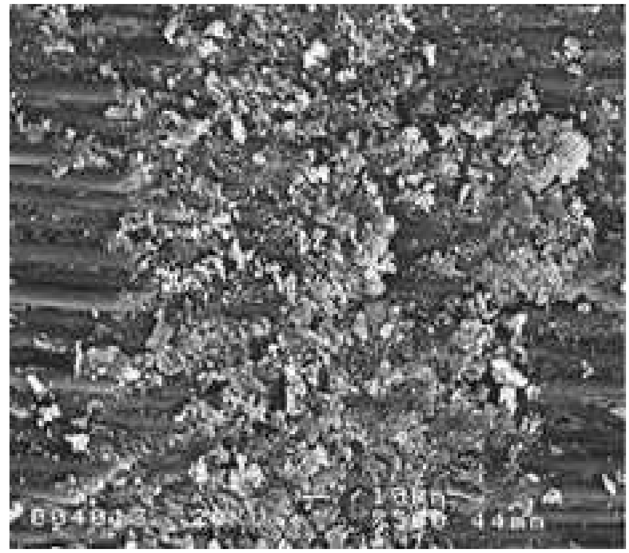
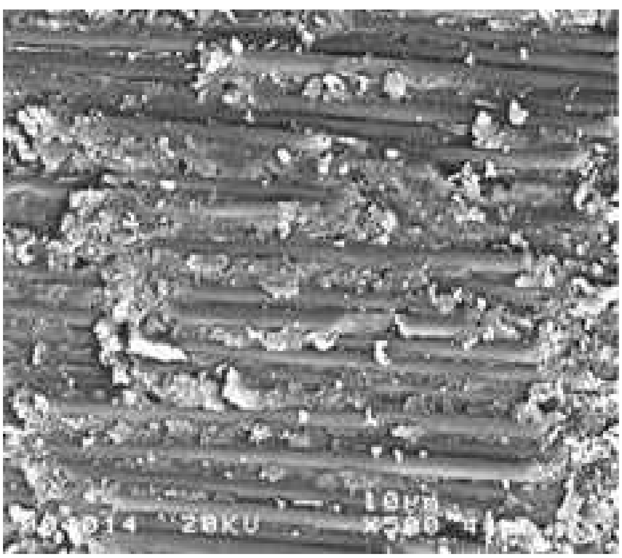
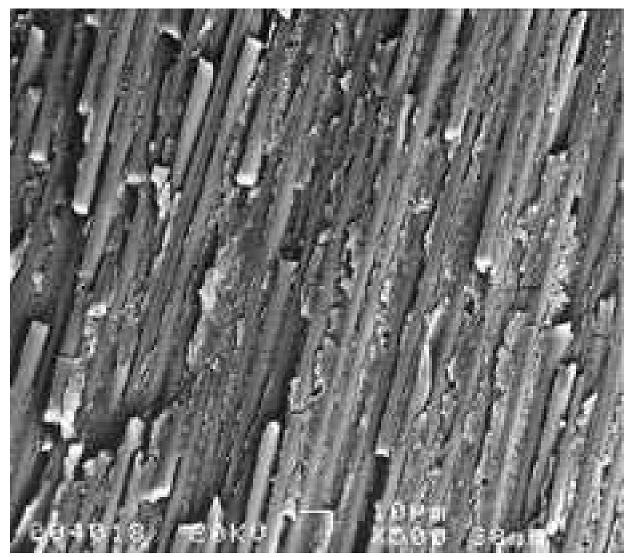


FIGURE 3 – Resin cores retention to carbon posts: mean values in Groups A, B, C, D and E.









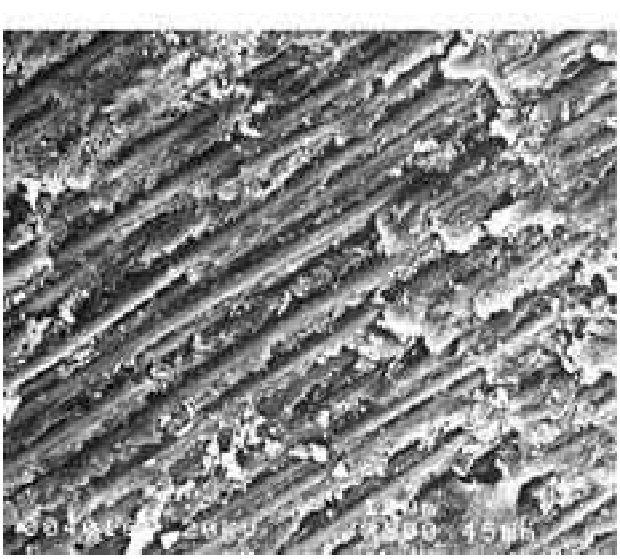


FIGURE 4 - Microscopic aspect of specimens after tension load of Groups **A** (a), **B** (b), **C** (c), **D** (d) and **E** (e), respectively. (S.E.M., 500X).

Discussion

Metal-free restorations are an aim in today's Dentistry, because of esthetics and absence of corrosion products (Deutsch et al.[6]1983, Plasmans et al.[21]1988, Schetritt & Steffensen[25]1995, Purton & Love[22]1996). Development of new generations of metal-free restorative materials has lead to rethinking guidelines for intra-radicular restorative materials.

Regardless of the presence of a luting agent, avoidance of different metal alloys for posts and crowns is recommended by Deutsch et al.[6]1983. Hornbrook & Hastings[11]1995 pointed out that use of cast posts and amalgam cores can be apparent through root surface, indicating for better aesthetic results tooth-colored cores. Chemical stability presented by carbon-fiber posts is their most advantageous characteristic when compared to metallic posts.

Carbon-fiber posts were introduced in order to benefit from their mechanical properties. Most important properties are: *modulus* of elasticity that is closer to dentin than metal (Duret et al.[7]1990) and elevated fatigue resistance (Freedman[9]). Maybe these properties are responsible for more retrievable fractures in these teeth when compared to pre-fabricated posts and cast posts in other studies (Plasmans et al.[21]1988, King & Setchell[14]1990, Torbjörner et al.[30]1995, Isidor et al.[13]1996, Sidoli et al.[26]1997). Metallic posts have a *modulus* of elasticity that can be ten times larger than dentin (Freedman[9]1996), resulting in greater tension to root structure (Caputo & Standlee[3]1987, Duret et al.[8]1990, Yaman & Thorsteinsson[32]1992). There is still a difference when comparing cast posts to post and core: according to Yaman & Thorsteinsson[32]1992, cast posts cause greater tension in the apical portion, whereas posts and cores, in the cervical region. Perhaps findings of these authors can justify greater number of failures with posts and cores in periodontally compromised teeth.

Fatigue is a disadvantage in metallic posts when compared to carbon-fiber posts; high percentage of fibers probably led to incomplete fractures in carbon-fiber posts (King & Setchell[14]1990).

As stated by Love & Purton[17]1996, plain carbon posts are mechanically superior to serrated ones, because of greater rigidity. In spite of that, smaller adhesion to core compromises tooth retention and resistance form to retain a crown. Results of this study concluded that macroscopic retention encountered in Groups **C**, **D** and **E** are favorable to core retention, corroborating other studies (Chang & Millstein[4]1993, Manning et al.[18]1995, Love & Purton[17]1996, Purton & Payne[23]1996). Alterations in Groups **C** and **D** transformed plain carbon posts into a good clinical alternative to serrated posts because they kept rigidity of plain posts, adding some retention to coronal end. Comparing results by Love & Purton[17] to results of this study, same kind of failure in Groups **C**, **D** and **E** was found, i.e. core fracture in all samples, which suggests tension induced in core material depending on head shape. Group **D** alteration is inconvenient for clinical purposes, but it is important as a suggestion to fabricate post plain in root portion and enhance coronal retention by changing coronal shape.

The use of composite resins as core materials is more popular nowadays because they are easy to handle and can be immediately prepared. Possible effect of thermal stress on composite resins must be analyzed cautiously. Linde[16]1983 made a very interesting observation concerning effect of thermal stress on a composite resin: considering a class V restoration, there is a thermal stress caused by direct influence of temperature on composite resin; under a crown, however, thermal changes are less direct and dependent on type of crown material and luting agent.

Failures related to use of composite resins as core materials are mainly related to their low *modulus* of elasticity (Wagnild & Muller[31]1997). Kovarik et al.[15]1992 pointed out that failures with composite resin cores occur at interface, stressing importance of a good interface; good quality interface should be expected with chemical/mechanical adhesion.

Many factors can contribute to integrity of post and core material interface. Chang & Millstein[4]1993 considered post and core less reliable when compared to cast posts because of great number of interfaces. These authors also stated that head form in post and core reconstruction is very important. Observing samples under S.E.M., we have noticed that there was greater amount of core material on surface of Groups **A** and **B**, with no macroscopic retentions; on the contrary, Groups **C**, **D** and **E** had greater retention values for tension load but less amount of composite resin on these surfaces when compared to Groups **A** and **B**.

Duret et al.[8]1990 stated that there is tension as a result of different *modulus* of elasticity between post and core material. Chemical compatibility of resin core and epoxy matrix in carbon posts would lead to better interface. However, Purton & Love[22]1996 state that thermal treatment during post's fabrication decreases amount of free epoxy resin to chemical linkage with Bis-GMA resins, interfering in this interface. Further studies should be developed for a better understanding of the relationship between resin core materials and new types of posts, in order to get better results in these interfaces.

From clinical standpoint, non-catastrophic failures (100% in Group **B** and 20% in Group **A**) represent not only failure of restoration but also great damage to tooth because of time interval between post failure and its detection, allowing microleakage and root caries development. Failures in Groups **C**, **D** and **E**, called catastrophic according to Huysmans et al.[12]1993, clinically represent failure of restoration and demand an immediate substitution of restoration.

Conclusions

Authors concluded that, under S.E.M. evaluation, groups without macroscopic retention (**A** and **B**) presented greater surface of core resin adhering to carbon post when compared to groups with macroscopic retention (**C**, **D** and **E**).

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