Fatigue resistance of bovine teeth restored with resin-bonded fiber posts: Effect of post surface conditioning

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This study evaluated the effect of post surface conditioning on the fatigue resistance of bovine teeth restored with resin-bonded fiber-reinforced composite (FRC). Root canals of 20 single-rooted bovine teeth (16 mm long) were prepared to 12 mm using a preparation drill of a double-tapered fiber post system. Using acrylic resin, each specimen was embedded (up to 3.0 mm from the cervical part of the specimen) in a PVC cylinder and allocated into one of two groups ($n = 10$) based on the post surface conditioning method: acid etching plus silanization or tribochemical silica coating (30 μm SiO_x + silanization). The root canal dentin was etched (H_2PO_3 for 30 seconds), rinsed, and dried. A multi-step adhesive system was applied to the root dentin and the fiber posts were cemented with resin cement. The specimens were submitted to one million fatigue cycles. After fatigue testing, a score was given based on the number of fatigue cycles until fracture.

All of the specimens were resistant to fatigue. No fracture of the root or the post and no loss of retention of the post were observed. The methodology and the results of this study indicate that tribochemical silica coating and acid etching performed equally well when dynamic mechanical loading was used.

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Although teeth restored with carbon, glass, and quartz fiber-reinforced composite (FRC) resin posts have produced good results (with a 95–97% success rate), some failures were noticed, including debonding of the cement-FRC-core set (loss of retention) and debonding of the composite core from the fiber post.[1,2]

For cementation, the manufacturers of the FRC recommend etching it with phosphoric acid; however, other post surface conditioning methods have been proposed for improving the resin bond to the FRC surface.[3,4] Compared to acid-etching, the tribochemical silica coating method appears to increase the resin bond to FRC significantly.[4] The abrasion pressure embeds the silica oxide-coated alumina particles on ceramic, polymer, and metal surfaces.[5] As a result, silane coupling agents (3-methacryloxyprophyltrimethoxy silane) make the silica-modified surface more chemically reactive to the resin.

Silane molecules react with water to form three silanol groups (–Si–OH) from the corresponding methoxy groups (–Si–O–CH_3).[6,7] The silanol groups react further to form a siloxane network (–Si–O–Si–O–) with the silica surface. The monomeric ends of the silane molecules react with the methacrylate groups of the adhesive resins through a free radical polymerization process.[6,7] However, those bond strength results were obtained from static bond strength tests, which do not simulate the oral condition the way mechanical fatigue tests do.[4,8,9]

Fatigue tests approximate the clinical performance of restorative techniques. *Fatigue* means that a structure may fracture after a repeated load due to the spread of microscopic cracks from areas of force concentration, usually from macroscopic or molecular structural defects.[9] Normally, fatigue tests are conducted in a humid environment, contributing to degradation of the physical and mechanical properties of the restoration materials.[8,10-17] In a 2002 study, Pontius and Hutter stated that 1,200,000 cycles in a mechanical fatigue test correspond to approximately five years of clinical function.[18]

This study sought to assess the effect of post surface conditioning on the fatigue resistance of bovine teeth restored with an adhesively luted FRC. It was hypothesized that the tribochemical silica coating could allow for fewer failures and higher fatigue resistance than acid etching.

Materials and methods

The coronal and cervical portions of 20 single-rooted bovine teeth (all mandibular incisors) were sectioned and the specimens were standardized at 16 mm. Thereafter, the coronal diameters of the canals were measured with a digital caliper (Starrett 727, Starrett, Athol, MA; 978.249.3551). Specimens whose diameters were larger than the diameter of the post (1.8 mm) were discarded and replaced with other specimens. The canals were instrumented sequentially and irrigated with 0.5% sodium hypochlorite.

Root canals were prepared with the preparation bur of a tapered glass FRC post system (Premier Anatomic IP-110-VR, Innotech Dental Innovation Technology, Robbio, Italy; 0384.673234) in which each post was 20 mm high and double-tapered with a mean diameter of 1.1 mm. The glass FRC posts were positioned in the root canal and the post coronal portion was cut to a standardized height of 6.0 mm.

After preparation, each root was embedded in a plastic cylinder (25 mm high and 12 mm in diameter) and filled with a chemically cured acrylic resin (Dencrilay, Dencril, Caieiras, SP, Brazil; 55.11.4441.8238). The preparation bur of the post system was placed inside the prepared root canal; at that point, the bur (with the root) was attached to an adapted surveyor, with the long axes of the bur, specimen, and cylinder parallel to each other and perpendicular to the ground. Acrylic resin was prepared and poured inside the cylinder up to 3.0 mm of the most coronal portion of the specimen.

After preparation, the specimens were allocated to two groups (n = 10), depending on the post surface conditioning method. The teeth in Group 1 were acid-etched; the FRC was treated with 32% phosphoric acid for 60 seconds (Uni-Etch, Bisco, Schaumburg, IL; 800.247.3368), washed, and dried. The teeth in Group 2 received chairside tribochemical silica coating; the FRC was air-abraded using 30 µm Al_2O_3 particles modified with silicon oxide (CoJet-Sand, 3M ESPE, St. Paul, MN; 888.364.3577). This blasting protocol utilized 2.8 bars of pressure for 20 seconds at a distance of 10 mm; the post was rotated manually during air abrasion. For both conditioning methods, the silane coupling agent (Espe-Sil, 3M ESPE) was applied to each post and allowed to dry for five minutes.

Two procedures were performed on each post cementation. First, each cementation received dentin treatment with a multiple-bottle, total-etch adhesive (ScotchBond Multi Purpose Plus; 3M ESPE). The root and coronal dentin were etched with 37% phosphoric acid for 15 seconds and washed with 10 mL of water using a disposable syringe. The excess water was removed with No. 80 paper points and the adhesive was applied using microbrushes (Cavi-Tip, Directa AB, Upplands Vasby, Sweden; 46.8.506.505.75).

In addition, each post cementation was treated with a dual resin cement (Rely-X, 3M ESPE). The A and B pastes of the cement were measured and mixed. The cement and post were carried to the root canal with a Lentulo No. 40 spiral (Maillefer). Finally, the area was photocured through the incisal surface for 40 seconds (XL 3000 unit, 3M ESPE) at a light intensity of 450 mW/cm^2.

After cementation, the core was prepared with a hybrid composite resin (W3D Master, Wilcos, Petropolis, Brazil; 24.2237.3000), using plastic matrixes at standardized dimensions. The composite was packed inside the matrix, which was positioned on the post and the top surface of the tooth. Photocuring was performed through the vestibular, lingual, medial, and distal surfaces for 20 seconds.

The specimens were stored in water for seven days at 37°C.

Fatigue test

The specimens were placed in a metallic base at a 45 degree angle so that a point from the cycling machine with a 1.6 mm diameter tip could induce load pulses of 50 N at a frequency of 8.0 Hz. During cycling, the specimens were irrigated with water at 37 ± 1.0°C (Fig. 1).[8] Specimens were not submitted to more than 1 million cycles, simulating approximately five years of clinical use.[8,9]

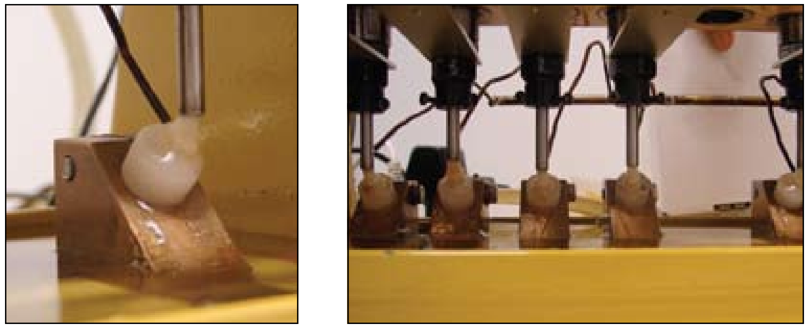

Fig. 1. *Left:* A specimen placed in the fatigue tester at a 45 degree angle for cycling. *Right:* A fatigue tester with the five stations for cycling.

Table. Fatigue resistance scores.

Score	No. of cycles before fracture
0	0–249,999
1	250,000–499,999
2	500,000–749,999
3	750,000–1,000,000
4	No root, post, or core fracture and no loss of retention of the post after one million cycles

Fatigue resistance scores and statistic analysis

After fatigue testing, a score was given based on the number of fatigue cycles administered before the specimen fractured (see the table). The collected data were submitted to statistical analysis (Kruskal-Wallis test) using a level of significance of 5.0%.

Results

All of the specimens were resistant to fatigue. No fracture of the root, post, or core and no loss of retention of the post were observed; both groups had a score of 4. The hypothesis was rejected, since both post surface conditioning methods allowed similar fatigue resistance.

Discussion

In the present study, no catastrophic failure occurred during fatigue testing. This is consistent with the results obtained by other investigations that studied mechanical cycling of endodontically treated teeth restored with a fiber post by applying loads of 40–250 N.[10-17]

A 2006 study used static testing (that is, microtensile bond strength) and noted that conditioning fiber posts with tribochemical silica coating improved the resin bond to fiber posts.[4] Conversely, the current study used dynamic mechanical cycling and reported no difference between the chairside tribochemical silica coating method and etching with phosphoric acid (per manufacturer's instruction), as all of the specimens survived the fatigue testing. Even though the results from the present investigation did not note differences between the two post surface conditioning methods, the prospective clinical studies noticed debonding of the composite core from fiber posts.[1,2] Those clinical studies etched the fiber post surface with phosphoric acid.

Additional *in vitro* and *in vivo* studies should be conducted to evaluate other fiber post conditioning methods to improve the bond between core composites and fiber posts, reducing debonding of the composite core-fiber post interface.

In the present study, the fatigue test (1 million cycles) was performed over the course of several days to simulate approximately five years of clinical function.[10,11,18] However, even though no macroscopically visible failure was observed during fatigue testing, it is important to clarify that marginal leakage may occur at an interface in an actual clinical situation. This microleakage could lead to degradation of the cement or adhesive interface and caries, neither of which were considered in the present study.[19]

In 2006, Baldissara *et al* commented that specimens restored with a fiber post may resist fatigue; however, different degrees of leakage may occur at the dentin-composite resin interface, especially at the lingual (as opposed to the buccal) aspect of teeth.[10,20] This leakage is due to the tensile stresses yielded during the test. The authors also mentioned that, despite the fatigue resistance, there might be failures at the interface that are not immediately visible.[10,20] The fatigue resistance or bond strength test in isolation should not be considered a parameter for the success of this technique. Other tests, including microleakage tests and microscopic evaluation of the interface integrity, should be conducted to complement the results observed in a fatigue study.

Conclusion

Considering the methodology and the findings of this study, the tribochemical silica coating and acid etching presented the same performance, using dynamic mechanical loading.

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References

1. Glazer B. Restoration of endodontically treated teeth with carbon fiber posts. J Can Dent Assoc 2000;66:613-618.
2. Malferrari S, Monaco C, Scotti R. Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. Int J Prosthodont 2003;16:39-44.
3. Sahafi A, Peutzfeldt A, Asmussen E, Gotfredsen K. Bond strength of resin cement to dentin and to surface-treated posts of titanium alloy, glass fiber, and zirconia. J Adhes Dent 2003;5:153-162.
4. Valandro LF, Yoshiga S, de Melo RM, Galhano GA, Mallmann A, Marinho CP, Bottino MA. Microtensile bond strength between a quartz fiber post and a resin cement: Effect of post surface conditioning. J Adhes Dent 2006;8:105-111.
5. Sun R, Suansuwan N, Kilpatrick N, Swain M. Characterisation of tribochemically assisted bonding of composite resin to porcelain and metal. J Dent 2000;28:441-445.
6. Ozcan M, Vallittu PK. Effect of surface conditioning methods on the bond strength of luting cement to ceramics. Dent Mater 2003;19:725-731.
7. Ozcan M, Matinlinna JP, Vallittu PK, Huysmans MC. Effect of drying time of 3-methacryloxypropyltrimethoxysilane on the shear bond strength of a composite resin to silica-coated base/noble alloys. Dent Mater 2004;20:586-590.
8. Baldissara P. Mechanical properties and *in vitro* evaluation. *In:* Scotti R, Ferrari M. Fiber post: Characteristic and clinical application. Milan: Masson;2002:39-51.
9. Wiskott HW, Nicholls JI, Belser UC. Stress fatigue: Basic principles and prosthodontic implications. Int J Prosthodont 1995;8:105-116.
10. Baldissara P, Di Grazia V, Palano A, Ciocca L. Fatigue resistance of restored endodontically treated teeth: A multiparametric analysis. Int J Prosthodont 2006;19:25-27.
11. Baldissara P, Zicari F, Valandro LF, Scotti R. Effect of root canal treatments on quartz fiber posts bonding to root dentin. J Endod 2006;32:985-988.
12. Bolhuis P, de Gee A, Feilzer A. Influence of fatigue loading on four post-and-core systems in maxillary premolars. Quintessence Int 2005;35:657-667.
13. Bolhuis P, de Gee A, Feilzer A. The influence of fatigue loading on the quality of the cement layer and retention strength of carbon fiber post-resin composite core restorations. Oper Dent 2005;30:220-227.
14. Bottino MA, Baldissara P, Valandro LF, Galhano GAP, Scotti R. Bonding of zirconia- and fiber-posts bonded to human root dentin: Mechanical cycling effect. J Adhes Dent 2007 (in press).
15. Dietschi D, Romelli M, Goretti A. Adaptation of adhesive posts and cores to dentin after fatigue testing. Int J Prosthodont 1997;10:498-507.
16. Mannocci F, Ferrari M, Watson TF. Intermittent loading of teeth restored using quartz fiber, carbon-quartz fiber, and zirconium dioxide ceramic root canal posts. J Adhes Dent 1999;1:153-158.
17. Scotti R, Valandro LF, Galhano GA, Baldissara P, Bottino MA. Effect of post length on the fatigue resistance of bovine teeth restored with bonded fiber posts: A pilot study. Int J Prosthodont 2006;19:504-506.
18. Pontius O, Hutter JW. Survival rate and fracture strength of incisors restored with different post and core systems and endodontically treated incisors without coronoradicular reinforcement. J Endod 2002;28:710-715.
19. Mannocci F, Qualtrough AJ, Worthington HV, Watson TF, Pitt Ford TR. Randomized clinical comparison of endodontically treated teeth restored with amalgam or with fiber posts and resin composite: Five-year results. Oper Dent 2005;30:9-15.
20. Goto Y, Nicholls JI, Phillips KM, Junge T. Fatigue resistance of endodontically treated teeth restored with three dowel-and-core systems. J Prosthet Dent 2005;93:45-50.