Fracture resistance and SEM observations of Fibrefill

ANDREA GESI[1], CECILIA GORACCI[1], STEFANIA GEPPI[1], MARIA CRYSANTI CAGIDIACO[1], MARCO FERRARI[1]

Abstract

The goal of this study was to evaluate a new system (Fibrefill) indicated for filling root canal space and building up the root simultaneously. Fracture resistance tests and SEM evaluations were performed under laboratory conditions and conducted on three groups of samples:

- Group 1, the Control group, where the roots were filled only with a flowable composite (Tetric Flow, Ivoclar-Vivadent, Schaan, Liechtenstein)
- Group 2, where the samples were endodontically obturated and restored with the Fiber-Fill system (Jeneric/Pentron, Wallingsford, CT, USA), using an obturator with a gutta-percha tip of 5 mm
- Group 3 where the ParaPost XH system was used (Còltene/Whaledent Int., Mahwah, NJ, USA).

A section of the samples from each group was used for SEM evaluations. Resin tags and hybrid layer formation were evaluated and the apical seal of root canal was observed. Statistical analysis revealed that the fracture strength of the FiberFill group was significantly higher than that of the control group ($p<0.05$) and that there was no statistically significant difference in the average load at failure between FiberFill and the Parapost group ($p>0.05$). SEM observations showed resin tags and hybrid layer formation along the root dentinal walls and a proper apical seal of the root canal. Clinicals trial are necessary for confirming the positive findings of this study conducted under laboratory conditions.

Clinical Significance

The Fibrefill system can bhe useful in several clinical several situations, reducing working chair-time and simplifying build-up procedures.

Key words: fiber posts, fracture resistance, root canal, luting, adhesive

Endodontically treated teeth often require a post and core restoration. The ideal post should impart minimal stress to the tooth, provide adequate retention to the core and be easily removable to permit endodontic retreatment[1-14]. Different types of posts have been introduced on the market in order to fulfill these requirements[2-9]. They are luted with a bonding technique, are passive and their modulus of elasticity is similar to that of dentin, minimizing the risk of root fracture. Current endodontic research tends towards the ideal solution of having not only gutta-percha cones, whose taper corresponds to the canal instruments used for shaping, but also fiber posts with a matching taper. This way the endodontist can easily choose the standardized gutta-percha cone and post after shaping, and use them simultaneously for endodontic filling and the coronal filling support. Interest is being shown in a new system for the obturation of the root canal space, FiberFill (Jeneric Pentron, Wallingsford, CT, USA)[2,4], which simplifies the sealing of a root canal both apically and coronally. The Fiberfill system consists of an adhesive bonding agent, a light-curable CaOH-based resin sealer liquid that allows the sealer to chemically bond to the canal dentine, and a fibre post with an apical terminus of gutta percha. A primer included in the system is a self-etching, two-bottle, self-curing adhesive. The Fiberfill root canal sealer (RCS) is a radiopaque, dual-cure resin sealer which contains UDMA, PEGDMA, HDDMA, and Bis-GMA resins with silane-treated barium borosilicate glasses, barium sulphate, calcium hydroxide and initiators. The Fiberfill obturator is a resin and glass-fibre post with a terminal gutta-percha tip. The gutta percha is available in either 5mm or 8mm lengths. The post is available in sizes 30, 40, 50, 60, 70 and 80 diameter.[2]

[1]Department of Restorative, Dental Material and Prosthodontics University of Siena - ITALY

Corresponding address:
Prof Marco Ferrari
Policlinico Le Scotte, Viale Bracci, Siena 53100
email: ferrarimar@unisi.it

The aim of this study is

- to measure the fracture strength under a static load and determine the mode of failure of endodontically treated roots filled with either gutta-percha or the FiberFill system
- to evaluate whether the new endodontic system can create resin tag, adhesive lateral branch and resin dentin

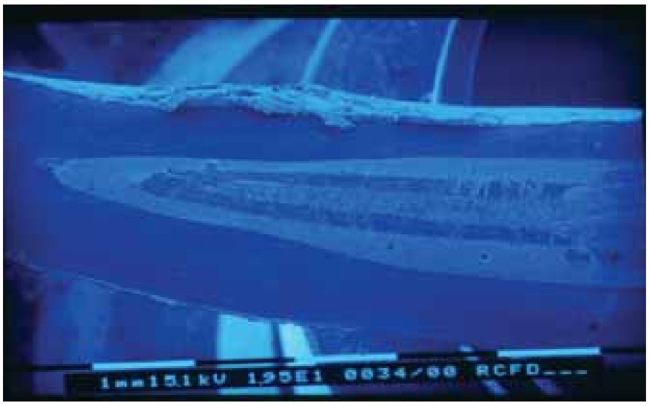


Figure 1: SEM image showing the apical part of the Fibrefill post after being luted into the root canal. It is possible to detect clearly the internal most apical part of the post surrounded by gutta-percha that is in contact with the luting material (SEM x20).

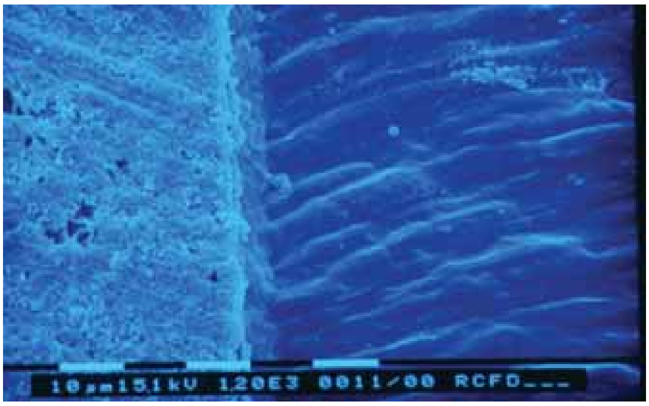


Figure 2: SEM images showing RDIZ formation along the root canal wall (coronal 1/3) (SEM x1200).

interdiffusion zone (RDIZ) formation under clinical conditions.

The tested null hypothesis was that the placement of a FiberFill post does not result in any significant increase in the fracture strength of endodontically treated roots and in any resin tag, adhesive lateral branch and resin dentin interdiffusion zone (RDIZ) formation.

Material and Methods

Forty single-rooted human teeth of similar dimension were selected and stored in saline solution at 37°C. They were cut coronally with a diamond bur 1mm above the cemento-enamel junction. A working length to the terminus of the root canal was established in direct vision and the root canals were instrumented using a stainless steel instrument K-File and rotary Ni-Ti Profiles (Maillefer, Switzerland). The root canals were then irrigated alternatively with 3% sodium hypochlorite and 17% EDTA solutions and the canal walls dried with paper points.

Fracture strength test

At this point 30 specimens were divided into three groups of 10 teeth each. The teeth of group 1 and 3 were endodontically obturated with gutta-percha (Hygienic, Coltène/Whaledent Inc., Mahwah, NJ, USA) and AH Plus endodontic sealer (Dentsply Maillefer, Switzerland) using a System B device (Analytic Technology, San Diego, CA, USA) and Obtura II Syringe (Obtura Corp., Fenton, MO, USA) to perform a vertical condensation.

In group 1, which served as control, the roots were filled only with a flowable composite (Tetric Flow, Ivoclar-Vivadent, Schaan, Liechtenstein).

In group 2, the samples were endodontically obturated and restored with the Fiber-Fill system (Jeneric/Pentron, Wallingsford, CT, USA), using an obturator with a gutta-percha tip of 5mm.

In group 3, the ParaPost XH system was used (Còltene/Whaledent Int., Mahwah, NJ, USA).

The endodontic-restorative system in all the cases was used strictly following the manufacturer's instructions. After the cement had set completely, crown build up was performed with proprietary resin composites.

After storing the sample teeth for 24 hours in physiologic solution at 37°C, thirty specimens were divided into three groups of 10 teeth each for the evaluation of the loading test.

All the systems were used strictly following the manufacturer's instructions, and in all the cases at least 4mm of root canal filling was left apically. The roots were then prepared for the loading test as follows:

Each root was inserted in an acrylic resin block leaving at least 8mm of root protuding. After waiting an hour for the embedding resin to set completely, each specimen was placed into a universal testing machine (Controls, Milan, Italy) that applied a shearing load at 90° angle to the long axis of the root 2mm from the cemento-enamel junction at a crosshead speed of 0,5mm/minute. Specimens were loaded until fracture. The load at the failure was measured in Newtons by a connected computer. The location of the failure was also recorded. When the specimens exhibited a vertical or a oblique fracture, extending also to the surrounding acrylic resin block, the fracture was considered unfavorable and unrestorable. Root fractures located above the acrylic resin block were instead considered to be restorable.

The One-Way Analysis of Variance was applied to test the significance of the differences in fracture strength among the three tested groups. The Newman-Keuls test was used for multiple comparisons. The level of significance was set in advance at a 95% probability level.

Resin-Dentin Interdiffusion Zone formation

The remaining 10 samples were endodontically obturated and restored with the Fiber-Fill system, strictly following manufacturer's instructions, and then processed for SEM evaluation. The teeth were sectioned parallel to the long axis of the tooth using a diamond saw (Isomed, Buhler,Lake Bluff, NY,USA) at slow speed under water. One section of each root was gently decalcified (32% phosphoric acid was applied for 30 seconds and the sample was then washed and gently air-dried) and deproteinized (the sample was immersed in a 2% sodium hypochlorite solution for 120 seconds) in order to evaluate RDIZ formation.

After extensive rinsing with water, the specimens were gently air-dried, sputter-coated with gold (Edwards Ltd,London, UK) and observed with a scanning electron microscope (Philips 515, Philips CO., Amsterdam, The Netherlands) at different magnifications (Figure. 1).

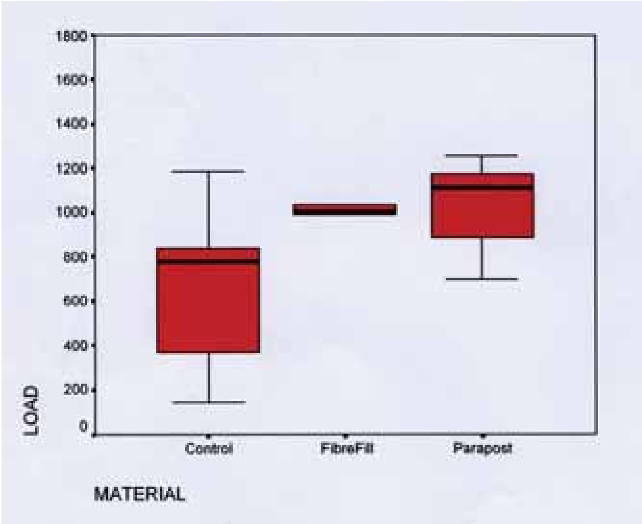
The formation and uniformity of the RDIZ along the entire length of the adhesive interface was evaluated by scanning electron microscope.

Resin Tag formation

The other section of each sample was stored in 30% HCl for 24 hours in order to dissolve the dental substrate completely and to detect resin tag and adhesive lateral branch formation. The samples were then processed for SEM observation as described above.

Serial SEM photomicrographs at x500 original magnification were taken of the canal walls at the 1, 5 and 8mm levels. The serial photomicrographs were aligned to form a continuous horizontal examination strip at the 3 levels. Irrespective of the number of photomicrographs needed to form a complete strip, each strip was subdivided into 8 "assessment units". The density and morphology of the resin tags were then assessed.

The density and morphology of resin tags present at x500 magnifications were graded between 0 and 3. A score of 0 was assigned where resin tags were not detectable. A score of 1 was recorded when few and short resin tags (resin plugs) were visible. A score of 2 was recorded where uniform resin tag formation without lateral branches was noted. A score of 3 was recorded when long resin tags with lateral branches were uniformly evident.



Result

Fracture strength

The results of the loading test are shown in Table I.

All fractures were located above the resin block margin, in the coronal level. Statistical analysis revealed that the fracture strength of the FiberFill group was significantly higher than that of the control group ($p<0.05$). On the other hand, there was no statistically significant difference in the average load at failure between FiberFill and the Parapost group ($p>0.05$).

Resin-Dentin Interdiffusion Zone observations

In all samples, RDIZ formation was evident along the interface between adhesive material and etched dentin. A good uniformity of the hybrid layer was observed (Figure. 2).

Resin Tag observation

The resin tags which formed in the coronal and middle areas of the roots exhibited the same morphology and similar length and did not show the characteristic inverse-cone shape (Figure. 3). The density of resin tags present in those two portion of the root canals and in all the samples was also similar (Score 3). In all samples, the area of resin tags reproducing demineralized

Table 1. Mean and standard deviation of the values of load at failure measured in Newtons for the three groups specimens. Groups statistically similar are marked by the same alphabetical letter.

	Mean	Standard Deviation
Group 1 - Control [a]	699.11	360.30
Group 2 - FiberFill [b]	1074.44	254.07
Group 3 - Parapost [a-b]	974.22	303.61

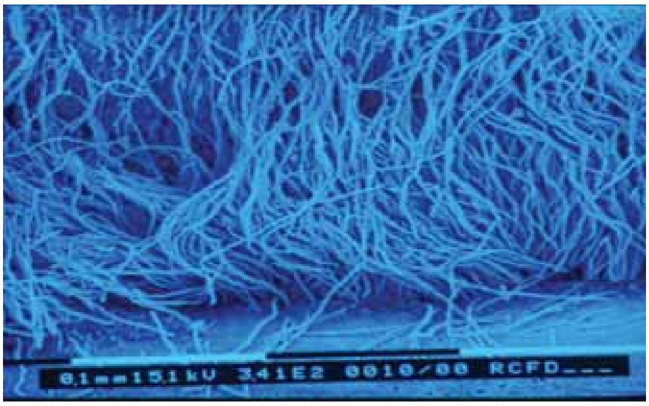


Figure 3: SEM image showing resin tag formation at the medium 1/3 (SEM x350).

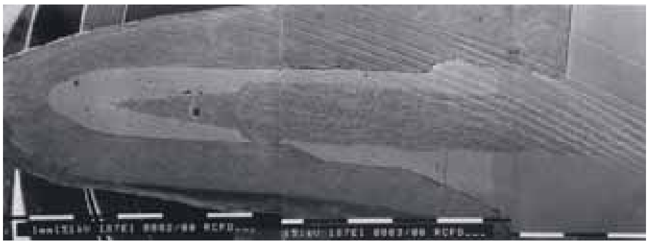


Figure 4a: SEM image showing a Fibrefill post luted into a root canal. The structure and shape of the post is clearly detectable (SEM x 15).

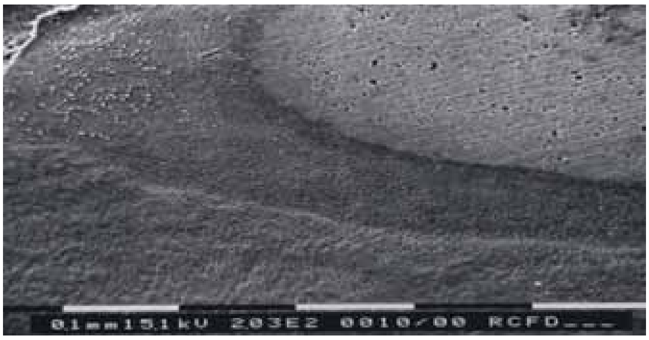


Figure 4b: SEM image showing a higher magnification of the apical part of root canal of Fig. 4A. The darker layer corresponds to the adhesive material used in combination with resin cement for luting the post (SEM x200).

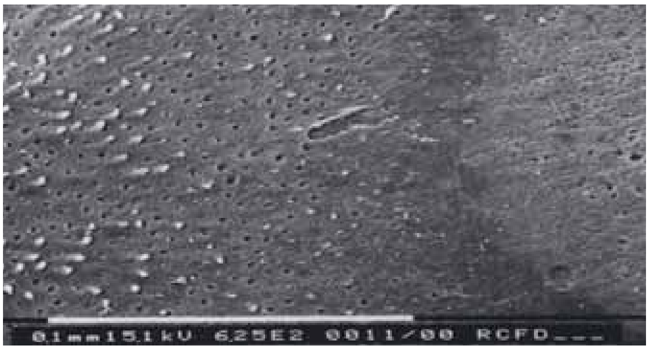


Figure 4c: SEM image showing a higher magnification of Fig. 4B. The seal of apical dentin made using the adhesive system can be noted (x625).

tubular dentin was rough and reflected the aspect of tubular dentin dissolved by the acid.

In the apical area all the samples showed a less evident resin tag formation (score 1-2). Anyway the apical seal obtained by the resin-cement and the gutta-percha showed a good adaptation and a proper closure of the apical part of the root canal (Figure. 4A-4C)

Discussion

Based on the loading test results, the null hypothesis that the use of the FiberFill system does not result in any significant increase in the fracture strength of endodontically treated roots has to be rejected. The results of the present investigation showed that the teeth restored using FiberFill system showed a statistically better resistance to fracture than the control group teeth. However the result also showed that the teeth restored with Fiberfill system have a similar fracture resistance to the teeth restored with Parapost. Result of previous studies demonstrated that the resistance of teeth restored with metallic posts and submitted to loading tests have a higher incidence of failure than the teeth restored with fiber posts [15]. This finding can be read like a similar behavior of the Fiberfill system to the metallic posts.

Interestingly, in all the samples of the present study, independently of the group to which they belonged, the recorded fractures were located above the acrylic resin block, involving the coronal portion of the teeth.

This kind of result is in contrast with the findings of previous studies where, in the presence of fiber posts, the root fracture is generally located more coronally and therefore more easily restorable[9-11]. The same finding was confirmed by Heydecke et al.[7] in a study where the resistance to the load of anterior teeth with class III cavities restored using zirconium posts, titanium posts, or just filling the coronal cavity with hybrid composite material, was compared using a chewing machine. The result obtained was that the presence of a rigid post, such as zirconium or titanium, causes radicular fractures which are difficult to treat. The teeth restored only with composite material instead showed only coronal fractures.

SEM observation allows for a high resolution assessment of the conditions of adhesion. The morphologic characteristics of adhesive interface, as revealed by scanning electron microscopy, can be evaluated through either a qualitative or a quantitative analysis. The latter is usually preferable, as it provides a repeatable method. For this reason, the present study followed a recently proposed quantitative analysis for the evaluation of cement thickness, as well as of the frequency of structural discontinuities in the adhesive interface, such bubbles, void or gaps.[13] This evaluation was performed because formation of both resin tags and RDIZ contribute to creating a proper mechanical bonding to etched dentin and consequently sealing it[18,19]. TEM examination and measurement of the bond strength are the best way to assess the quality of the resin-dentin interdiffusion zone[20,21]. However, even if the SEM evaluation of RDIZ is not the ideal method of measuring the quality of the adhesion, it gives quantitative information on its uniform formation.

The null hypothesis that the placement of a FiberFill post does not result in any resin tag, adhesive lateral branch and resin dentin interdiffusion zone (RDIZ) formation must also be discarded.

The adhesive system is able to remove the smear layer completely, as well as demineralize the dentine, thus exposing a fine network of collagen fibrils. The infiltration of this network with resins allows the formation of a RDIZ with resin tags and adhesive lateral branches. A thin microbrush was used with the Fiberfill system to introduce the adhesive solution into the root canal preparation and allow RDIZ and resin tags in the apical portion of the post space. This allowed the formation of RDIZ and resin tags, with a good distribution and diffusion along the post at every level. Not only was the existence of the resin tags less evident in the most apical portion, but it was also possible to find the formation of an effective micromechanical bonding mechanism. The importance of this kind of instrument to carry the adhesive into the root canal to the deeper portion has been stressed[12-14]. The microbrush is able to reach all the prepared root canal dentin, and apply a certain pressure on the adhesive solution, maximizing its penetration into the etched substrate. This results in a deep diffusion of resin into the tubules and in the formation of lateral branches[16-17].

The resin tag length is not particularly important from a clinical point of view, but demonstrates the efficacy of the dentinal adhesive system used and the validity of the method of its use inside of the root canal.

In the present study similar systems were not used to evaluate the relationship between resin and dentine, because good results were obtained in the direct observation of the samples without residual interference.

The SEM observation of the apical region of the root canal also reveals a good adaptation of the gutta-percha tip to the dentinal walls. This should be verified using a test capable of measuring the apical microleakage of the Fiberfill system compared with other more traditional root canal filling techniques.

References

1. Al-Wahadni A, Gutteridge DL An in vivo investigation into the effects of retained coronal dentine on the strength of a tooth restored with a cemented post and partial core restoration. Int.Endod.J. 2002;35:913-918.
2. Kurtzman GM, Jones OJ, Lopez L. Endodontic root reinforcement using a bonded, fiber-reinforced gutta-percha--tipped obturator. Pract Proced Aesthet Dent. 2004;16(2):147-51.
3. 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;10:710-715.
4. Trope M, Ray H Resistance to fracture of endodontically treated roots. Oral Surg. Oral Med. Oral Path. 1992;1:99-102.
5. Vichi A. Grandini S. Ferrari M. Clinical procedure for luting glass-fiber posts. J. Adhes. Dent. 2001;3:353-359.
6. Akkayan B, Gulmez T Resistance to fracture of endodontically treated teeth restored with different post system. J.Prosthet. Dent. 2002;87:431-437.
7. Heydecke G, Butz F, Hussein A, Strub JR Fracture strength and dynamic loading of endodontically treated teeth restored with different post and core systems. J.Prosthet. Dent. 2002;87:438-445.
8. Heydecke G, Butz F, Strub JR Fracture strength and survival rate of endodontically treated maxillary incisors with aproximal cavities after restoration with different post and core systems. J. of Dent. 2001;29:427-433.
9. Cormier CJ, Burns DR, Moon P In vitro comparison of the fracture resistance and failure mode of fiber , ceramic and conventional post systems at various stages of restoration. J. of Prosthodontics 2001;10:26-36.
10. Reagan SE, Fruits TJ, Van Brunt CL, Ward CK. Effects of cycling loading on selected post-and-core systems. Quintessence Int. 1999;30:61-67.
11. Ukon S, Moroi H, Okimoto K. Influence of different elastic moduli of dowel and core on stress distribution in root. Dent. Mater. 2000;19:50-64.
12. Ferrari M, Scotti R Fiber posts. Characteristics and clinical applications. Chapter V: 2003; Ed Masson, Milano, Italy
13. Ferrari M, Vichi A, Grandini S. Influence of adesive application technique on efficacy of bonding to root canal walls: a SEM investigation. Dent. Mater. 2001; 17: 422-9.
14. Vichi A, Grandini S, Ferrari M. Comparison between two clinical procedures for bonding fiber posts into a root canal: a microscopic investigation. J. Endodont. 2002;28:355-60.
15. Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 1984; 51:780-4.
16. Chappel RP, Cobb CM, Spencer P. Dentinal tubule anastomosis: a potential factor in adhesive bonding J. Prosthet. Dent. 1994;72:183,8.
17. Mjor IA, Nordhal I. The density and branching of dentinal tubules in human teeth. Arch. Oral Biol. 1996;41:401-2.
18. Nakabayashi N, Pashley DH Hybridization of dental hard tissue. Berlin: Quintessence Co. Publ., 1998.
19. Vichi A, Grandini S, Davidson CL, Ferrari M An SEM evaluation of several adhesive system used for bonding fiber posts under clinical conditions Dent. Mater. 2002; 18: 495-502.
20. Sano H, Takasu T, Ciucchi B, Horner JA, Matthews WG, Pashley DH. Nanoleakage: leakage within the hybrid layer. Oper. Dent.; 20:18-25.
21. Tay FR, Gwinett AJ, Pang KM, Wei SHY. Micromorphologic relationship of the resin dentin interface following a total-etch technique in vivo using a dentinal bonding system. Quint. Int. 1995;26:63-70.