

## Long-Life Physical Property Preservation and Postendodontic Rehabilitation With the Composipost™

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**M**ost coronal radicular reconstructions are carried out using cast inlay cores or a combination of metal posts and reconstruction composites (Figure 1). The major disadvantage of these techniques is that the stress is concentrated in uncontrolled areas that are sometimes vital to the root. These reconstructions have three major drawbacks:

1. The elements—dentine, post, composite, and the metal inlay core—all have very different and

### Abstract

Most coronal radicular reconstructions are made of cast inlay core metals or prefabricated posts covered in composite. The differences in the mechanical properties of these elements create a heterogeneous mass with inconsistent mechanical behavior. Studies using the Finite Element Method have shown the biomechanical disturbances caused by the inclusion of materials with a modulus of elasticity that is superior to that of dentine (ie, nickel, chrome, zircon, etc). The use of materials with a modulus of elasticity close to that of dentine does not disturb the flow of stress inside the root. To our knowledge, only a composite material structured with programmable mechanical properties would be capable of producing both high mechanical performance and a modulus of elasticity adapted to dentine values. The C-POST™, made of carbon epoxy, accommodates the demands of the dentine, as well as the in vitro stress linked to the prosthesis. The internal structure, consisting of long high-performance carbon fibers, unidirectionally and equally stretched, confers a totally original behavior that is adapted to clinical objectives. In addition, the C-POST™ has a fracture resistance superior to most metals.

### Learning Objectives

After reading this article the reader should be able to:

- explain the advantages of a post with a high modulus of elasticity.
- list the advantages of using the direct composite method.
- discuss the advantages and disadvantages of both metal and carbon-fiber posts.

incompatible mechanical properties.

2. Because of the nature of these elements, bonding is very difficult and remains, on the whole, heterogeneous.

3. In many cases, the method used involves a supplementary loss of dentine that cannot be ignored.

These drawbacks have caused us to reconsider the problem of



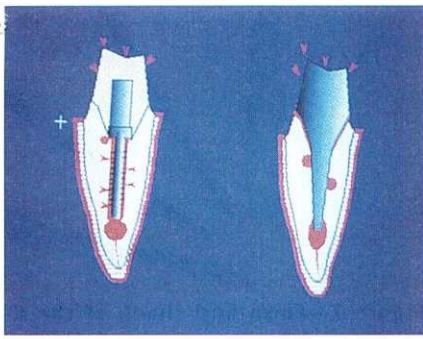


Figure 1—The most common metal, coronal, radicular reconstructions and their strength represented schematically.

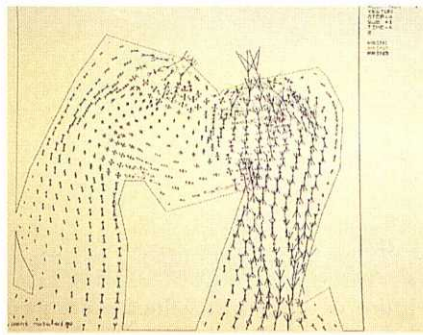


Figure 2—Results on a natural tooth.

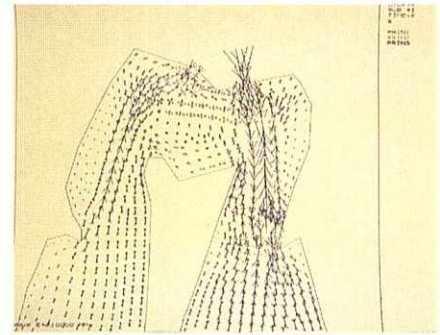


Figure 3—Crown with a high Modulus.

coronal radicular reconstructions. In the authors' opinion, it is not by improving an unadapted concept detail that a significant change would be observed. We think that the time has come to make a clean sweep of our methods, to gather our scientific knowledge, and to reconsider the question entirely.

Because of the extent of decay on a tooth, the crown obturation has to be anchored in the radicular part of the tooth.

Before going any further, we would like to ask the following question: With our knowledge of dental histology and of the biomechanics of dentine, would a clinician consider placing a metal pin or screw in the dental root to ensure a coronal obturation? No, of course not—it would be inappropriate.

This article addresses, in three parts, how it is possible to get around these obstacles. First, we will discuss the research of a new concept through two different experiments.

## First Experiment

Before choosing a material for clinical use, we consider it essential to study the strength to which the material is going to be exposed.

## Materials and Methods

The best method for evaluating the direction, nature, and intensity of stress is the Finite Element Method. This method consists of decomposing an object

into as many elementary volumes as possible. Each volume takes on the mechanical properties of the part in which it is situated. At this point, it is possible to apply a strength, the direction and intensity of which are known, to any part of the surface of this object, and study the behavior of each elementary volume.

Because a coronal radicular reconstruction is primarily intended to support a crown without affecting the underlying dentine, we will discuss the dentine in the following cases:

- under natural enamel;
- under a nickel/chrome crown with a high modulus of elasticity (210 GPa) (Dentalloy<sup>a</sup>); and
- under a crown (Vectris Targis System<sup>b</sup>) with a low modulus of elasticity (18 GPa).

This will allow us to address the real-life stresses that dentine has to bear.

## Results

Suppose that a strength of 50 N is applied using a 4-mm-diameter sphere on the occlusal surface of a bicuspid (eg, upper premolar).

In natural teeth (Figure 2), we noted that according to the direction of the strength, it is dispersed in the dentine after having traversed the enamel. The stress is pressurized under the point of application strength. By examining the other areas of dentine, important tensile strength appears to be

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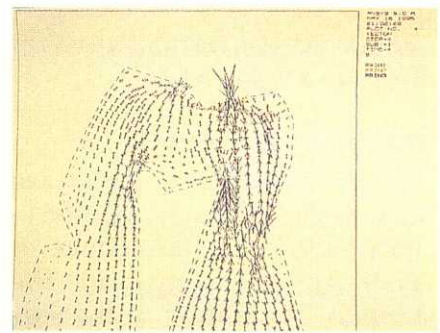


Figure 4—Crown with a low Modulus.

near the principal compressive strength. The direction, however, is perpendicular to the axis.

Under the metal crown, with a modulus of elasticity equal to 210 GPa (Figure 3), we noticed that the compressive strength disappears in the area where it was observed in the natural tooth. The stress is absorbed by the metal volume of the crown and retransmitted into the radicular dentine at the junction between the coronal dentine and the metal crown. Compressive and tensile strength are associated on the occlusal surface of the metal crown.

If, on the other hand, we place a crown with a weak modulus of elasticity, such as 18 GPa (Figure 4), we noticed that the strength traverses the crown more easily than it does enamel but that the strength chart is much closer to that of a natural tooth than that of a metal crown. Therefore, the presence of a metallic body radically changes the direction of the strength, concentrating it in a chaotic way in the underlying



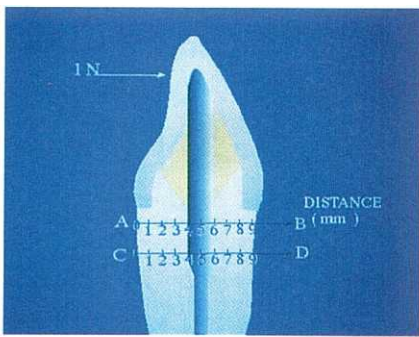


Figure 5—Cross-section of the preparation studied by using the Finite Element Method. The strength was measured between AB and CD.

dentine. Moreover, the strength diffusion is anisotropic.

## Second Experiment

In the second experiment, we used the Finite Element Method to study the effect of the modulus of elasticity of the post on the strength transmitted to the surrounding dentine in all directions.

## Materials and Methods

Three posts of identical shape are implanted in an upper central incisor. The modulus of elasticity is 210 GPa for the nickel/chrome, 110 GPa for the titanium, and 8 GPa for the carbon epoxy (applied at a 90-degree angle). We applied 1 N strength (Figure 5) on the incisive edge of the tooth, perpendicular to the axis of the tooth and the post. The strength value is noted over two distances, AB and CD, perpendicular to the axis of the tooth.

## Results

The stress is at its highest on the cervical area. The strength values were almost identical for the three posts in the surrounding dentine areas farthest from the post.

In the areas near the post, the strength varied significantly. The post with the highest modulus of elasticity has the largest differences in strength. Moreover, it is at the dentine-post interface that the strength differential is at its greatest (Figure 6).

These results show that a post

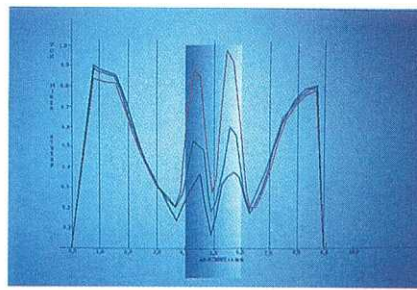


Figure 6—Strength values measured along the cervical/palatovestibular distance with a strength of 1 N applied to the free edge of the crown and perpendicular to the post.

with a high modulus of elasticity affects the dentine considerably more than a post with a modulus closer to that of a radicular modulus. Of course, the strength differential, which is situated at the dentine-post interface, shows that in a case where the modulus is identical to dentine, the bond junction is not affected as much as if the modulus was very different. On the distance between CD, these strength values are weaker, but their dispersion remains identical to the distance between AB.

These two experiments have brought us to three major conclusions. We now know that a similarity must exist between the mechanical properties of a coronal radicular reconstruction and that of the residual dentine, especially as far as the modulus of elasticity is concerned. The whole of the reconstruction, after bonding, must behave in the same manner.

The above-mentioned conclusions are:

- Any material used for restoration required because of the loss of substance should have mechanical properties and a modulus of elasticity as similar to dentine as possible.
- The conservation of dentine should be of the utmost importance.
- The bond between the system's three elements—the tooth, restoration material, and the post—should be solid and long-lasting. No known material

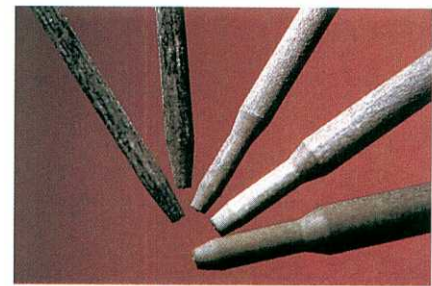


Figure 7—Form and shank of the C-POST™ and the Endo•Composipost™.

alone can ensure such a complex requirement. Because of this, a new material had to be conceived, and the only type we believed capable of solving the problem was a compound. The compound material must consist of at least two substances—a reinforcement substance and a matrix. The reinforcement substance is made of long, aligned, high-performance fibers, and the two components are linked together by a very strong interface, so that the strength applied on one component is entirely transmitted to the other and vice versa.

Previous experiments show that the coronal radicular reconstruction materials must have a modulus of elasticity as near to dentine as possible. Under these conditions, only solid and long-lasting liaisons can be made between the two elements, the coronal radicular reconstruction and the tooth.

After lengthy research on compound material, we chose a carbon-epoxy combination. We are now able to provide an adjoining reconstruction material and liaison elements that meet the criteria necessary for long-life restorations: the Composipost™.

## The C-Post™

We used three elements to carry out homogeneous coronal radicular reconstruction: a post, a

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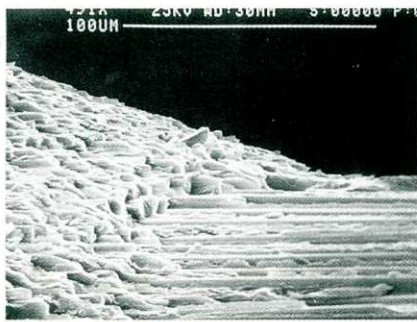


Figure 8—Surface of the C-POST™ on the upper shank.

reconstruction composite, and an interface made of microloaded bonding resin.

### Chemical Composition and Structure

The constituting material is a carbon-epoxy composite; its reinforcement is made of long carbon unidirectional, high-performance fibers, which are equally stretched according to the axis of the post. The fibers represent 64% of the structural volume, and the matrix, which binds the fibers together, is an epoxy resin.

### Form and Design

The post is cylindrically shaped and has a two-stepped shank section of different diameters tapered into a conically shaped seating face for stabilization (Figure 8).

### The Surface

After manufacture, the post is a 3-mm-diameter cylindrical pole. The final stepped shank shape is obtained through specific milling, which leaves a rough surface particularly well adapted for bonding.

### Mechanical Properties

The Composipost™ has the following mechanical properties:

- compression 440 MPa
- shearing 170 MPa
- tension 1,600 MPa
- modulus of elasticity: variable between 110 GPa and 8 GPa, according to the angle of the fibers.

In the case of a 90-degree incidence angle with the axis of the

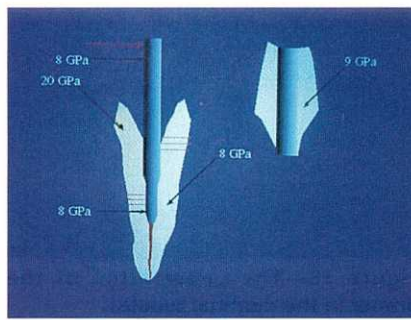


Figure 9—A 90-degree incidence angle, 8 GPa; E = 8 GPa.

post, the modulus of elasticity will be 8 GPa, which is identical to the radicular dentine (Figure 9).

In the case of an incidence angle between 20 degrees and 45 degrees with the fiber axis, the modulus of elasticity will be between 18 GPa and 30 GPa, and the strength will be transmitted into a deep area at an angle between 90 degrees and 70 degrees with the fiber axis with, therefore, a modulus very close to the radicular dentine (Figure 10).

In the case of an incidence angle of 0 degrees, the conically shaped stepped shanks can carry out their most important function, mechanical compensation for the lack of a modulus of elasticity, which, in this case, is between 100 GPa and 110 GPa (Figure 11).

Finally, the post is radiolucent, which, in our opinion, is not a disadvantage. However, for legal purposes, a radiopaque post exists.

### The Reconstruction Composite

The structure of the root canal presents considerable individual variations. Therefore, a plastic material compatible with the carbon-epoxy material of the post is essential. The function of this material is to fill and act as a bond between the dentine and the post.

The ideal modulus of elasticity is approximately 20 GPa to 22 GPa, according to the position in the coronal part. An average value of 20 GPa seems very suitable. We

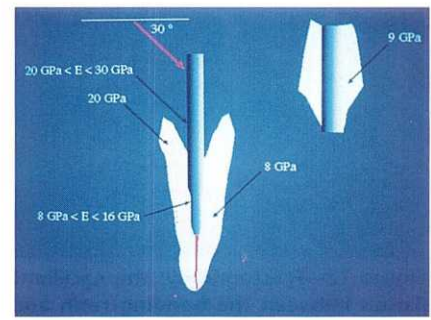


Figure 10—Between 20-degree and 45-degree incidence angles; 18 GPa < E < 30 GPa.

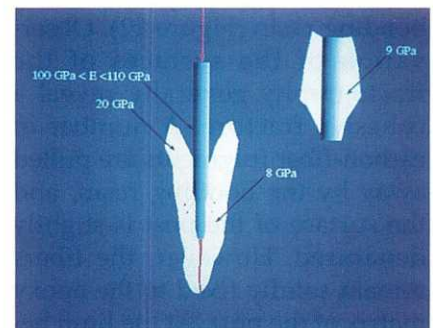


Figure 11—A 0-degree incidence angle, 110 GPa; E = 110 GPa.

do not recommend a particular reconstruction material; however, it must be compatible with the epoxy resin of the matrix of the post and adapted to the latest generation of dental bonding. We chose a range of the BISCO products, properties of which were particularly well adapted to our concept (ALL-BOND 2™,c, DUO-LINK™,c, and BIS-CORE™).

### The Interfaces

The quality of the interface between the elements of the coronal reconstruction composite ensures the homogeneity and the life span of the work.

Four interfaces *must* be considered:

- post-to-bonding resin;
- bonding resin-to-dentine;
- dentine-to-composite;
- composite-to-post.

### Post-to-Bonding Resin Interface

In addition to the mechanical test, the fractography provides information on the quality of the



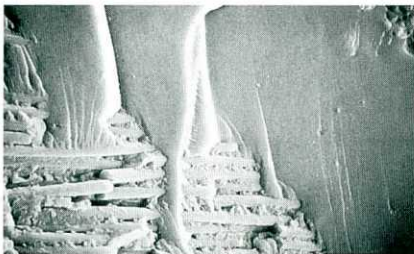


Figure 12—Fractography: the excellent liaison between the bonding resin and the carbon fibers of the C-Post™ are clearly visible.

bond between the post and the bonding resin (Figure 12). Observation of the surfaces of the fractography generally reveal a cohesive fracture. A number of carbon-fiber fragments are pulled away by the bonding resin, and the surface of the post is slightly denatured. However, the fibers remain solidly fixed to the epoxy matrix of the post. At the limit between the bond resin and the post, we note the excellent bonding of the adhesive on the carbon fibers as well as on the epoxy matrix. This property was verified during our mechanical extracting tests. None of the posts removed demonstrated a lack or loss of their bonding resin layer.

### Bonding Resin-to-Dentine Interface

This bond is the most delicate because it links two bodies of a different chemical nature. The dentine is mechanically cleared of all obturation material remains (cement, etc). The surface is treated by etching (EDTA 17% Dentine Etching<sup>d</sup>) and then cleaned with hypochlorite<sup>d</sup> (5.25%).

The dental tubules are penetrated using a primer and then an autophotopolymerized bonding material (Figure 13). The micro-loaded bonding resin fills and unites the prepared surface of the dentine either to the post impregnated with primer or to the reconstruction composite. The interface presents no break (Figure 14).

<sup>d</sup>Ivoclar, Schaan, Liechtenstein

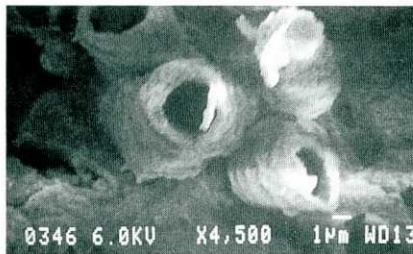


Figure 13—The penetration of the primer in the dentinal tubules.

### Dentine-to-Reconstruction Composite Interface

This is carried out in the same manner as the above.

### Composite-to-Post Interface

The mechanical values of this interface are greater than those of the composite. This is a result of the chemical compatibility between the resin matrix and the effects of the microclavage caused by the state of the surface of the post.

### Inlay Core Composite Using the Direct Method

To avoid the risk of polymerization contraction in the case of advanced radicular decay, it is advised to follow the direct method for an inlay core composite and then to bond as usual. An inlay core composite resulting from this method is depicted in Figure 15.

First, the endodontic cavity is cleaned out and tapered, followed by specific drilling. After simple root cleaning with an air/water spray, a post that has been cut to the right height is positioned in the radicular cavity. The emerging part of the post is coated with primer and an autophotopolymerizing bond. The reconstruction composite is then placed in the coronal radicular cavity around the post and polymerized. After polymerization, the post is removed from the root. The dentinal walls are treated as usual, and the inlay core composite is sealed with the resin, which has also been coated in primer and an autopho-

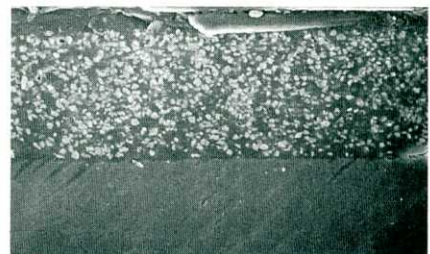


Figure 14—The bonding interface. Note the penetration of the bonding resin in the dentinal tubules.



Figure 15—Inlay core composite using the direct method.

topolymerizing bond. This technique permits control of the thickness of the bonding interface in cases of advanced radicular decay.

These tests allow us to precisely characterize the mechanical values of materials after manufacture. However, the question is whether these values decrease after the materials have undergone repeated stress applications. Samples should undergo stress-fatigue tests that represent the future mechanical stress to which the material will be subjected.

We decided to test Composit<sup>TM</sup>, as well as some of the most widely used metal posts.

Our experiments have shown that by including materials which are mechanically different from dentine, normally dangerous levels of stress/strength can be accommodated by the supporting root.

### The Third Experiment

The C-POST™ had to be compared with metal posts under a load that was close to the buccal strength. The first tests on the C-



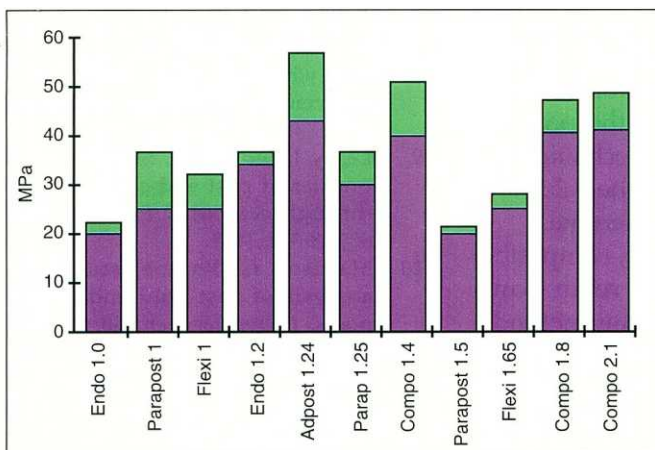


Figure 16—Fracture resistance of the different posts before the stress-fatigue tests.

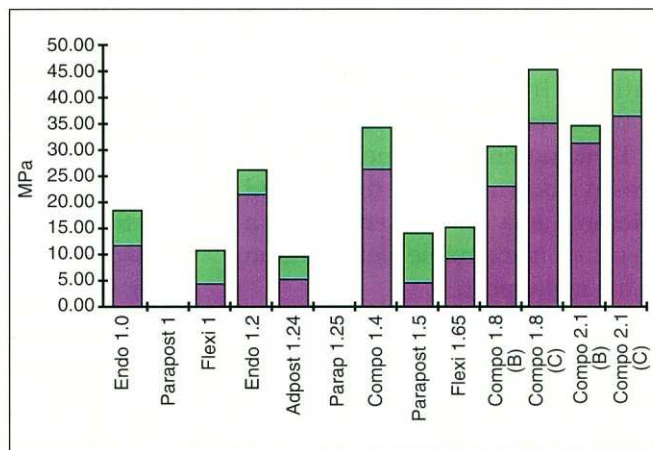


Figure 17—Fracture resistance of the different posts after the stress-fatigue tests.

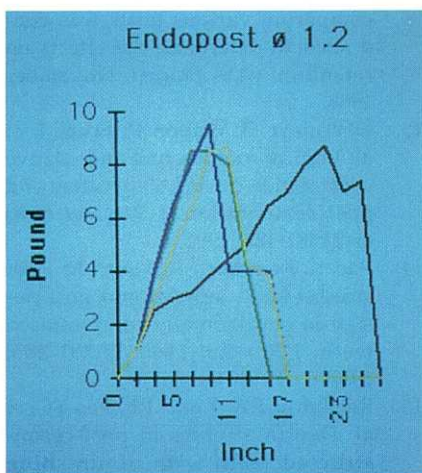


Figure 18—Fractograph of a Composipost™. The Endo•Composipost™ diameter is 1.2 mm. The material is strong and vigorous.

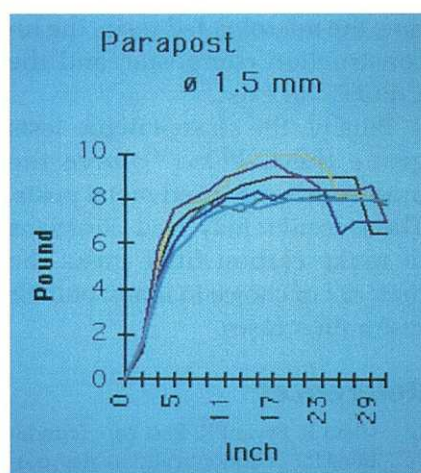


Figure 19—Fractograph of a metal post. The Para-Post diameter is 1.5 mm. The material is weak and deforms.

POST™ and the three metal posts were conducted at the University of Southern California in Los Angeles between 1990 and 1993.

### Materials and Methods

The Composipost™ and Endo•Composipost™<sup>e</sup>, as described, with and without stepped shanks, were tested against the following metal posts: (1) Para-Post<sup>f</sup> with screw threads; (2) Flexi-Post<sup>g</sup> with center groove; and (3) Adpost<sup>h</sup>. The diameters of these posts are close to that of the C-POST™.

Each post was secured in a rigid cylindrical sleeve made of

white polyvinyl acetate. A weight of 75 lb was applied on the post at a distance of 11.6 mm from its point of protrusion from the sleeve. The crankshaft applied a cyclical speed of 16 cpm to 32 cpm. The stress-fatigue cycles, for the most important cases, went from 0 (population A); to 15,000 (population B); or 500,000 (population C). The post was studied before and after the cycle tests by comparing the fracture graphs on an Instron<sup>i</sup> No. 1195.

### Results

The carbon-epoxy material resists in a more vigorous manner than the metal post, which tends to deform progressively.

<sup>i</sup>Instron Corp, Canton, MA 02021

Only two C-POSTS™ were broken during the fatigue tests, and the metal posts very often broke before the end of the series of cycles. We noted a slight drop in fracture resistance (less than 20%) for the C-POSTS™ after the stress cycles. The metal posts had no resistance whatsoever (Figures 16 through 19).

Elasticity appears not to have been affected for the C-POST™ and was considerably decreased for the metal posts.

### Discussion

Our results have guided us toward developing and using a new composite material consisting of long unidirectional fibers. We have demonstrated the properties of the different elements of the coronal radicular reconstruction and the methods used to bond them solidly together so that the reconstruction material and the remaining tooth create a homogeneous mass. We have discussed tests between the C-POST™ and the other types of metal posts.

The risk of radicular fracture has always been the focal point of studies and observations made by various persons concerned with radicular reconstruction. Observations performed during testing, particularly those involving the metal posts' weak resistance to stress and the permanent deformities that can occur early in the cycling process, led us to seek a

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<sup>f</sup>Coltene-Whaledent, Kista, Sweden

<sup>g</sup>Essential Dental Systems, Hackensack, NJ 07601

<sup>h</sup>Morita, Osaka, Japan



correlation between our experimental results and clinical observations. Irreversible deformities of the metal posts can lead to:

- **Detachment** of the post by progressive destruction of the bonded interface area (or the cement) as a result of irreversible deformation of the metal post.

- **Fissuring** of the pericanular dentine because of perpendicular stress on the post's axis. The damage progresses as the bonded interface is destroyed and is accentuated by the permanent deformations of the post caused by function under stress conditions.

- **Root Fracture.** It has been demonstrated that concentrated stress can have negative effects on metal posts as a result of a modulus of elasticity that differs from that of dentine. It has been found that intense and repetitive stress causes post deformation, which results in root fractures.

Therefore, it is important not just to test a radicular post's mechanical strength properties, but also to ensure that these properties are permanent even after prolonged stress.

This aptitude for stress resistance is becoming increasingly necessary with the acceptance of new types of esthetic preparations (Empress<sup>TM,j</sup>, In-Ceram<sup>®k</sup>, etc). The post's role in such devices, prefabricated or otherwise, becomes a dominating one because of the lack of cervical crimping capability that exists with the metal posts. To meet the new requirements of such cases, carbon-epoxy composite materials such as C-POSTS<sup>TM</sup> will be used more often than metal posts in some clinical situations.

## Conclusion

Different and independent experiments have proven that the C-POST<sup>TM</sup>, with its internal structure of high-performance carbon-fiber

reinforcement, does not disturb the biomechanical balance of the dentine. The unidirectional fibers, in line with the axis of the post, induce an anisotropic mechanical behavior that is close to the value and directions of natural dentine.

Its chemical nature, compatible with the Bis-GMA resin commonly used in bonding methods, ensures a very efficient liaison with the reconstruction composite as well as with the microloaded bonding resin. The latest techniques for bonding permit effective interfaces between the dentine, the microloaded resin, the reconstruction composite, and the C-POST<sup>TM</sup> to exist.

Finally, the stress-fatigue tests grade the C-POST<sup>TM</sup> above the most commonly used metal posts. These results may lead clinicians to make carbon-fiber posts the material of choice in many of their restoration cases.

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<sup>j</sup>Ivoclar-North America, Amherst, NY 14228

<sup>k</sup>Vident, Brea, CA 92621