

# Evaluation of the Mode of Failure of Glass Fiber Posts: An *In Vitro* Study

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## Abstract

**Introduction:** It is the era of increased esthetic demands. Post and core systems used for restoration of the mutilated endodontically treated tooth are no exception. Post and core system used for supporting translucent all-ceramic restoration had to be looked for. The glass fiber posts were introduced in 1992 with this aim. Although fiber-reinforced post systems are becoming very popular, they are not foolproof and failures of restorations have been reported.

**Purpose:** The purpose of the present study is to evaluate the mode of failure of glass fiber post.

**Materials and Methods:** 20 extracted single-rooted teeth were endodontically treated and restored with glass fiber posts. They were then loaded using Universal testing Machine until catastrophic failure occurred. Then, the mode of failure of each sample was determined and categorized as (a) root fracture, (b) core fracture, (c) post fracture, and (d) post debonding.

**Results:** 11 samples showed post debonding as a mode of failure. In 05 samples, there was core fracture and post fractured in the remaining 04 samples.

**Conclusion:** The mode of failure for prefabricated glass fiber post is predominantly post debonding followed by core fracture and post fracture.

**Key words:** Core fracture, Glass fiber post, Mode of failure, Post debonding, Post fracture

## INTRODUCTION

A tooth though a small part of the human body serves many functions such as mastication, improving phonetics, enhancing esthetics, and providing self-confidence to one's personality. However, the presence of a healthy tooth is usually taken for granted unless they are affected by caries or damaged by trauma. Centuries ago the only treatment of choice for such conditions was extraction. However, with the advent and improvement in the field of endodontics, the dental treatment and techniques have evolved from

“removing the infected tooth” to “treating the infected tooth.”<sup>1</sup>

With proper endodontic therapy, pulpless mutilated teeth have proved to be the useful members of the dental arch.<sup>2</sup> However, badly broken-down pulpless tooth has few features such as: (1) They are brittle; (2) they possess little or no coronal tooth structure; and (3) they have lower resistance to decay. These features make them far more vulnerable than vital tooth. So, to become useful members of the chewing apparatus and function effectively, such mutilated teeth require special reinforcement provided either intracoronally by post and core or extracoronally by crown restoration or both.<sup>3</sup>

Various methods of restoring these pulpless teeth have been reported in the past 200 years. The available post and core systems can be classified into two types. (a) Metal post and the core cast as a single unit. (b) 2 - element design

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comprising of prefabricated posts to which core have been subsequently attached.

The traditional custom-cast dowel core provides a better geometric adaptation to excessively flared or elliptical or irregular canals, they almost always require minimum tooth structure removal and can be used in roots with minimal remaining coronal tooth structure. But, there are some drawbacks such as root fractures, post separation, and failures.<sup>4</sup> Furthermore, on esthetic consideration, the cast metallic post can result in discoloration and shadowing of the gingiva and the cervical aspect of the tooth. Moreover, they require two appointments with added laboratory fee.<sup>5</sup>

The use of prefabricated posts and composite resin core was introduced in the 1966.<sup>6</sup> Since then prefabricated post systems have become more popular because they provide acceptable results, better esthetics, and function while saving clinical time and reducing cost of treatment.<sup>7</sup>

In earlier days, prefabricated posts were made of metal alloys such as stainless steel, titanium, and its alloys, and gold plated brass. Stainless steel has been used for a long time in prefabricated posts.<sup>8</sup> Although successful they do have certain disadvantages such as high elastic modulus, unesthetic appearance, corrosion, and catastrophic root fracture.<sup>9</sup>

In 1990, Bernard Duret and M. Reynaud introduced a non-metallic material for fabrication of post.<sup>10</sup> These posts were based on carbon fiber reinforcement principle (Composipost, RTD). These posts had high tensile strength and modulus of elasticity similar to that of dentin. However, this post system had a major disadvantage of being unesthetic due to the unsightly black of the carbon.

With the increasing demand for esthetics in today's era post and core system used for supporting translucent all-ceramic restoration had to be looked for. The glass fiber posts were introduced in 1992 with this aim.<sup>11</sup> Glass fiber posts provide increased light transmission through the root, giving more life-like appearance to the prosthesis. The modulus of elasticity of glass fiber post is comparable with that of dentin which reduces chances of root fracture due to stress concentration. Glass fiber posts also eliminate the problem of corrosion and hypersensitivity that occurs with metal posts.<sup>6</sup> With its many advantages, the fiber-reinforced post is becoming a paramount restorative option for endodontically treated tooth. Although fiber-reinforced post systems are becoming very popular, they are not foolproof and failures of restorations have been reported.

Hence, the purpose of this *in-vitro* study is to evaluate the mode of failure of endodontically treated tooth restored with glass fiber posts.

## MATERIALS AND METHODS

Step 1: Collection of extracted maxillary anterior tooth.

20 freshly extracted maxillary anterior teeth were collected.

### Inclusion Criteria

- a. All samples were caries free
- b. All samples were fracture free
- c. All Selected samples were devoid of debris and calculus
- d. All samples had complete root formation.

### Exclusion Criteria

- a. Tooth with two or more canals
- b. Roots with aberrant anatomy
- c. Roots with open apices.

All samples were cleaned, disinfected, and stored as per the recommendations, and the guidelines laid down by the Center for Disease control and Prevention.

Teeth were stored in phosphate buffer saline solution. During all stages of the study, dehydration of the specimens was avoided.

Step 2: Sectioning of the sample.

- a. All the collected samples were marked and decoronated 2 mm above the cemento-enamel junction with diamond rotary bur mounted on high-speed handpiece
- b. Exposed surface of the dentine was made flat and perpendicular to the long axis of the tooth.

Step 3: Root canal treatment.

- a. The root canal was prepared using the sequential endodontic file from No.10 to size of No. 35
- b. 17% ethylenediaminetetraacetic acid for 30 s was used as lubricant with intermittent irrigation of 3% sodium hypochlorite for 1 min followed by final irrigation with saline for 1 min
- c. Canals were dried with absorbent paper points
- d. Obturation was done using gutta-percha and endodontic sealer.

Step 4: Post space preparation.

- a. Gutta-percha was removed using the heated plugger
- b. DT light post drill size no: 1 (red) was marked at a length of 10 mm and post space was prepared.

Step 5: post cementation.

- a. The prepared canal walls were etched with 37% phosphoric acid for 15 sec, water rinsed for 1 min, and gently air dried. Excess water from the post space was removed using absorbent paper points.
- b. 20 DT light fiber post of size 1.5 mm were marked at the length of 14 mm and cut with double sided

- diamond disk mounted on a micromotor handpiece.
- Next calibra dual cure composite resin base and catalyst paste were mixed for 20 s, applied on the post surface. Then, the post was placed into the root canal under constant finger pressure for 10 min. Excess luting material was removed light activation was done through a cervical portion of the root for 40 s on buccal and lingual surfaces, totalizing 80 s of light exposure.

- Step 6: Mounting of tooth sample in acrylic resin block.
- The root part of each prepared sample was marked and encircled with a thin single sheet of spacer wax (0.3 mm thickness) 2 mm below the cement-enamel junction.
  - A custom made two-piece stainless steel mold was used for the fabrication of standardized resin blocks in which the specimen were mounted.

Each tooth specimen with cemented post was attached to mandrel on surveying arm of the dental surveyor. The custom made stainless steel mold was lubricated with petroleum jelly and placed on the horizontal table of the surveyor.

- The surveyor was adjusted to stabilize the tooth specimen at the center of the mold such that 1 mm of the root structure lies above the mold.
- After confirming proper positioning of specimen and mold on surveyor, auto polymerizing acrylic resin powder and liquid was mixed in thin consistency and poured around tooth specimen to fill the mold completely.
- The tooth was removed from acrylic resin block after the first signs of polymerization to eliminate the effect of heat of polymerization.
- Then, the spacer wax was removed, and the space created in the block was filled with light body vinyl polysiloxane impression material.
- Then, the tooth was again placed back in the block; excess impression material was removed. Moreover, the entire block was removed from the mold.

- Step 8: Testing of samples.
- The specimens were positioned in a customized jig so that the longitudinal axis will be perpendicular to the load direction.
  - The teeth were then loaded from buccal surface of the core at 90° to the long axis and 3 mm from tooth core interface.
  - A universal testing machine with 1 mm diameter rounded loading plunger was used to load the specimens at a crosshead speed of 0.5 mm/min.
  - The specimens were loaded until catastrophic failure occurred.
  - The ultimate failure load was recorded.

- Step 9: Identification of mode of failure.
- All samples were subjected to radiographic evaluation.
  - The mode of failure was recorded as:
    - Root fracture
    - Core fracture (Figure 1)
    - Post fracture (Figure 2)
    - Post debonding (Figure 3).

## RESULTS AND OBSERVATIONS (TABLE 1 AND GRAPH 1)

### Discussion

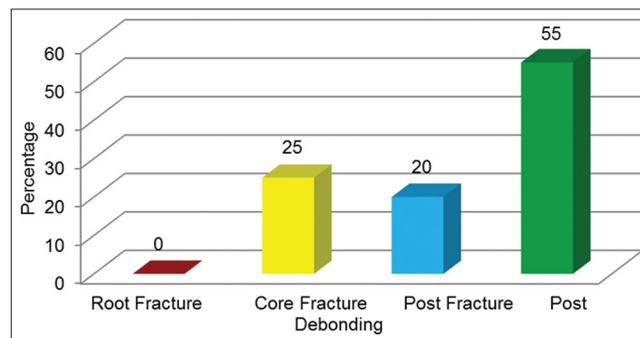
After endodontic treatment, the dentist is still faced with the problem of restoring the crown and reinstating the tooth as a permanent, functional, and esthetic member of masticatory apparatus. Endodontic treatment dose saves the tooth, but they become weaker as compared to a normal vital tooth. These affected physical properties of pulpless teeth are often attributed to loss of moisture, loss of structural integrity due to endodontic access preparation and changes in collagen cross-linking.<sup>12</sup>

Reinforcement of endodontically treated tooth was suggested by many authors as a viable option to regain lost strength. Such reinforcement can be in form of intracoronary reinforcement (post and core) and extracoronary reinforcement (crown) or both.<sup>2,3</sup>

With the advanced technology of today, we, as clinicians, have at our disposal a wide range of dental materials of ever-increasing quality. In addition, the field of intraradicular posts is no exception. We have an increasing extent of

**Table 1: Mode of failure of glass fiber post (Group II)**

Glass fiber post	Type of failure	No. of samples
Group II	Root fracture	00
	Core fracture	05
	Post fracture	04
	Post debonding	11



**Graph 1: Mode of failure of restoration in glass fiber post system**



Figure 1: The core fracture in the sample.



Figure 2: Post debonding in the sample

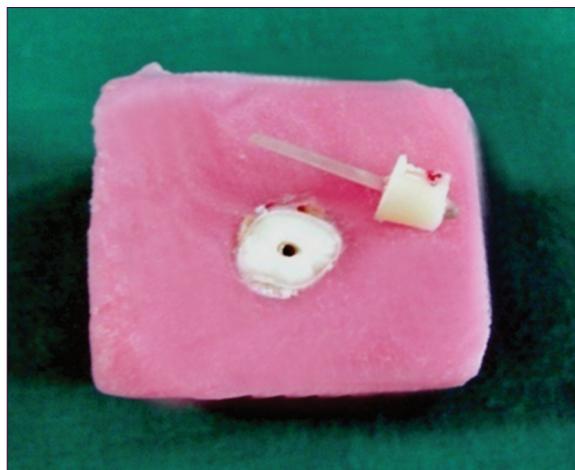


Figure 3: The post debonding in the sample

materials at our disposal. The materials used for posts and core can be divided into cast posts and prefabricated posts.

The cast metal post and core have been the traditional and time-honored method of restoring endodontically treated

teeth. However, there are some disadvantages associated with the conventional post and core systems such as poor retention of the post, greater incidence of root fracture, and risk of corrosion when different metals are used in the system. Fabrication of cast metal post and cores can be time-consuming and involves additional laboratory cost. The laboratory procedure itself may introduce errors within casting and thus increase the risk of failures. Application of a cast post often contributes to further loss of tooth structure that may interfere with the mechanical resistance of the teeth, increasing the risk of damage to residual tooth structure.

At around 1966, the prefabricate posts and composite resin core came into use. This system in which the prefabricated posts is cemented in root canal and the core is built up using composite resins was devised for forming a dowel and core which provides strength and serviceability comparable to, and often exceeding, that of cast dowels.<sup>6,7</sup>

According to material composition, the posts are classified as:

- a. Metal posts: Titanium and stainless steel
- b. Ceramic and zirconium posts
- c. Fiber posts: Carbon fiber posts, quartz fiber, glass fiber, and silicon fiber post.<sup>13</sup>

Pre-fabricated metal posts were used successfully for restoring endodontically treated tooth for many years. However, they were not the ideal materials. Their high elastic modulus, corrosion or esthetic problems have led to the development of other type of post systems such as zirconia posts and fiber-reinforced post.

Duret and his co-investigators in 1990 introduced carbon fiber-reinforced posts. After that, many other fiber-reinforced materials have been made available to the dental profession and are now seen as an alternative to cast and prefabricated metal posts.<sup>10</sup>

The fiber-reinforced composite posts are made of carbon, quartz, glass, and polyethylene fiber embedded in a matrix of epoxy or methacrylate resin.<sup>7,14</sup> The fibers are oriented parallel to the post longitudinal axis, and their diameter ranges from 6 to 15  $\mu\text{m}$ . Fiber density, i.e. the number of fibers per  $\text{mm}^2$  of post cross-sectional surface, varies between 25 and 35, depending on the post type. Therefore, in a transverse section of the post, 30-50% of the area is occupied by fibers.<sup>15</sup> The adhesion between quartz or glass fibers and resin matrix is enhanced by fiber salinization before embedding. A strong interfacial bond enables load transfer from the matrix to the fibers and is essential for an effective use of the reinforcement properties.<sup>16</sup>

Fiber-reinforced posts have various desirable properties. Among all the available post systems, the modulus of elasticity of fiber-reinforced post (13-40 GPa) is very close to dentin (18 GPa).<sup>17</sup> Fiber posts also have many other advantages such as biocompatibility, provide increased light transmission through root, giving more life-like appearance to prosthesis, and they are easy to remove when endodontic retreatment is required.<sup>6</sup>

Thus, so far various post and core systems have evolved from the cast post to prefabricated metal post to the newer glass fiber posts. Although the glass fiber post seems to be better than the previous systems yet their clinical success is yet to be proved. Moreover, further research in this aspect is warranted. Hence, this study was undertaken to evaluate the mode of fiber post.

Post length of 10 mm was selected which was in accordance with the study by Giovani, Vansan, Neto, and Paulino which concluded that a post length of 10 mm significantly increased the fracture resistance.<sup>18</sup>

Post diameter of 1.5 mm is recommended for maxillary anterior tooth,<sup>19</sup> size: 1 of DT light post was used as these size corresponds to post diameter of 1.5 mm.

To simulate the movement of the periodontal ligament, each root was embedded in an acrylic resin socket lined with a polyvinyl siloxane impression material.<sup>20</sup> Although no measurements of actual mobility were made. Specimens were removed from the resin blocks after the first signs of the polymerization to eliminate the effect of heat of polymerization on dentin. The heat generated leads to decreased moisture content, crazing, and weakening of the sample, which indirectly affects the fracture resistance value. The loading angle of 135° from palatal to labial was selected on the basis that it simulates the average angle of contact between maxillary and mandibular incisors in Class I occlusion and is a test of function. A crosshead speed of 1.5 mm/min was selected to allow time for distribution of the force from the point of application, i.e. from the core to throughout the post.<sup>21</sup> The samples were loaded until the failure occurred. The fracture resistance was recorded. The mode of failure was then determined by observation of the samples. Then, confirmation of the failure mode was done by evaluating each sample radiographically using the digital radiographs.

The type of failures was classified into:

- a. Root fracture
- b. Post deboning
- c. Core fracture
- d. Post fracture.

The mode of failure for each sample was evaluated; collective data were tabulated category wise.

### Post Debonding

Most of the failure associated with the fiber posts are due to the debonding. The debonding between post-cement interface rather than cement-dentin or intracement fracture (cohesive failure of cement). This debonding is often attributed to various causes like Most of the fiber post are made of highly cross-linked epoxy resin which makes it difficult to bond with methacrylate based resin cement.<sup>22</sup> Other reasons might be change in physical properties such as flexural strength and modulus of elasticity due to water sorption during prolonged storage (leading to expansion), changes in temperature (difference in coefficient of thermal expansion of fiber post, dentin, and core material), and dynamic functional loading.<sup>12,22-25</sup>

### Core Fracture

When considering fiber post and composite core, it was suggested that resin fiber posts are industrially cured, with a high level of polymerization and concomitant relatively small quantities of free resin available to interact with the reactive chemical constituents present in resin lutes or composite resin cores.

### Post Fracture

20% of the fiber post fractured this could be attributed to less rigidity of fiber post as compared to that of the metal post. Three-point bending tests of fiber based post compared with metal post are in accordance with these results.<sup>10,26,27</sup>

Zhi-Yue and Yu-Xing (2003) proposed a classification of failure modes as:

- a. Resin core or post fracture
- b. Cervical root fracture
- c. Mid root fracture
- d. Apical root fracture
- e. Vertical root fracture.

The resin core/post fracture was considered as the favorable mode of fracture; whereas, all other fracture modes involving root were considered as unfavorable.<sup>28</sup>

In the present study, all the failures of the fiber post are favorable.

Research is also going on to increase the retention of glass fiber posts through various surface treatments. The effects of these treatments on the failure mode of the post can be verified in further studies.

In this study, a continually increasing static load was applied on the samples which are not the kind of loads in the

oral cavity. A study under cyclic loading would provide a better understanding for the findings observed in the present study.

Furthermore, this was an *in vitro* study. The performance of the materials might be different in clinical situations. A long-term clinical evaluation of success of these materials in restoring the tooth to its natural strength will help in their comparison.

The purpose of this study was to provide useful information and help dental professionals in choosing the most appropriate post system. As on today, extensive research has been carried out in this field, and a lot will be done in the future. It is understandable that each system has its own advantages and disadvantages and no system can be considered the gold standard for restoring the endodontically treated tooth. Until a single system is considered to be adequate, research in this aspect to find new systems and improve the old ones will be conducted.

## CONCLUSION

The mode of failure of the restoration of endodontically treated tooth restored with glass fiber post was evaluated and within the limitations of this study, following conclusion was drawn. Prefabricated fiber post mostly shows debonding as a mode of failure which is favorable and amenable to retreatment.

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