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The Relationship Between Fibre Post Geometry and Flexural Properties: An Assessment Through a Modified Three-Point Bending Test

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Abstract - *The aim of this study was to investigate the flexural properties of five types of fiber-reinforced dowels using a modified three-point bending test. Fiber-reinforced resin dowels were tested by a modified three-point bending test associated with models for cylindrical and conical simple-supported beams. The fracture load ranged from 86 to 246 N and the flexural strength from 423 to 1192 MPa. FRC Postec had significantly higher flexural strength and fracture loads values. Thus, the present study demonstrated higher flexural strength values for the FRC Postec fibre posts, suggesting that this system would present a better response to the forces of mastication.*

KEY WORDS: Post. Fibre post. Flexural strength. Three-point bending test.

INTRODUCTION

There are some theoretical advantages in using fibre reinforced composite posts when restoring endodontically treated teeth. They are currently accepted for this kind of restorations, mainly because they present an elasticity modulus closer to that of dentin and allow absorption and uniform distribution of stresses to the remaining root structure instead of concentrating them[1-7]. These are clear potential advantages when compared to the traditional cast posts and the prefabricated metallic and ceramic posts.

Several types of fibre posts are available on the dental market, and their mechanical properties must be taken into consideration in order to make a good clinical decision. Two of the stated clinical physical requirements of root canal posts are a high flexural strength[8] and an elasticity modulus close to that of dentin[9]. When a fibre post is excessively flexible, the force applied on the interface between dowel, resin, and dentin may lead to restoration fracture[10].

Many studies in the literature evaluated the flexural strength of fibre posts using the three-point bending test that has been commonly used to evaluate the strength of polymer-based restorative materials[11-14]. Several factors have been verified as affecting the values of strength such as span length and cross-sectional design. Also the length / cross sectional design ratio is essential for interpretation of flexural strength and flexural modulus values of small test specimens[15]. In addition, the approach of the traditional three-point bending test does not take into account specifics related to post geometry. To the authors' current knowledge, these geometric particularities should also be considered for testing conical and cylindrical posts. Hence, the present study was designed to investigate the flexural properties of five different types of fibre-reinforced posts. To perform this testing, a modified three-point bending test was introduced and its advantages and limitations are addressed in throughout the text. Two null hypotheses were formulated: (1) there is no difference in the flexural strength among the fibre-reinforced posts tested and; (2) there is no difference in the fracture load among the fibre-reinforced posts tested.

MATERIALS AND METHODS

Twenty-five prefabricated, intraradicular, fibre-reinforced resin posts were divided into five groups of five posts with the largest available diameter, according to the type of fibre used in their composition, their geometric form, and their manufacturer, as shown in Table 1 and Fig. 1.

Modified three-point bending test

A modified three-point bending test was carried out in accordance with the norm ASTM D2344/D2344M[16], associated with models for analyzing the bending of cylindrical and conical simple-supported beams to determine flexural strength and maximum fracture load for the specimens tested. Simple models were developed for analysis, based on the statics and dynamics of beam loading, aimed at mechanically proving the importance of considering the conical design of posts in flexure tests, since distinct geometries (conical and cylindrical) were chosen for the specimens to be tested. These models are described below and as shown in Fig. 2a and 2b, respectively.

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Table 1. *Posts systems tested, characteristics and values*

Product name and manufacturer	*Size*	*Post Design*	*Fiber material*	*Diameter (mm)*	*Compensation (mm)*	*Span length + SRS* (mm)*
White Post DC, FGM Produtos Odontológicos LTDA, Santa Catarina, Brazil	3	Double conicity	Glass	Mean Dm = 1.58	0.40	6.34 + 3
Reforpost Ângelus, Indústria de Produtos Odontológicos LTDA, Paraná, Brazil	3	Cylindrical serrated	Glass	Maximum Do = 1.42	-	5.68 + 3
FRC Postec, Ivoclar Vivadent AG, Schaan, Liechtenstein	3	Double conicity	Glass	Mean Dm = 1.52	0.47	6.10 + 3
Fibrekor, Jeneric/Pentron, Wallingsford, CT, USA	3	Cylindrical serrated	Glass	Maximum Do = 1.44	-	5.76 + 3
DT Light Post, Bisco Incorporated, Illinois, USA	3	Double conicity	Quartz	Mean Dm = 1.71	0.50	6.84 + 3

*SRS (Sum of radii of supports)

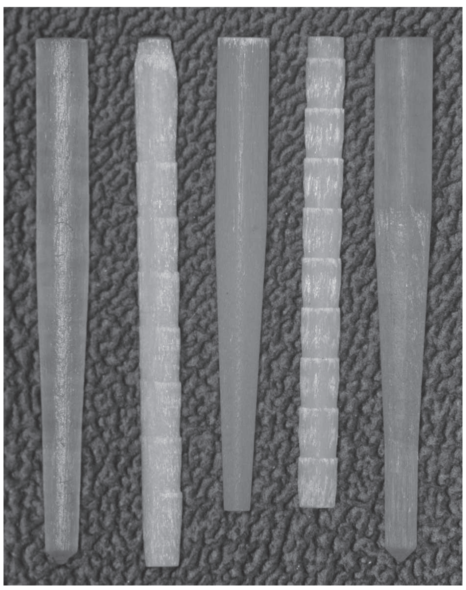
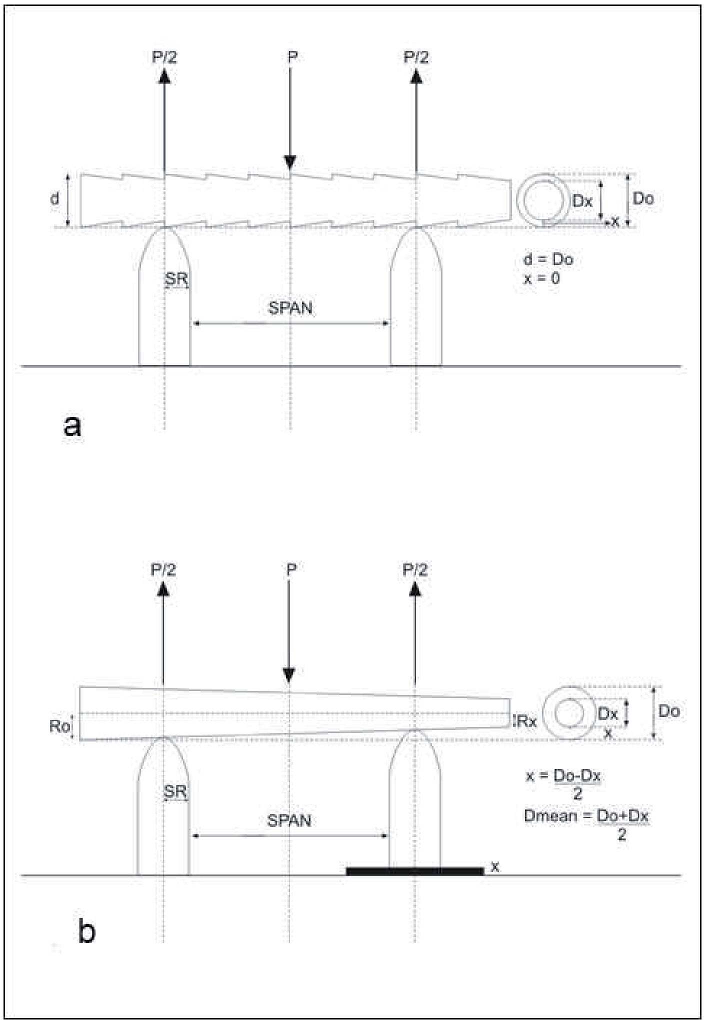


Figure 1. *Examples of fibre posts tested. From the left: White Post DC, Reforpost, FRC Postec, Fibrekor, and DT Light Post.*



Figures 2A and B. *(A) Force system and geometry's model for the flexural test on cylindrical simple-supported beams, where D_0 (mean major diameter), D_x (mean minor diameter), d (cross-section diameter), x (compensation measurement taken with a feeler gauge), SR (support radius in mm) = 1.5, Span (c) (distance between supports in mm), P (load in newtons). (B) Force system and geometry's model for the flexural test on conical simple-supported beams, where D_0 (mean major diameter), D_x (mean minor diameter), R_0 (initial radius), R_x (final radius), d (cross-section diameter), D_{mean} (diameter of specimen tested), x (compensation measurement taken with a feeler gauge), SR (support radius in mm) = 1.5, Span (c) (distance between supports in mm), P (load in newtons).*

a) Model for flexure test of simple-supported cylindrical beams

The maximum tensile and compressive stresses applied to the superior and inferior parts of the beam are equal in absolute value:

$$\sigma_{max} = \frac{M_{max}}{Z}$$

where s_{max} is the maximum stress observed in both the upper (tensile) and lower (compression) surfaces of the specimen (N/mm^2), M_{max} is the maximum bending moment, observed in the middle of specimen's length (N.mm) and Z is the circular cross section resistant modulus;

$$Z = \frac{\pi d^3}{32}$$

where d stands for the cross-section diameter.[17] In the proposed model, the maximum stress observed was therefore:

$$\sigma_{max} = \frac{8PL}{\pi d^3}$$

where P is the force applied (N), L is the span length (mm) and d is the diameter of the specimen (mm), constant with values obtained previously by other authors[10,12].

In groups of fibre-reinforced posts where the cross section was not constant, as in those containing serrated posts (Fig. 1 – Reforpost, Fibrekor), the model for flexure testing of simple-supported cylindrical beams was used. In this case, the mean major diameter (D_0) was considered, with the aim of applying the load perpendicularly to the region with the largest diameter.

b) Model for flexure test of simple-supported conical beams

This model was used in groups of posts with conical cross sections (Fig. 1 - DT Light Post, White Post DC, FRC Postec) to obtain adequate values from the data, since the conical design required a change in the placement of one of the supports to keep the post aligned and the shear force perpendicular to its geometric centre during the test. This change in the support placement was made using a feeler gauge (Fig. 3), a device largely employed in the metal-mechanic industry to measure tolerances and coupling adjustments.

Initially, measurements were taken with a digital caliper (Model 500-144B) to obtain the mean major and minor diameters of the posts systems subjected to the flexure test of simple-supported conical beams. The mean diameters of each system were then calculated. Compensation calculations to adjust the placement of one of the device supports were also made so that the loading could be applied perpendicularly to the test specimen, as demonstrated in the equations:

$$x = \frac{D_0 - D_x}{2} = \frac{D_0}{2} - \frac{D_x}{2} = R_0 - R_x$$

and

$$D_{mean} = \frac{D_0 + D_x}{2}$$

where D_x = mean minor diameter, D_0 = mean major diameter, R_0 = initial radius, R_x = final radius, x is the compensation measurement taken with a feeler gauge, and D_{mean} is the average diameter of the specimen tested. Likewise, the compensation measurement x corresponds to the difference between the test specimen radii ($R_0 - R_x$) at both ends of the post. After determining the value of x, a feeler gauge blade with a thickness close to the value of x was selected to provide bilateral support at the base of one of the device supports.

To carry out the test, it was necessary obtain the length of the support span for each group, using the following equation: c = 4d, where c is the support span and d is the mean major diameter of each group (D_0) for simple-supported cylindrical beams or the mean diameter (D_{mean}) for simple-supported conical beams. Moreover, it was necessary to adjust this span according to post length and width, given that it was impossible to change the loading nose and support diameters due to norm requirements, which were of 6 mm and 3 mm, respectively. Consequently, the span had to be considered as the distance between the internal walls of the supports, using the ratio $c/d = 4$ added up to the measurement taken from the centre of load application on each support to its internal surface (1.5 mm + 1.5 mm), that is, the radius of each support (**SR**) (Figs. 2 a and b). Thus, a ratio of 4 between specimen length and diameter ($c/d = 4$) was established and always added up to the radius of both supports (1.5 mm x 2 = 3 mm). Table 1 shows the values obtained for each group tested.

After setting the supports at the distance corresponding to its group, each post was placed in the device to receive a preload with the objective of stabilizing it. This procedure was used because the cylindrical design could displace test specimens. The test was conducted until fracture occurred. The Trapezium 2.0 software was installed on a static servo-electric universal testing machine (model Autograph AG-IS MO), with a capacity of 100 kN, and stored all obtained measurements. The results for maximum load (N), flexural strength (MPa) and displacement (mm) were then obtained.

STATISTICAL ANALYSIS

The preliminary analysis of the raw data from the experimental groups showed a bell shaped distribution (D'Agostino & Pearson omnibus test) for all parameters tested. Further statistical analysis was performed and the raw data was assessed using One-way ANOVA analysis. To isolate the statistical differences between the different posts systems the post hoc Bonferroni-test for multiple comparisons was subsequently applied. The alpha-type error was set at 0.05. The StatGraphics Plus 5.1 and Origin 6.0 software were used as analytical tools.

RESULTS

The fracture load of the tested systems ranged from 86 to 246 N and the flexural strength from 423 to 1192 MPa. The mean, minimal and maximal fracture loads and flexural strengths values, as well as the data distribution for each experimental group are presented in the box-plot graphs in Figures 4 and 5. Different letters indicate significant difference among groups. Therefore, regarding flexural

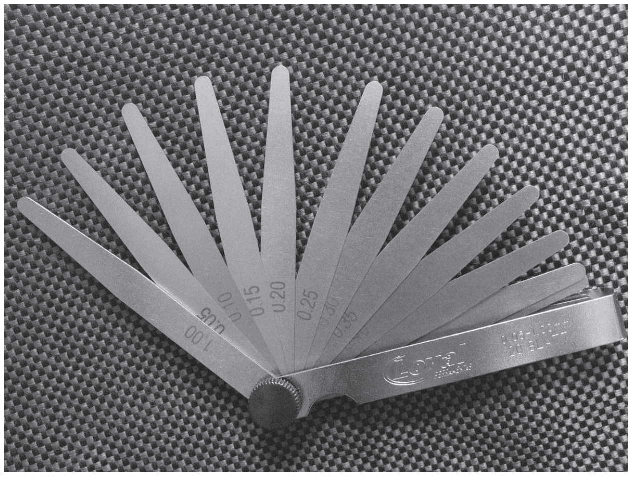


Figure 3. *Feeler gauge used in the test.*

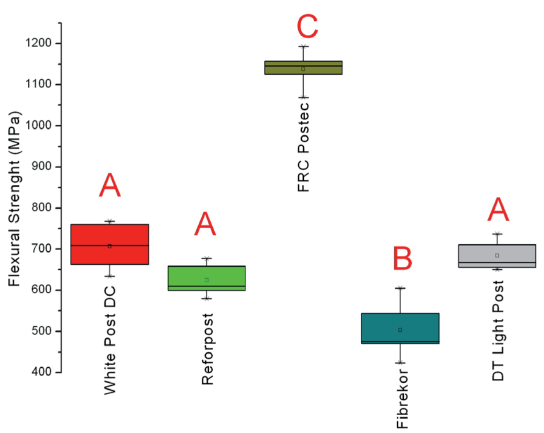


Figure 4. *Mean, minimal and maximal flexural strengths values and the data distribution for each experimental group are presented in the box-plot graph. Different letters indicate significant difference among groups.*

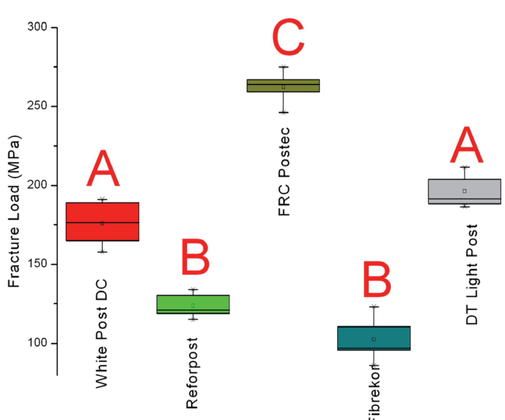


Figure 5. *Mean, minimal and maximal fracture loads values and the data distribution for each experimental group are presented in the box-plot graph. Different letters indicate significant difference among groups.*

strength evaluation, White Post DC, Reforpost and DT Light post revealed similar results ($P < 0.05$). The highest flexural strength result was achieved by FRC Postec ($P < 0.05$) while Fibrekor displayed the lowest result ($P < 0.05$). As about the fracture load results, White Post DC and DT Light post displayed similar results ($P > 0.05$). In the same manner, Reforpost and Fibrekor revealed similar data ($P > 0.05$) while FRC Postec showed the highest fracture load resistance ($P < 0.05$).

In general, FRC Postec had significantly higher flexural strength and fracture loads values than all the other tested posts ($P < 0.05$).

DISCUSSION

The current results showed higher values of flexural strength for the FRC Postec group. Consequently, the first null hypothesis was rejected. In addition, as to maximum fracture load, the FRC Postec group also displayed higher values. Thus, the second null hypothesis was also rejected. Therefore, FRC Postec has the best performance among all fiber posts tested in the present study; this being in agreement with other results found in the literature[18]. Although the FRC Postec group showed excellent results, desirable values of flexural strength were achieved by all the other fibre posts tested when compared to other studies[10,12,13,14], even with different methodologies. In other words, from a biomechanical point of view, the results present desirable values, which assure that all fibre posts tested can be used as excellent clinical restoration alternatives.

In the present study, the results obtained for maximum fracture load were close to those found in the literature for different methodologies[14], which confirms their accuracy.

The modified three-point bending test provided reliable results, since the criteria adopted in the analysis became more rigid due to the implementation of models based on the statics and dynamics of beam loading. In the present study, the specimens had different geometries (conical and cylindrical). Therefore, a preliminary theoretical analysis using models that take conical design into account in flexure tests was used. The use of the modified three-point bending test enabled the ability to apply a load properly on the test specimens, even considering the particular geometry of the post. The mechanical assay can be conducted at an angle of 90°, according to what is established as the norm; this way, unwanted shear forces that can, in some measure, interfere in the quality of the results can be prevented. In others words, the use of the modified three-point bending test allows the use of a specific norm for cylindrical fibre-reinforced resin test specimens[16] and could be used when compared to other norms, which are more appropriate for non-cylindrical resin materials without fibre reinforcement[13,19] or ceramic materials[14,20].

CONCLUSIONS

In summary, the present study demonstrated higher flexural strength values for the FRC Postec fibre posts, suggesting that this system would present a better response to the forces of mastication. Moreover, the modified three-point bending test can be seen as a modest but required improvement in order to produce more reliable biomechanical data about fibre posts with different geometry features

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MANUFACTURES' DETAILS

- Angelus - Indústria de Produtos Odontológicos LTDA, Paraná, Brazil
- Jeneric/Pentron, Wallingsford, CT, USA
- Bisco Incorporated, Illinois, USA
- FGM Produtos Odontológicos LTDA, Santa Catarina, Brazil
- Ivoclar Vivadent AG, Schaan, Liechtenstein
- Mitutoyo Sul Americana Ltda., Suzano, Brazil – Digital caliper
- Shimadzu Scientific Instruments, Columbia, USA
- Shimadzu do Brasil Comércio Ltda. – Divisão Analítica, Barra Funda, São Paulo, Brazil
- Statistical Graphics Corporation, Copyright 1994-2001, USA
- Microcal Software, Inc., Northampton, MA, USA

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