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THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: "Flexural strength of everX Flow short-fiber reinforced flowable composite vs. RelyX fiber posts"

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Degree: Master of Science
Date: June 30, 2022

THESIS/MANUSCRIPT APPROVED:	SIGNATURE/DATE:
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Flexural Strength of everX Flow Short-Fiber Reinforced Flowable Composite vs. RelyX Fiber Posts

COL Joseph R. Lowe

TABLE OF CONTENTS

ABSTRACT

Purpose: To evaluate the flexural strength of two post materials in the restoration of endodontically treated teeth.

Materials and Methods: Fifty-six cylindrical samples of composite resin restorative materials were assessed for maximum flexural strength (FS) following manufacturers' instructions and ISO 4049. The samples were evenly divided between two different materials (ESPE 3M RelyX Fiber Post and GC America everX Flow short-fiber reinforced flowable composite). RelyX posts were pre-manufactured and packaged by ESPE 3M. In contrast, everX Flow posts were indirectly fabricated using molds duplicating the dimensions of the RelyX post size tested. Flexural strength of each specimen was measured using a three point test on the Instron® 5943. The resulting force in megapascals (MPa) necessary to flex specimens to result in a permanent change in the material or a break of the material was used to calculate flexural strength.

Results: The flexural and compressive strengths of the RelyX posts was determined to be significantly greater in comparison to the everX Flow posts. Test results showed 2,018 Mpa flexural and 104.28 Mpa compressive strengths for RelyX, versus 611.31 Mpa and 32.26 Mpa for everX Flow. This finding indicated a statistically large difference between the two groups.

Conclusion: The use of everX Flow as a comparable restorative alternative to pre-fabricated posts was not demonstrated. The significantly weaker flexural and compressive strengths of everX Flow posts when evaluated to this particular pre-fabricated post system may not warrant its use as an adequate substitute.

INTRODUCTION

The restoration of endodontically treated teeth often requires the use of posts to retain the core, thereby serving as a stable foundation for the crown. Prefabricated posts, both metal, ceramic, carbon fiber and composite fiber, have been routinely utilized in the restorative dentistry armamentarium for decades [1-9]. A disadvantage of prefabricated posts are that they require preparation of the root canal to fit a particular post size, thereby removing supportive dentin which could make the tooth more susceptible to root fracture. Common failures of teeth restored with posts depend on the type used. Generally, metal post placement observe more catastrophic root fractures whereas fiber posts result in more de-bondings [7-8].

Core build-up materials are used to replace missing coronal tooth structure to help retain the definitive restoration, typically a full-coverage crown. When restoring endodontically treated teeth, the additional retention of the core by a post is routinely required. The most common trend is that these core materials are non-metallic and composed of particulate filled composites (PFCs). Generally, PFCs consist of filler particles embedded in a resin matrix. A common reason cited for PFC failure is their inadequate fracture toughness and flexural strength in comparison to dentin. Recently, manufacturers have developed short fiber reinforced composites (SFRCs) to help mitigate the biomechanical shortcomings of PFCs [10-14].

The dental profession is always striving to simplify procedures and the materials used for restorative purposes. Likewise, the trend in Army dentistry is to standardize processes and minimize dental material inventory. If a particular material can be use in different clinical applications, it could also be employed to replace multiple products that individually have a single specific use. A novel SFRC restorative material, everX Flow by GC America, has been touted as such [15]. The product is marketed for use as a core build-up and bulk filling material. A GC America sales representative claimed that this material could possibly be used as an alternative to fiber posts that have traditionally been used for restorative purposes. If true, posts could be fabricated on demand with the product and thereby eliminate the need for prefabricated posts. Also, if it could be used in vivo the additional removal of supportive dentin required for the fit of prefabricated posts would be minimized.

MATERIALS AND METHODS

The flexural strength of everX Flow Short-Fiber Reinforced Flowable Composite fabricated posts were tested and compared to prefabricated RelyX Fiber Posts. Post specimens of the everX Flow were fabricated using an injection mold of the standard size 3 (1.9mm) RelyX Fiber Posts. In total, 56 cylindrical samples of composite resin restorative materials were assessed for maximum flexural strength (FS) following ISO 4049[16]. The samples were evenly divided between two different composites (ESPE 3M RelyX Fiber Post and GC America everX Flow short-fiber reinforced flowable composite). In order to compare the relative strengths between the two samples, only the parallel portions of each post group was analyzed. RelyX samples were pre-manufactured and packaged by ESPE 3M (Figure 1). The dimensions of the RelyX posts tested was 20mm overall length, with 10mm of the total coronal length having a parallel 1.9mm diameter. The apical portion of these posts tapered to its smallest dimension of 0.9mm. Samples of the everX Flow group were constructed as cylinders 1.9mm in diameter and at least 8mm in length (Figure 2).

Fig. 1. RelyX Fiber Posts, 3M ESPE

Fig. 2. everX Flow, GC America, injection mold fabricated posts

The indirect fabrication of posts using GC America everX Flow was performed in a manner that essentially duplicated the dimensions of the tested ESPE 3M RelyX Fiber Post samples. Molds of the RelyX posts were made using a clear polyvinyl siloxane (PVS) impression material (Exaclear, GC America). Spent clear glass anesthetic carpules were used to confine the injected PVS material, then RelyX posts were immediately centered and inserted within the complex. The set PVS material was extruded from the carpules, then the RelyX posts were retrieved from the PVS. Approximately 1mm of the apical ends of the molds were removed to prevent air entrapment. Syringes of the everX Flow material were loaded and pre-heated for 15 minutes in a composite heater (BioClear HeatSync). The everX Flow material was then injected into the full length of the mold with some apical extrusion to avoid air entrapment. Lastly, the samples were circumferentially cured (ESPE 3M Elipar DeepCure-S curing light) for 90 seconds then removed from their respective molds (Figure 3).

Fig. 3. Materials & Methods for fabrication of everX Flow posts

Three-point loading FS testing [17] was conducted using the Instron® 5943, with 6 mm between the supports and at a crosshead speed of 1.00 mm/min until fracture (Figure 4). Testing parameters were set using BlueHill® 3 software (Instron®; Norwood, MA; USA). Each sample was tested until fracture. The maximum load prior to failure was used to calculate FS. The following equation was used to determine the flexural stress at maximum load: $\sigma_f = 3FL / \pi r^3$. In this equation, F refers to the maximum load exerted (N), L is the distance between the supports (mm), and r is the radius of the sample (mm). Subsequently, the Modulus of elasticity (Young's modulus) was calculated using the formula: $E = FL^3 / 48\delta\mathbf{I}$. Here, **I** is equal to the moment of inertia for a cylinder and δ = deflection at maximum load.

Fig.4. Instron 5943

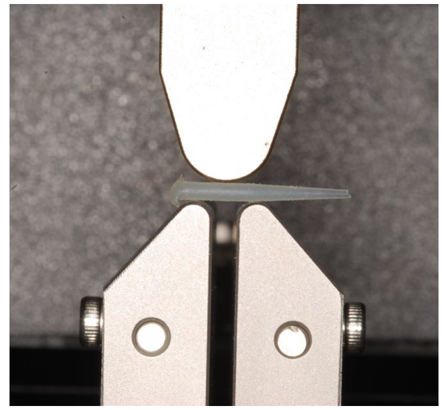


Fig.5. everX Flow post

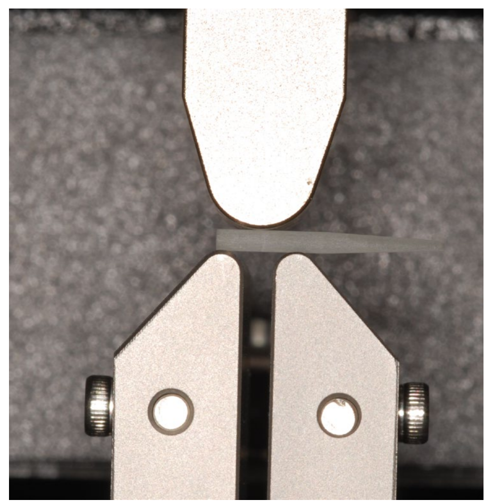


Fig.6. RelyX post

Exploratory data analyses were conducted on continuous data. The Shapiro-Wilk test was used to assess the normality of the data distributions. Consequently, measures of central tendency are presented as means with associated standard deviations. An analyses of variance (ANOVA) was conducted to assess differences FS between the two composites (Figures 5 & 6). Eta squared (η^2) statistics are presented as measures of effect size for significant ANOVA [18]. Statistical significance for all statistical tests was declared at $P < 0.05$. Data were analyzed using SPSS 25.0 (IBM, Armonk, NY, USA).

RESULTS

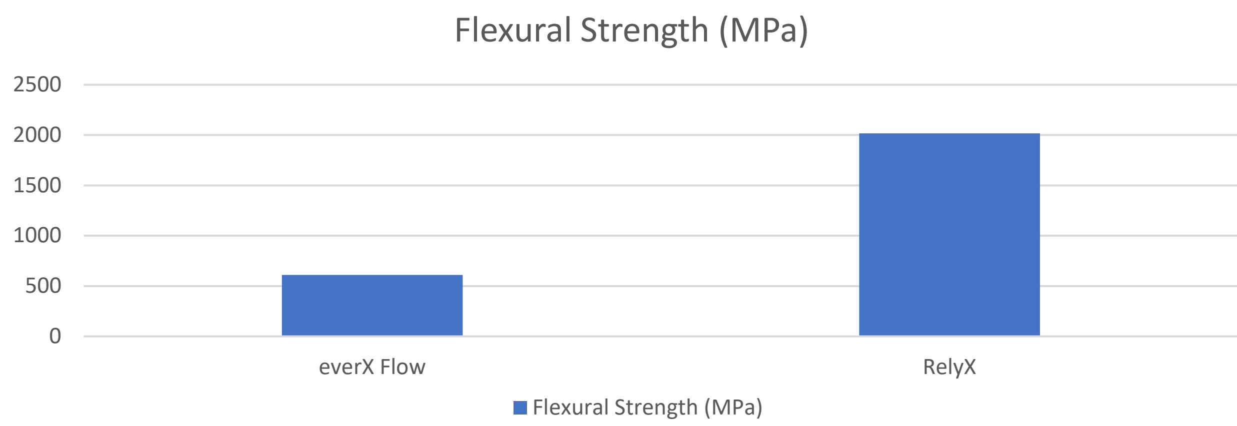
One sample from the ESPE 3M RelyX Fiber Post group was removed as an outlier from the analysis due to having a FS value greater than 2 standard deviations from the group mean. Sample characteristics at maximum load are summarized in Table 1.

A significant difference was found between the composites with respect to FS at maximum load, $P<0.001$. The RelyX samples had a higher mean maximum FS (M = 2018.30 MPa, SD = 165.94) compared to the everX Flow samples (M = 611.32 MPa, SD = 57.01). The effect size for the differences in FS was $\eta^2 = 0.97$, which indicates the significant difference between the two groups which accounts for 97% of the variance. The remaining 3% is error variance due to quality variation within each group or in measurement. Similarly, the RelyX samples endured higher levels of compressive stress at maximum load (M = 104.28 MPa, SD = 18.56) compared to the everX Flow samples (M = 32.26 MPa, SD = 3.01), $P < 0.001$.

Table 1. Material Characteristics at Maximum Load, M(SD)

Material	everX Flow	RelyX	P[1]	η^2
Flexural Strength (MPa)	611.32 (57.01)	2018.30 (165.94)	<0.0001	0.97
Compressive Stress (MPa)	32.26 (3.01)	104.28 (18.56)	<0.001	0.88
Deflection (mm)	0.22 (0.02)	0.41 (0.14)	<0.001	0.47

1. Significance based on ANOVA.



Finally, examining the mean deflection at maximum load revealed a difference consistent with the FS findings above (P<0.001). The RelyX group showed a mean deflection at maximum load of 0.41mm (SD = 0.14) compared to a mean of 0.22 (SD = 0.02) among the everX Flow samples. This corresponds with a modulus of elasticity for the RelyX and everX Flow groups of 5538MPa and 2926MPa respectively.

DISCUSSION

The design of this study centered on the production of everX Flow posts in an ideal setting: complete moisture control and circumferential light curing, In the testing of various aspects of strength, the pre-fabricated ESPE 3M posts performed significantly better than the group indirectly fabricated with the everX Flow short fiber reinforced material.

If the trial results had a near comparable performance, then the everX Flow could possibly deliver desirable applications. Fabrication of posts on-demand might be desirable, and the clinical in vivo fabrication of a post/core complex could be very advantageous. Depth of cure has always been a critical limiting factor in the complete polymerization of composite materials, and that obstacle remains the same with both PFCs and SFRCs. Even if everX Flow in vitro fabricated posts demonstrated acceptable strength, the intraoral fabrication of such posts could only be polymerized into a short depth within the root canal space. Depth of cure restrictions could be overcome with auto-polymerizing composites, but those materials with proven adequate strength have yet to be developed.

Another hypothetical advantage of a direct intraoral post fabrication material would be the conservation of tooth structure. This would prevent the removal of sound dentin to the precise dimensions of pre-fabricated posts. Direct fabrication could also take advantage of irregularities within the root canal space and thereby help with retention- a common issue with fiber post systems.

CONCLUSION

If only comparing facets of physical properties, the use of the novel short fiber reinforced composite product (everX Flow) as viable alternative with comparable flexural strength and physical properties to that of pre-fabricated fiber posts (RelyX) may not have been established. The data clearly shows the superior strength of RelyX versus everX Flow in the comparative analysis. Continued advancements in the field of dental materials may eventually develop products that could perform at the same level, or even better, than present pre-fabricated fiber post systems. More research and development of innovative materials in this specific field could lead to the next restorative dentistry breakthrough.

AUTHOR CONTRIBUTIONS

Joseph Lowe contributed to conception, design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript. Thomas Beltran contributed to design, analysis, and data interpretation. Research Advisor Garrett Wood contributed to research design and manuscript editing.

DECLARATION OF CONFLICTING INTERESTS

The authors and contributors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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