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Effect of dimethyl sulfoxide on bond strength of individually formed posts with different polymerization conditions – An in Vitro Study

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Abstract

Background: Restoration of endodontically treated teeth with a significant loss of coronal tooth structure requires the placement of a post to ensure adequate retention of a core foundation. Everstick glass fibre reinforced composite post is a soft, flexible and adaptable unpolymerized glass fiber post. Achieving a highly durable bond between the resin cement and root dentin is a critical factor to obtain adequate retention. Presently, Dimethyl sulfoxide is used to treat the root dentin to preserve the bond stability of resin dentin interface. The purpose of this study was to compare the effect of Dimethyl Sulfoxide on bond strength of everstick posts cemented with dual cure resin cement with different polymerization conditions.

Method: Forty samples of extracted human maxillary central incisors were used in this study. All the samples were sectioned 2mm above cementoenamel junction followed by root canal treatment. Post space preparation was carried out for all samples. They were divided into 2 main groups based on their cementation technique; Group A (indirect technique: n=20) Fibre post was cured inside the canal followed by complete curing outside the canal and cemented with dual cure resin cement. Group B (direct technique: n=20): Unpolymerized fibre post was cemented with dual cure resin cement and cured together inside the canal. Each group was again divided into two subgroups. Subgroup 1(n=10) and Subgroup 2(n=10) ; root canal space was treated with distilled water and dimethyl sulfoxide respectively. All the samples were mounted in autopolymerizing resin block and tested to check for pull out bond strength in universal testing machine with crosshead speed of 0.5mm/min.

Results: The results of the present study showed the maximum bond strength in group A (subgroup 2) followed by group B (subgroup 2), group A (subgroup 1) and group

B (subgroup 1) respectively. The combination of prepolymerized fibre post with dimethyl sulfoxide treatment yielded highest mean bond strength and lowest was recorded in combination of distilled water treatment with prepolymerized post.

Conclusion: Prepolymerized posts (indirect technique) showed significantly higher bond strength values than unpolymerized (direct technique) posts. Also, Dimethyl sulfoxide treated root canal space showed significantly higher bond strength values when compared with distilled water treated root canal space for both prepolymerized and unpolymerized posts.

Keywords: Everstick, dimethyl sulfoxide, pull out bond strength, dual cure resin cement, prepolymerized, unpolymerized.

Introduction

Restoration of endodontically treated teeth with a significant loss of coronal tooth structure requires the placement of a post to ensure adequate retention of a core foundation. Traditionally, cast metal posts and core have been used to provide necessary retention for the subsequent restoration.[1]

Currently, the fiber posts are perceived as a promising alternative to cast metal posts producing favourable stress distribution and providing better esthetic outcomes.

The usage of Everstick glass fibre reinforced composite post is a novel method introduced lately for restoring mutilated tooth. It is a soft, flexible and adaptable unpolymerized glass fiber post[2]

An individually formed fibre reinforced composite post can be polymerized in situ in the root canal thus precisely following the shape of the canal. The manufacturer's recommendation has been to light polymerize in two phases first a short curing is carried out when the post is placed inside the root canal after that final curing is carried out to ensure complete curing of the post[3]. The present study compares this procedure with a simplified technique of polymerization.

Achieving a highly durable bond between the resin cement and root dentin is a critical factor to obtain adequate retention. Presently dimethyl sulfoxide is used to treat the root canal space to enhance the bond stability of resin dentin interface.

Dimethyl Sulfoxide (DMSO) is a dipolar aprotic solvent which has the ability to dissociate the highly cross-linked collagen in the dentin matrix[4]. This allows DMSO to efficiently penetrate biological surfaces, which makes it perhaps the best currently known penetration enhancer for medical purpose.

As DMSO has good penetrating effect, this study assessed the effect of Dimethyl Sulfoxide on bond strength of everstick posts cemented with dual cure resin cement with different polymerization conditions.

Materials and Methodology

Specimen preparation

40 extracted non carious, human maxillary central incisor teeth were selected, cleaned and stored in 10% formalin and 0.2% thymol. Teeth were decoronated 2mm above the Cemento enamel junction.

Root canal preparation

Root canals were prepared with K files followed by obturation with guttapercha cones using Zinc oxide eugenol sealer. Root canal filling material were removed with gates glidden drill. These specimens were divided into 2 main groups.

Group A (indirect technique: n=20): Fibre post was cured inside the canal followed by complete curing outside the canal and cemented with dual cure resin cement.

Group B direct technique: n=20): Unpolymerized fibre post was cemented with dual cure resin cement and cured together inside the canal. Each group was divided into 2 subgroups

Sub group 1: Root canal space was treated with distilled water.

Subgroup 2: Root canal space was treated with dimethyl sulfoxide.

Post space preparation

Group A: Parapost drill was used to prepare the root canals followed by irrigation with water. The root canals were acid etched with 37% phosphoric acid for 30 seconds and rinsed with water. Then the specimens were divided into 2 subgroups[n=10] in which one group acts as a control and the other group was treated with 1ml of 5% DMSO aqueous solution for 60 seconds. In all the groups solutions were delivered into the root canals with a disposable syringe having 30 gauge needles.

The root canals were dried with paper points and treated adhesive for 30 seconds. This adhesive layer was dried with gentle air. Before cementation, everstick post of 1.5mm diameter was initially light polymerized inside the root canal for 20 seconds. After that final curing was carried out outside the canal for 40 seconds.

Base paste and catalyst paste were mixed and delivered into the canal followed by post placement. Both the post and the cement were cured together for atleast 20 seconds from above the post.

Group B: Preparation of root canals was same as Group A. The single unpolymerized fibre post was inserted into the root canal after cement placement. Post and cement were then be cured together for 30 seconds.

Mounting of specimen: Each specimen was mounted on an autopolymerizing resin block. All samples were numbered 1 to 20 for group A and 21 to 40 for group B.

Testing bond strength

Fabricated specimens were stored in distilled water at 37^{o}C. After that specimens were secured in a universal testing machine (Instron). Post was dislodged by grasping the post head and pulling the post along its long axis. A constant loading rate of 0.5mm/min was applied until debonding occurred. The peak force was recorded at the point of extrusion of the post from the tooth root. Force was recorded in Newton.

Statistical analysis

The categorical variables were presented as frequency tables and represented graphically. The quantitative data was described using descriptive statistics like mean and standard deviation/ median whichever is applicable. Graphical representations were made wherever necessary. The decision criterion is to reject the null hypothesis if the p value is less than 0.05.

Results

Higher mean bond strength values were recorded in group A (prepolymerized) when compared to group B (unpolymerized). The difference in mean bond strength values were found to be statistically significant.(Table 1)

Fiber post	Mean	Standard deviation	Lowest mean	Highest mean
Group A	155.80	47.10	135.03	176.57
Group B	129.98	37.10	113.72	146.24

Table 1

Higher mean bond strength values were recorded in subgroup 2 (DMSO) when compared with subgroup 1 (distilled water). The difference in bond strength values amongst the groups were statistically significant (Table 2)

Fiber post	Mean	Standard deviation	Lowest mean	Highest mean
Distilled water	155.80	47.10	135.03	176.57
DMSO	129.98	37.10	113.72	146.24

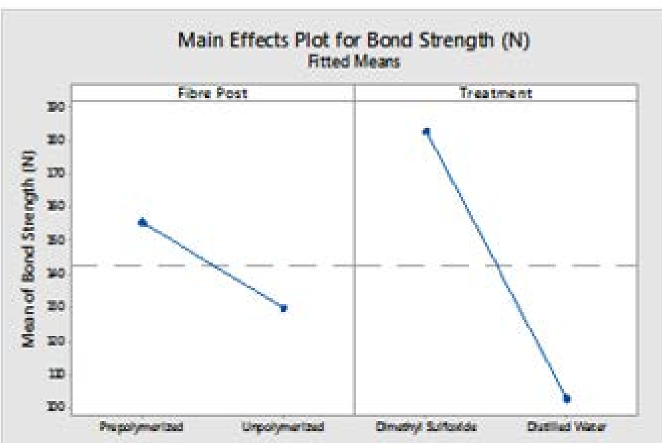
Table 2

Higher mean bond strength values were recorded in group A (subgroup 2) followed by group B (subgroup 2), group A (subgroup 1) and group B (subgroup 1) respectively. The combination of prepolymerized fibre post with

DMSO treatment yielded highest bond strength and lowest was recorded in combination of distilled water with prepolymerized post. The joint effect of fibre post and treatment was found to be statistically significant (Table no 3).

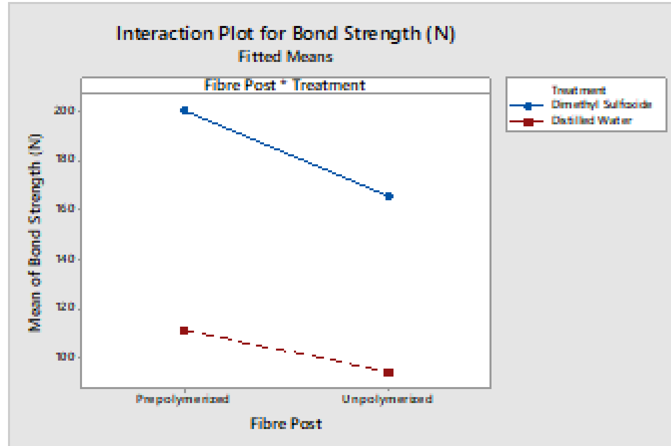
Fiber post	treatment	Mean	Lowest mean	Highest mean
Pre-polymerized	Distilled water(1)	111.29	106.7	115.84
	DMSO (2)	200.28	189.81	210.7
Unpolymerized	Distilled water (1)	94.43	91.47	97.39
	DMSO (2)	165.53	160.19	170.87

Table 3



Graph 1

This main effect graph shows two plots where in one plot is for the technique used (prepolymerized and unpolymerized) and the other one is for the treatment done (DMSO and distilled water). In plot 1, prepolymerized post shows higher mean bond strength values than unpolymerized post. In plot 2, DMSO shows higher mean bond strength values than distilled water.



Graph 2

This interaction plot shows the mean bond strength values recorded in combination of the technique used (prepolymerized and unpolymerized) and the treatment done (DMSO and distilled water). The combination of prepolymerized fibre post and DMSO treatment shows higher bond strength values whereas the combination of unpolymerized and distilled water shows lower values.

Discussion

Endodontically treated teeth are known to present a higher risk of biomechanical failure than vital teeth. Posts are generally indicated to restore missing tooth structure. The choice of an appropriate restoration for endodontically treated teeth is guided by strength and esthetics. Available prefabricated posts were traditionally made of metal, and their use resulted in complex combinations of materials (dentin, metal posts, cements, and core materials) with different degrees of stiffness.

Newer tooth-colored posts have improved the esthetics of teeth restored with posts and cores. Based on the current literature, placement of a post should be considered only when the remaining cervical tooth tissue can no longer provide adequate support and retention for a restoration. Although the most common complication in post-core retained treatment is crown debonding, root fracture is still the complication that results in the greatest damage. When using posts, factors such as the length, design, and material of the post should be considered.

Glass fiber–reinforced resin post systems were introduced in 1992. These posts are composed of unidirectional glass fibers embedded in a resin matrix. Matrix polymers are commonly epoxy polymers with a high degree of monomer conversion and a highly cross-linked structure. An advantage of glass fibers is that they distribute stress over a broad surface area, increasing the load threshold at which the post begins to show evidence of micro-fractures. Consequently, fiber-reinforced posts are reported to reduce the risk of tooth fractures and display higher survival rates than teeth restored with rigid zirconia posts.

The main advantages of FRC posts over metal posts include improved restoration esthetics, adhesive bonding to tooth structure, and an elastic modulus closer to that of dentin. The similar elastic modulus provides homogeneous stress distribution in the canal and a lower risk of root fracture with favorable biomechanical properties. Although resin-based materials for prefabricated FRC posts are compatible with adhesive restorative techniques, their highly cross-linked structure and high degree of conversion do not allow the monomers of composite resin luting cements to penetrate and achieve chemical bonding. Thus, to improve this interaction, the fiber posts must be surface treated with a silane coupling agent. The root canal dimensions should be adjusted to the predefined size of the posts by using the corresponding drill, but this can sometimes require considerable dentin removal in the apical parts, weakening the tooth root. Furthermore, 25% of tooth roots have elliptical canals, so prefabricated posts with a circular cross section do not fully fit in those canals. Lack of fit could jeopardize bonding and the long-term clinical success of a tooth restored with an FRC post.

To avoid preparing the root canal and to enhance the adhesion between polymer-based materials and luting cements, a new type of post that can be polymerized in situ in the root canal has been introduced.

These posts are formed in the dental office and are made of unidirectional, silanated E-glass fibers impregnated with a combination of polymethyl methacrylate as a linear phase and bisphenol A glycidyl methacrylate as the cross-linked phase, which together form a semi-inter penetrating polymer network (semi-IPN). Because of the unpolymerized semi-IPN, the monomers of adhesive resins and cements can diffuse into the polymethyl methacrylate, and by polymerization, they form inter diffusion bonding and so-called secondary semi-IPN structure.

With individually formed IPN posts, it is not necessary to adjust the root canal to the shape of the post. Rather, the post is adapted to the morphology of the root canal, and in the case of very large coronal openings, additional material can be easily added. According to the manufacturer, the risk of perforation is reduced, stress in the apical parts of the root canal is minimized, and adhesive surface is maximized. Therefore, it could be assumed that this kind of structure has fewer or no voids. It has already been suggested that absence of voids at the fiber post resin cement interface indicated a good bond between the post surface and resin cement.

An individually formed FRC post can be polymerized in situ in the root canal, thus precisely following the shape of the canal. In situ polymerization of an individually formed FRC post enables free radical polymerization to occur between the resin matrix of the FRC post and the composite resin luting cement. An oxygen inhibition layer is formed on the coronal part of the post, which allows free radical polymerization between the post and core-built-up composite resin.

The manufacturer's recommendation has been to light-polymerize in two phases; first a short curing is carried out when the post material is placed in the root canal to copy the anatomical shape of the canal. After when the post material is placed in the root canal to copy the anatomical shape of the canal. After that the final curing is carried out after removing the post from the canal, in order to ensure complete curing also at the apical parts of the post. The final cementation of the individually formed FRC post is carried out in the same way as with the conventional solid prefabricated FRC posts (indirect technique).

However, in spite of the advantages of the minimal invasive preparation, the extra clinical steps, when forming the uncured individual FRC post, can make the use of this post material clinically more complicated and may need simplification if important properties of bonding and cement sealing are not compromised. So dominica et al proposed a simpler technique in which individually formed FRC post was polymerized together with luting cement directly in the root canal (direct technique).

Achieving a highly durable bond between the resin cement and root dentin is a critical factor to obtain adequate retention5. Presently dimethyl sulfoxide is used to treat the root dentin to preserve the bond stability of resin dentin interface.

In this study, the bond strength of glass fibre reinforced composite (FRC) post to root dentin with different polymerization techniques was evaluated. The samples used in this study were carefully selected and they were divided into two main groups (A and B) according to the polymerization method with group A being prepolymerized fibre post and group B being unpolymerized fiber post.

Results showed higher mean bond strength with respect to group A (prepolymerized) when compared with group B (unpolymerized) and the difference between them were statistically significant.

Groups A and B were again divided into subgroup 1 and 2 where in subgroup 1, root dentin was treated with distilled water and in subgroup 2 with dimethyl sulfoxide.

Despite the differences between the two polymerization techniques used in this study, when comparing the distilled water group and DMSO group, the latter yielded a higher bonding stability. The residual water causes phase separation of the hydrophilic and hydrophobic components of adhesives, preventing complete monomer penetration into the full depth of demineralized dentin. This is due to the fact that hydrophobic methacrylates are insoluble in water-saturated dentin. The created porous hybrid layer is responsible for the instability of resin dentin bonds. These factors could explain the observed reduction of bond strength because sufficient resin impregnation of the intra radicular dentin is clinically more difficult than that of the coronal dentin.

DMSO, as an additional primer on acid-etched root dentin improved the bond strength in this study. The number of adhesive failures at the root dentin-cement interface in the DMSO-treated group was less than the distilled water group. This finding might be attributed to unique properties of DMSO. The dissociative effect on demineralized dentin collagen was indicated with high concentration of DMSO. This effect may not be adequate with low concentration of DMSO used in this study to influence bond durability positively. However, DMSO treatment might result in enhanced collagen wetting by adhesive and subsequent adhesive penetration into the acid-etched exposed collagen. Therefore, resin impregnation of the demineralized dentin could be more complete.

The retention test carried out was pull-out test. Pull out test was selected in this study to measure bond strength because it provided the highest values of bond strength than push out and microtensile bond strength test due to stress distribution in all post surfaces and low stress values in the bond interface and the results in shear force are comparable to clinically findings. This may be a consequence of the design as well, where the tensile load was applied farther away from bond interface than the compression load in the push out test. The alignment of the testing apparatus was visually approximated to the longitudinal axis of the post. Treated teeth were kept in water for 24 hours before pull-out testing. Each specimen was subjected to a tensile force parallel to the longitudinal axis of the posts (Instron; x-head speed, 0.5 mm/min)until post separation. The pull-out force (N) was recorded for each specimen. Statistical analysis was performed using statistical software (SPASS version 20). Data were analyzed using ANOVA and the coefficient of variance as the ratio of the standard deviation to the mean.

The use of DMSO treatment as an extra step in the complex bonding procedures in root canal space may be considered a disadvantage. To solve this, DMSO could be possibly incorporated into adhesive compositions because it is able to solvate commonly used adhesive monomers and is fully miscible in all the solvents. The compatibility of this combination in short- and long-term bond strength tests should be evaluated in future studies.

In this in vitro study, the intraoral conditions were not simulated. A single load testing on bonded root without thermo mechanical cycling was used. These were considered as the limitations of the current study.

Conclusion

1. Prepolymerized posts (indirect technique) showed significantly higher bond strength values than unpolymerized (direct technique) posts.
2. Dimethyl sulfoxide treated root canal space showed significantly higher bond strength values when compared with distilled water treated root canal space for both prepolymerized and unpolymerized posts.

Legend Figures

Fig 1: post space preparation

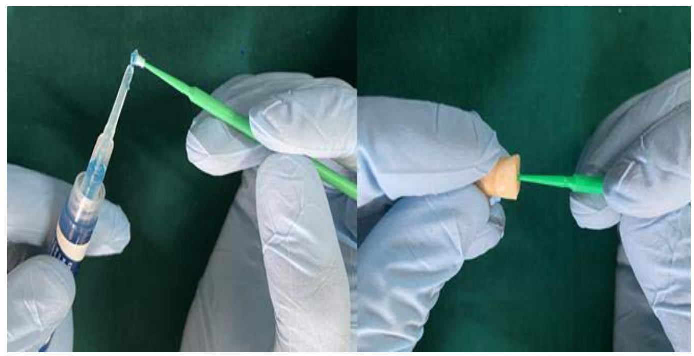


Fig 2: Application of etchant to root dentin

Fig 3: Treatment of root dentin with distilled water

Fig 4: Treating root dentin with DMSO

Fig 5: Application of bonding agent

Fig 6: Delivery of cement into prepared post space

Fig 7: Everstick post

Fig 8: Prepolymerization of Everstick post

Fig 9: Placement of post into the post space

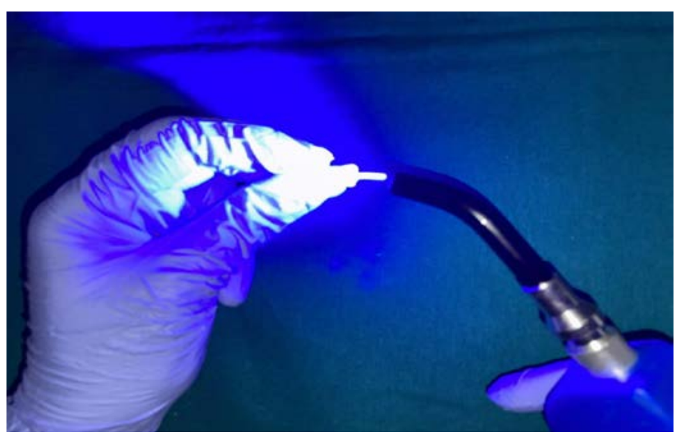


Fig 10: light curing glass giber post with cement

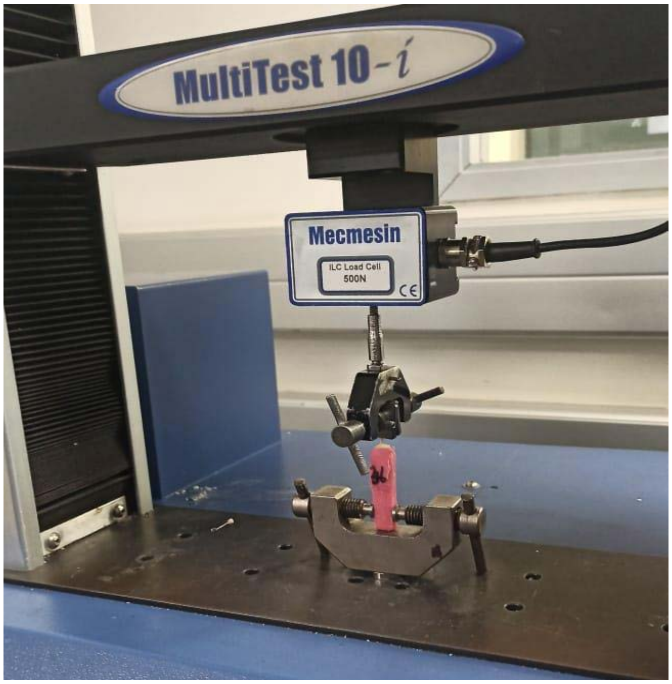


Fig 11: Sample placed in UTM for pull out test

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