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Original Article

The effect of pressure changes during simulated diving on the pull out strength of glass fiber posts

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ABSTRACT

Background: Scuba diving is one of the fastest growing sports in the world. The objective of this study was to evaluate the effect of pressure variations to which divers are exposed on the pull out strength of glass fiber post luted with different cements.

Materials and Methods: In this *in vitro* study, 120 extracted, single-rooted lower premolars were endodontically treated. They were randomly divided into six groups and restored using the glass fiber post (Ivoclar Vivadent AG) and the following luting agents: Zinc phosphate, conventional glass ionomer, resin reinforced glass ionomer, resin cement with etch-and-rinse adhesive, resin cement with self-etching adhesive, and self-adhesive resin cement. Each group was randomly divided into two equal subgroups, one as a control, and the other to be used experimentally. After 7 days of storage, experimental groups were pressure cycled. The force required to dislodge each post was recorded in Newton (N) on Universal testing machine (Star Testing System) at a crosshead speed of 1 mm/min. Data were statistically analyzed using the ANOVA and Student's *t*-test ($P < 0.001$).

Results: The pull out strength of posts cemented with zinc phosphate and conventional glass ionomer in pressure cycle group was significantly less than their control group. Although, no significant difference was found between pressure cycle and control group using resin reinforced glass ionomer cement and resin cements.

Conclusion: Dentist should consider using resin reinforced glass ionomer or resin cement, for the cementation of glass fiber post, for the patients such as divers, who are likely to be exposed to pressure cycling.

Key Words: Baro-trauma, diving, fiber post, luting cement, pull out strength, scuba

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INTRODUCTION

An oral (dental or non-dental) pain caused by change in barometric pressure in an otherwise asymptomatic organ is known as barodontalgia. The name of this dental pain was given the prefix "aero" (i.e., aerodontalgia) and was reported for the first time as an in-flight physiologic and pathologic phenomenon at the beginning of the 20th century. In the 1940s, with the appearance of scuba, many in-flight manifestations caused by barometric changes were found to be associated with diving as well. Consequently, the prefix was changed to "Baro."[1,2] Barotrauma is a pathological response to changes in barometric pressure that occur during flying, diving or hyperbaric oxygen therapy.[1]

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In recent years, it has become increasingly common to go to a tropical destination for a holiday. There is often an opportunity to dive. Furthermore, scuba diving is one of the fastest growing sports in the world.[3] A diver at 30 m is subjected to four times the pressure encountered on the surface.[4] Previous literatures reported that, the pressure changes can affect retention of restoration[5,6] and crown.[4,7,8] Although this subject is rarely and only briefly discussed in dental text books,[9] it is important for a dentist to be aware of the effect of pressure changes on other dental components in term of retentive strength as danger resulting from dislodgement of component during a dive is obvious.

Endodontically treated teeth may be damaged by decay, excessive wear or previous restorations, resulting in a lack of coronal tooth structure. The restoration of endodontically treated teeth with a significant loss of coronal tooth structure may require the placement of a post to ensure an adequate retention of a core foundation.[10] The most common luting agents used for cementing post are zinc phosphate, resin, glass ionomer, and resin reinforced glass ionomer cements. The recent trend has been toward resin cements because they increase retention,[11-13] tend to leak less than other cements[14-16] and provide atleast short term strengthening of the root.[17] Some luting resins are used with a separate etchant and primer (etch-and-rinse method), where as others contain an acidic primer in the luting cement (self-etching primer). More recently, a third category has been added (self-adhesive method), in which there is no etching and no primer.

Amaral *et al*.[18] found that the glass fiber posts cemented with resin cement and the etch-and-rinse adhesive system presented higher pull out strength when compared to the resin cement with self-etching adhesive and self-adhesive resin cement. Post length and relining procedure are also key factors for improving the retention of glass fiber post.[19] Cecchin *et al*.[20] evaluated the effect of different root canal sealers on the bond strength of glass fiber post cemented with resin cement, found that the eugenol-based sealer inhibit polymerization of resin cement, negatively affecting the bond strength.

However, whether the pressure variations that the divers are exposed affects the retention of a post is still unknown. The aim of this study was to investigate the effect of pressure variations to which scuba divers are subjected on the pull out strength of glass fiber post luted with different luting cements.

MATERIALS AND METHODS

In this *in vitro* study, 120 extracted; single-rooted lower premolars, with straight root canals were selected. The inclusion criteria were: Straight roots; absence of root decay, defects, cracks, and/or previous endodontic treatment; and root length of atleast 15 mm. The selected teeth were cleaned of both calculus deposits and soft tissue using ultrasonic scaler. Each tooth was placed in 5.25% sodium hypochlorite for 2 h for surface disinfection[21] then stored in distilled water and prepared within 1 month of extraction. The coronal portion of each tooth was sectioned at the cemento-enamel junction perpendicular to the longitudinal axis using a slow-speed, water-cooled diamond disc (Isomet 2000, Buehler Ltd., Lake Bluff, IL, USA).

All root canals were prepared by one trained operator and the root canal of each tooth was explored using a size 06K-File (Dentsply Maillefer, Ballaigues, Switzerland). Roots lesser than 15 mm in length and with significantly smaller or larger root canal spaces were discarded to standardize the extent of dentine preparation for the posts as much as possible. Endodontic treatment was carried out following a standard crown-down technique using the profile system (Dentsply Maillefer, Ballaigues, Switzerland) and the X-Smart-Endo-Motor (Dentsply Maillefer, Ballaigues, Switzerland). The apical foramen was prepared to size 40 and 0.06 taper. The root canal was irrigated between instruments with 2 mL of 5.25% sodium hypochlorite. Final irrigation was carried out with 2 mL of 17% Ethylene Diamine Tetraacetic Acid (EDTA) solution for 3 min followed by 5 mL of distilled water. The root canals were dried with absorbent paper points (Sure Dent Corporation, Seongnamsi Gyeonggi-do, Korea) and filled with epoxy based endodontic sealer (AH Plus, Dentsply Caulk, Milford, DE, USA) and 0.06 taper gutta-percha points (Dia-dent Gutta-percha points, DiaDent Group International, Chongchong Buk Do, Korea) using the cold lateral condensation technique. Extra coronal excess of gutta-percha was removed using the heated instruments. The canal access was sealed with a temporary restorative material (Cavit G, 3M ESPE, St. Paul, MN, USA).

After storage at 100% humidity for 1 week at 37°C, the coronal seal was abraded by means of #240 Silicon Carbide (SiC) paper under water cooling and the gutta-percha was removed with Largo Peeso Reamer #1 (Dentsply Maillefer, Ballaigues, Switzerland), using the surgical operating microscope (D. F. Vasconcellos, M900-25X, SãoPaulo, Brazil), leaving 5 mm of apical seal. The post space was then prepared with FRC Postec Plus Reamer #1 (Ivoclar Vivadent AG, Schaan, Liechtenstein) to a fixed depth of 10 mm from cement-enamel junction. The canal was irrigated and dried as described previously.

Each root was embedded into a Poly-Vinyl Chloride (PVC) cylinder (height: 35 mm, diameter: 15 mm) filled with chemically cured acrylic resin (Orthocryl, Dentaurum, Ispringen, Germany) using the following steps: Micro retention were carried out with diamond burs at the apical third of each root, perpendicular to its long axis, promoting retention during the pull out test; FRC Postec Plus Reamer #1 was placed inside the prepared root canal; the reamer (with the root) was attached to an adapted surveyor (Degussa, Geschaftsbereich Dental, Frankfurt, Germany), where the long axes of the reamer, specimen and cylinder were parallel to each other and perpendicular to the ground [Figure 1]; the acrylic resin was prepared and poured inside the cylinder upto 3 mm of the most coronal portion of the specimen. Immediately after the acrylic reached its doughy stage, samples were detached from the surveyor and placed into a cool water bath so that polymerization reaction heat from the setting acrylic diffused away from the samples; when the acrylic had cooled to bath temperature, the samples were dried with compressed air and bench dried for 2 h.

Samples were randomly divided in six groups of 20 samples each, depending on luting cement used for inserting fiber post. FRC Postec Plus glass fiber post #1 (Ivoclar Vivadent AG, Schaan, Liechtenstein) of tip diameter 0.08 mm and head diameter 1.5 mm were tried in. The cements used and detail of luting procedure are described in Table 1. Cements of Groups 1, 2, 3 were inserted into the root canal with Lentulospiral (Dentsply Maillefer, Ballaigues, Switzerland). The posts were inserted as close as possible to the centre of the post space, to maintain as even film thickness of cement circumferentially.

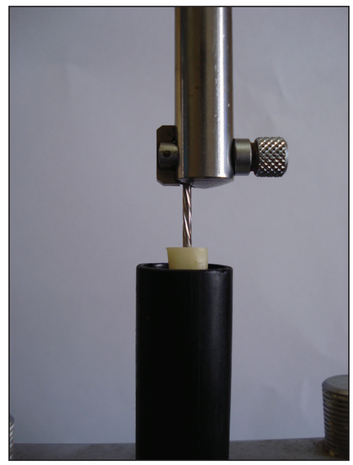

Figure 1: Sample being mounted using surveyor

Table 1: Description of cements used in this study and the application protocols

Group	Cement type	Brand name and lot number	Application protocol
1	Zinc phosphate cement	DeTrey Zinc (powder: 1003001659, liquid: 1003101049); Dentsply DeTrey GmbH, Konstanz, Germany	The cement was prepared with standard powder to liquid ratio of 2.8 g: 1 g and mixed for 90 s
2	Conventional glass ionomer cement	GC Gold Labal Luting and lining cement (powder: 1105091, liquid: 1104211); GC Corporation, Tokyo, Japan	The cement was prepared with standard powder to liquid ratio of 1.8 g: 1 g and mixed for 20 s
3	Resin-modified glass ionomer cement	GC FujiCEM (1101071); GC Corporation, Tokyo, Japan	The canal walls were prepared with GC Fuji Plus Conditioners for 20 s, followed by thorough rinsing with distilled water and drying with paper points. The cement was prepared following the manufacturing instructions and mixed for 10 s
4	Resin cement with etch-and-rinse adhesive	FluoroCore2+ with Prime and Bond NT and self cure activator (110823); Dentsply DeTrey GmbH, Konstanz, Germany	The canal walls were etched with 34% phosphoric acid for 15 s, rinsed for 10 s, and gently air dried. Excess water was removed from the post space with paper points. Prime and Bond NT and self cure Activator mixed in 1:1 ratio. The mixture was applied onto the post surface and into the post space using microbrush, left it in place for 20 s. Dried by gentle air flow for 5 s. Cured for 10 s. FlooroCore2+ was dispensed from auto mix syringe onto the post surface and into the post space
5	Resin cement with self-etching adhesive	Multilink N with Multilink N Primer A & B (P21069); Ivoclar Vivadent AG, Schaan, Liechtenstein	Multilink N primer liquids A and B mixed in a 1:1 ratio. Mixed preparation was applied into post space using a microbrush, left it in place for 15s. Excess material was removed with paper point. Multilink N was dispensed from auto mix syringe onto post surface
6	Self-adhesive resin cement	Multilink speed (P49709); ivoclar Vivadent AG, Schaan, Liechtenstein	Multilink speed was dispensed from auto mix syringe into post space

The excess of luting material was removed. Dual-cure luting resin cements of Groups 4, 5, 6 were polymerized from the coronal side of the post with Litex 695 (Dentamerica, CA, USA) with a light output not less than 800 mW/cm^2 for 20 s, holding the curing light close to post.

Each group was randomly divided into two subgroups of 10 samples, one to act as a control, and the other to be used experimentally. At 30 min after the cementation procedures, the specimens of control groups and experimental groups were stored in distilled water and 0.9% NaCl solution respectively for 1week at 37°C.[7,8] All the experimental samples, in open glass containers were then placed in a pressure pot. Compressed air was introduced into the pressure pot at a rate of 1 atmosphere/min, allowing the maximum pressure to be reached in 3 min. The posts in the pressure pot were subjected to 3 atmospheres pressure for 3 min and then decompressed over a 3 min period. The 15 cycles were repeated one after the other.[4,7,8]

A hole was prepared in the inferior third of the PVC cylinder for attachment to the inferior portion of a universal testing machine (Star Testing System, Mumbai, India). An adapted mandrel fixed to the upper part of the testing machine grabbed the coronal part of the fiber post [Figure 2].[18] The pull out test was performed at a crosshead speed of 1 mm/min, until the post were dislodged from the roots. The maximum force to dislodge each post was recorded in Newton (N). Dislodged posts were also examined under surgical operating microscope (D. F. Vasconcellos, M900-25X, SãoPaulo, Brazil) at a magnification of ×25. The type of failure was classified in five categories:

a. Adhesive between post and cement (no cement visible around the post);
b. Mixed with cement covering 0-50% of post diameter;
c. Mixed with cement covering between 50% and 100% of post surface;
d. Adhesive between cement and dentine (post enveloped by cement);
e. Cohesive in dentine.

The statistical analysis was performed using the statistical analysis software SPSS 15.0 (Chicago, IL, USA). Descriptive statistics that included mean and standard deviation were calculated. Data were subsequently analyzed using the ANOVA variance to determine whether significant differences exist among tested groups. Further, Student's *t*-test was carried out to determine whether significant differences existed among the control and experimental sub-groups. Significance for all statistical tests was predetermined at $P < 0.001$.

RESULTS

The mean pull out strength values of each group are shown in Table 2. The pull out strength of posts cemented with zinc phosphate and conventional glass ionomer cement in pressure cycle group was significantly less than their control group. Although, no significant difference was found between the pressure cycle group and the control group using resin reinforced glass ionomer cement, resin cement

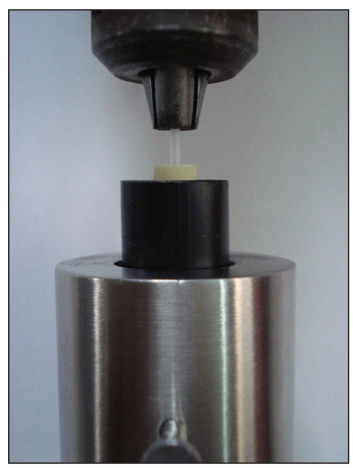

Figure 2: Pull out strength test

Table 2: Mean pull out strength (N) and standard deviations for the study groups

Group	Cement type	Control N±SD	Pressure cycled N±SD	*P* value
1	Zinc phosphate cement	112.1±18.3	52.1±17.4	<0.001*
2	Conventional glass ionomer cement	174.2±17.7	141.9±18.4	<0.001*
3	Resin-modified glass ionomer cement	252.2±12.9	246.2±10.2	0.264
4	Resin cement with etch-and-rinse adhesive	399±25.6	378.5±29.9	0.117
5	Resin cement with self-etching adhesive	298.7±13.1	294.5±12.9	0.479
6	Self-adhesive resin cement	256.7±10.3	254.2±12	0.623

*Significant (*P*<0.001)

with etch-and-rinse adhesive, resin cement with self-etching adhesive, and self-adhesive resin cement. Modes of failure varied appreciably between groups [Table 3]. High number of mixed failure was observed for fiber post cemented with zinc phosphate and conventional glass ionomer cement. The failure mode observed for resin reinforced glass ionomer cement and resin cement was predominantly adhesive between fiber post and the cement.

DISCUSSION

The importance of sport dentistry has gained increasing recognition.[22] In recent years, recreational sports diving has become very popular.[3] It is inevitable that the dental practitioner will have patients who participate in sports diving and they should be aware of a number of problem that a diver can experience that are associated with the teeth and related structures.

Post-retained crowns may present mechanical or biological failure,[23] commonly due to loss of retention.[24,25] Thus, endodontic post should have enough retentive strength to avoid the displacement during function. The present *in vitro* study was to investigate the effect of pressure variations to which scuba divers are subjected on the pull out strength of glass fiber post luted with different luting cements.

In the present study, it was found that the pull out strength of glass fiber posts cemented with zinc phosphate and conventional glass ionomer was reduced significantly after pressure cycling. Resin reinforced glass ionomer provided clinically sufficient retention above 200 N, a limit considered as the minimum requirement to ensure clinical success of fiber post[25,26] and was not significantly affected by pressure cycling. The pull out strength of fiber posts cemented with resin cements was also not significantly affected by pressure cycling.

Table 3: Percentage of types of fracture of the specimens submitted to pull out test

Group	Subgroups	a	b	c	d	e
1	Control	10	50	40	0	0
	Pressure cycled	0	50	50	0	0
2	Control	0	50	40	10	0
	Pressure cycled	0	50	50	0	0
3	Control	70	10	10	10	0
	Pressure cycled	60	10	10	20	0
4	Control	50	10	20	10	10
	Pressure cycled	40	20	20	10	10
5	Control	60	10	20	0	10
	Pressure cycled	50	20	20	10	0
6	Control	70	10	10	10	0
	Pressure cycled	60	10	20	10	0

The possible reason for reduction of the retention of glass fiber post cemented with zinc phosphate cement or conventional glass ionomer cement could be associated with Boyle's law, which states that at a constant temperature, the volume of a gas varies inversely with the surrounding pressure.[4] Problem arises when the enclosed spaces containing gases cannot expand or contract to adjust the internal pressure to correspond to the outer pressure. During the mixing process of luting cement, air may become incorporated into mixture, forming voids.[27] The expansion or contraction of these microbubles during pressure cycling, which eventually led to disruption and weakening of cement layer, this could affect the retention of the component.[7] Davidson *et al*.[28] found that micro-cracks appears as a result of volumetric contraction in luting cements, and when subjected to the pressure cycling may have produced tensile stresses that exceeded the cohesive and adhesive strength of the material, resulting in the significant reduction in tensile bond strength. This study confirmed the findings of Musajo *et al.*[4] and Lyons *et al*.[7] that the retention of full cast crowns cemented with zinc phosphate and conventional glass ionomer cement was reduced after pressure cycling.

The retentive strength of glass fiber post cemented with resin modified glass ionomer cement was not significantly affected by pressure cycling; this can be attributed to the higher tensile strength, lower elastic modulus, and greater amount of plastic deformation that can be sustained before fracture.[29] Furthermore, the consistent mixing of the two pastes, always accurately measured with a dispenser, minimizes the variation of mechanical properties of the two paste resin reinforced glass ionomer cements caused by the mixing of powder-liquid type cements.[30] Moreover, the retention of post luted with resin reinforced glass ionomer cement may be related to the frictional retention provided by hygroscopic expansion occurring after cement maturation,[31] which also aids the self-sealing at the dentine-cement interface. The failure mode observed for resin reinforced glass ionomer cement was predominantly adhesive between fiber post and the cement, suggesting the formation of a hybrid layer, and dentine pre-treatment with a weak acid may helped in the removal of the smear layer and increased dentin wetability, there by enhancing adhesion.

Milutinović-Nikolić e*t al*.[27] investigating the porous structure of cements by mercury intrusion porosimetry found that zinc phosphate cement contains higher porosities than glass ionomer cement while resin based cement has the lowest porosities. Davidson *et al.*[28] found that the bond strength of resin cement (Panavia Ex) was not significantly affected by volumetric contraction. In a study that used finite element analysis, Kamposiora *et al.*[32] found that under normal functional loads, resin cements exhibited less average internal stresses than zinc phosphate cement. Brittle cements, such as zinc phosphate and glass ionomer may be subjected to greater internal stresses than resin cements.[7] It is likely therefore that the brittle and porous cements will be affected more by environmental pressure cycling as has been found in this study.

Resin cement with etch-and-rinse adhesive demonstrated significantly higher pull out strength compared to resin cement with self-etching primer and self-adhesive resin cement. It can be assumed that as a result of the preparation of post space on root dentine, a smear layer is created.[33] A previous study investigating the adhesion of fiber posts to dentine showed that the use of phosphoric acid completely dissolved the smear layer, whereas the weaker self-etching primer revealed only partial dissolution of the layer. Both systems were able to etch the underlying dentine. Self-adhesive resin cement lacks in genuine hybridization of the intact bonding substrates.[34] This is in accordance with the present results, which indicate that the pull out strength values depend on the etching capacity of the adhesive systems used.

The clinical significance of this study should be tempered by its limitations. First and foremost, the current study ignores the role of the core material and crown upon the retention of a fiber post. Furthermore, the retention strength was evaluated using a single-tensile load rather than a cyclical compressive-tensile load. The pressure in this study was held only for 3 min, whereas in real life a diver would spend a much longer time under water. It would be interesting to investigate the behavior of cements for longer duration of time. Finally, it must be noted that *in vitro* studies are limited in predicting the success of a material or technique in clinical use. Hence, the need for further *in vivo* and *in vitro* studies with more similar conditions seems rational.

CONCLUSION

Within the limitations of this study, it can be concluded that:

1. The retention of the glass fiber post cemented with zinc phosphate cement or conventional glass ionomer cement is reduced after pressure cycling.
2. Using resin modified glass ionomer cement or resin cement for glass fiber post cementation appear to be good strategy, for the patients such as divers, who are likely to be exposed to pressure cycling.

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