RESEARCH ARTICLE

Effect of types of resin cements on the bond strength of fiber post under simulated dives

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ABSTRACT

Background: Changes in barometric pressure conditions that occur during flying and diving under hyperbaric oxygen conditions were found to influence the retention of dental restorations.

Aim: This experimental laboratory study aimed to evaluate the bond strength of glass fiber posts after being cemented with self-adhesive resin cement (RelyX™ Unicem, 3M ESPE) and self-etch adhesive resin cement (RelyX™ Ultimate, 3M ESPE) under normal atmospheric pressure and hyperbaric pressure cycles that simulate diving conditions.

Methods: A total of 40 extracted, single-rooted mandibular premolars were treated endodontically and randomly divided into two groups according to the cements used for fiber post cementation. Each group was further randomly divided into two equal subgroups that were subjected to normal atmospheric pressure conditions and a simulated hyperbaric condition in a hyperbaric chamber. The pull-out bond strength of fiber posts was tested using a universal testing machine. Data were analyzed using one-way analysis of variance with Tukey post-hoc test ($p<0.05$).

Results: At normal atmospheric pressure the mean value of the pull-out bond strength of RelyX Ultimate cement was significantly higher than that of RelyX Unicem cement. At hyperbaric pressure condition no significant difference was found between the mean values of the pull-out bond strength of RelyX Ultimate and RelyX Unicem cement.

Conclusion: Hyperbaric pressure cycles demonstrated improved pull-out bond strength of glass fiber posts in RelyX Unicem cement but did not have significant effect on pull-out bond strength in RelyX Ultimate cement. Both resin cements have similar pull-out bond strength of glass fibers post after simulated dives.

KEYWORDS: hyperbaric chamber; fiber post; pull-out bond strength; resin cement; simulated diving

INTRODUCTION

Barometric pressure or atmospheric pressure changes are always experienced by those who are involved in diving or flying activities. The barometric pressure is 1 bar atmosphere (atm) at the ground level. The barometric pressure of divers – for instance, during a dive descent underwater – will increase by one atm every 10 meters [1]. Divers will be subjected to a greater pressure when they reach deeper depths. The diving environment creates changes in barometric pressure that can initiate oral pain (dental or non-dental pain) called barodontalgia [2]. Apart from barodontalgia, other dental implications such as fractured dental restorations and reduction of indirect restoration retention have been reported as a result of changes in barometric pressure related to dive activities [3-5]. A study conducted by Ranna et al. reported that a high proportion of recreational divers experienced dental symptoms related to diving and suggested that dental decay and damaged restorations were to be addressed before dive activities [6]. Knowledge among dentists on the effect of change in pressure on retention of dental restoration is important, as divers might be at risk of swallowing dental components as a result of their dislodgement.

Endodontic treatment is one option for a patient who has been diagnosed with irreversible pulpitis due to deep caries, pulpal necrosis, periapical disease or complicated tooth fracture [7]. Endodontically treated teeth are often considered weaker than vital teeth; this is due to the reduction of the coronal portion as a consequence of trauma or extensive loss of tooth structure [8]. In the case where the tooth has significant loss of coronal tooth structure, a post placement is required to ensure and increase an adequate retention of a core restoration after endodontics treatment. This has become one of the preferred choices among dental practitioners [9]. The similar modulus elasticity of glass fiber post and root dentin promotes favorable stress distribution and reduces the complication of vertical root fracture beneath the bone level [10].

The conventional luting agents used for cementing posts are zinc phosphate, resin, glass ionomer, and resin-reinforced glass ionomer cements [11]. Pereira et al. in an in vitro study investigated the used of resin cements and resin-modified glass ionomers (RMGICs) in cementation of fiber posts. They found that the bond strength values that were produced by resin cements were two times higher than RMGICs [12]. Another study by Bitter et al. also reported that resin cements had good mechanical interaction with the root dentin through formation of resin tags that provided micromechanical interlocking between resin and the demineralized root dentin [13]. Resin cement appears to have low shrinkage because of its visco-elastic properties that lead to better intimate contact of the resin cement with the root canal dentin [14].

Changes in pressure experienced by divers can potentially lead to stresses in teeth and fractures in weak areas or sites of restoration. Lyon et al. in 1997 studied the effect of different cements on the retention of full crowns on extracted premolar teeth after environmental pressure cycling changes (up to 3 atm) [15]. The crowns that were cemented with either zinc phosphate cement or glass ionomer cement had significant reduced retention in approximately 90% and 50% of cases, respectively, whereas crowns that were cemented with resin cement did not have reduced retention after pressure cycling. Gulve et al. evaluated the effect of pressure variations toward bond strength of glass fiber posts secured with different cements by using a pressure pot to simulate diving conditions [16], suggesting the use of RMGIC or resin cement rather than zinc phosphate and conventional glass ionomer to cement glass fiber posts. However, the duration of pressure was held for only three minutes.

A research study on simulated diving conditions using a dive chamber at a maximum pressure of 456 kPa found that fiber-reinforced composite (FRC) post luted with adhesive resin cement had highest pull-out bond strength compared to titanium and zirconia posts, and the changes in pressure did not have significant influence on the bond strength in a control and simulated dive condition [17]. This adhesive resin cement involved multiple steps with self-etch adhesive in combination with dual-cure resin cement. The success of the adhesive depends on the accuracy in handling the material inside the canal. The use of self-adhesive resin cement has also been recommended to increase efficiency by reducing the time and potential mistakes in bonding protocol [10]. However, the pull-out bond strength of the glass fiber post among self-adhesive resin cement and self-etch adhesive resin cement under a simulated diving condition using hyperbaric chamber was not explored.

This experimental study aims to evaluate and compare the bond strength of glass fiber post cemented with RelyX^{TM} Unicem resin cement (self-adhesive resin cement) and RelyX^{TM} Ultimate resin cement (self-etch adhesive resin cement) after being exposed to normal atmospheric pressure and hyperbaric pressure condition.

METHODS

This is an in vitro study using 40 extracted human lower premolar teeth that were endodontically treated and restored with glass fiber posts. Ethical approval was obtained from the Research Ethical Committee in The National University of Malaysia. Freshly extracted straight single-rooted premolar teeth with single-canal teeth were used in this study. Each tooth was placed in a 5.25% sodium hypochlorite (NaOCl) solution for two hours for surface disinfection and followed by ultrasonic scaling to remove soft tissue and calculus. Then the extracted teeth were stored in distilled water. Teeth with previous root caries, cracks, curved canals, endodontic treatment, internal resorption or calcification were excluded. The specimens were divided into two test groups of different barometric pressures, which were normal atmosphere pressure and hyperbaric pressure.

Sample preparation

The crowns were decoronated along the cementoenamel junction using a high-speed diamond saw under water cooling. The length from the tip of the root to coronal surface was standardized to 15.0 mm. Root canals were prepared 1 milliliter (mL) short from the apex using ProTaper® Universal Hand Files (Dentsply Maillefer, Ballaigues, Switzerland) to a standardized working length of 14.0 mm. Irrigation was carried out with 2 mL of 2.5% NaOCl solution. Final irrigation was done with 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) solution and followed by rinsing with normal saline. The root canal was dried with paper point and obturated with a warm vertical compaction of gutta-percha with epoxy-based endodontic sealer (AH Plus®; Dentsply DeTrey, Konstanz, Germany). The canal access was sealed with temporary restorative material (Cavit G, 3M ESPE, St. Paul, Minnesota, U.S.).

After one week of storage in 100% humidity at 37°C to allow the sealer to set, post space was prepared on a standardized length of 10 millimeters (mm) and 4mm gutta-percha (GP) was left apically. The post space was prepared with drill size no. 1, followed with drill size no. 2 (RelyX™ Fiber Post). Each canal was flushed with 2 mL of 2.5% NaOCl and 2 mL of saline solution to complete the post preparation procedure.

Each root was embedded into a plastic container (size: 52mm x 15mm x 15mm) filled with cold-cured acrylic. Before embedding in acrylic a microretentive groove was made with diamond bur at the apical third of each root perpendicular to its long axis, promoting retention during the pull-out test. The cold-cured acrylic was prepared and poured inside the plastic container. At the same time, a glass fiber post drill size no. 2 was placed inside the prepared root canal. A surveyor was used to ensure of the parallelism of the glass fiber post drill, specimen and cylinder (Figure 1) before polymerization. After the acrylic polymerized it was removed from the plastic container and dried with compressed air and bench-dried for two hours.

The samples were randomly divided into two groups of 20 samples each. All the samples were rinsed with a saline solution and gently dried with paper point. In the self-adhesive resin cement group, RelyX Unicem (3M ESPE AG, Seefeld, Germany; Lot 607923) cement was mixed according to manufacturer instruction. After that resin cement was applied into the root canal by using Elongation Tip (3M ESPE). The glass fiber post (RelyX Fiber Post, 3M ESPE) size no. 2 was then seated in the root canal and the excess resin subsequently removed. Finally, the light activation (Elipar trilight®; 3M ESPE, Seefeld, Germany) was performed for 20 seconds. In the self-etch adhesive resin group, Single Bond Universal Adhesive (3M ESPE AG, Seefeld, Germany) was applied into the canal space by using a microbrush for 20 seconds. Excess adhesive was removed with air spray and paper points. RelyX Ultimate (3M ESPE, Seefeld, Germany; Lot 612069) was mixed according to manufacturer instruction, glass fiber post (RelyX Fiber Post, 3M ESPE) size no. 2 was coated with mixed cement evenly on the post surface and seated into the canal. Excess resin cement was subsequently removed and light-cured for 20 seconds. All samples were stored at 37°C on wet gauze for 24 hours before exposing to different barometric pressure.

For exposure to higher atmospheric (hyperbaric) pressure condition, the samples were subjected to a descent and ascent rate of 8 meters/minute in a hyperbaric chamber (Hyperbaric Health: Keysborough, Victoria, Australia). A descent was simulated by progressive pressure to a maximum of 5 atm within five minutes followed by a decompression pressure to normal atmospheric pressure in five minutes. The compression cycles were repeated for 15 compression cycles consecutively in order to simulate a recreational diving depth of 40 meters. The other 10 experimental samples from each group of cement were kept on the wet gauze for one month at a normal atmospheric pressure at the ground level, which was equal to 1 atm.

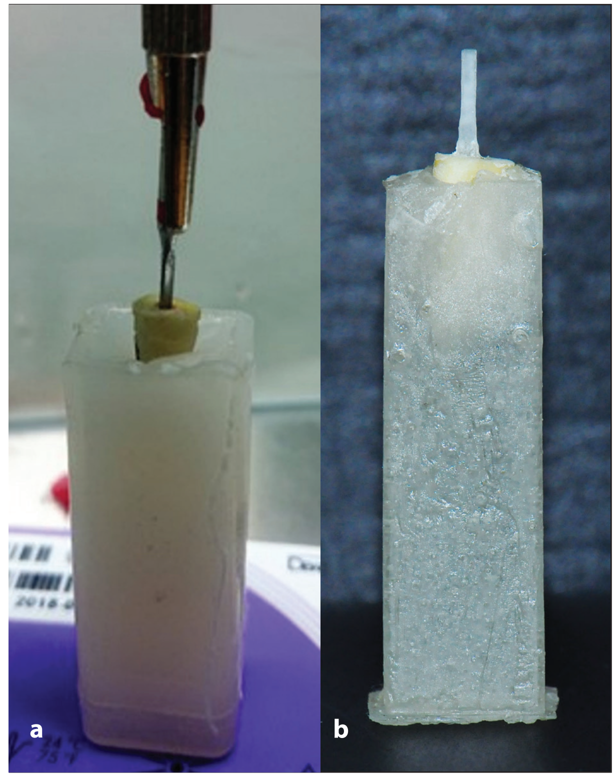


Figure 1: Preparation of samples

a) Root was mounted in acrylic resin using surveyor.

b) Samples mounted in acrylic resin block

Pull-out test

Acrylic resin blocks were mounted to the inferior portion of a Universal Testing Machine (AGS-X series; Shimadzu Corporation., Kyoto, Japan). An adapted metal holder was fixed to the upper part of the testing machine that grabs the coronal part of the fiber post (Figure 2). The pull-out test was performed at a crosshead speed of 1mm/minute, until the post was dislodged from the root. The maximum force to dislodge each post was recorded by the system's software in Newtons (N).

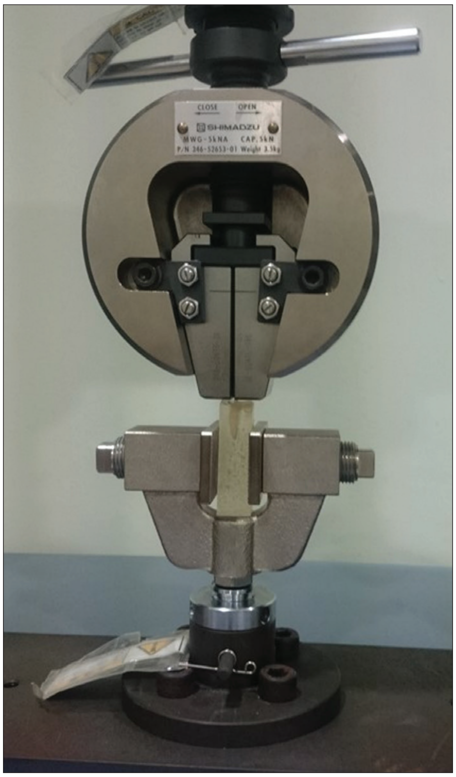


Figure 2: Universal Testing Machine.
Adapted metal holder clamps the fiber post and acrylic resin block mounted at lower metal clamp.

Table 1: Mean pull-out bond strength of glass fiber post

luting cements	barometric pressure	mean pull-out bond strength (N) and standard deviation (SD)
RelyX™ Unicem	atmospheric	148.5 (±35.0)
	hyperbaric	245.8 (±46.3)
RelyX™ Ultimate	atmospheric	299.7 (±77.9)
	hyperbaric	275.0 (±73.4)

Table 2: Tukey's post hoc test for multiple comparison of different groups in p-values

	Un_Atm	Un_Hyp	Ul_Atm	Ul_Hyp
Un_Atm	–	*0.005	*<0.001	*<0.001
Un_Hyp	*0.005	–	0.22	0.71
Ul_Atm	*<0.001	0.22	–	0.80
Ul_Hyp	*<0.001	0.71	0.80	–

p-values of pairwise comparison (bond strength) of the luting system types using Tukey's post-hoc test. * display statistically significant differences.

Un_Atm, RelyX Unicem in atmosphere (control group);

Un_Hyp, RelyX Unicem in hyperbaric;

Ul_Atm, RelyX Ultimate in atmosphere(control group);

Un_Hyp, RelyX Ultimate in hyperbaric

Statistical analysis

All data were analyzed by using Statistical Package for the Social Sciences (SPSS) by IBM version 22. A one-way between-groups analysis of variance (ANOVA) was used to compare the mean differences of bond strength in two different barometric conditions (atmosphere and hyperbaric pressure). Statistical significance adopted was $p<0.05$.

RESULTS

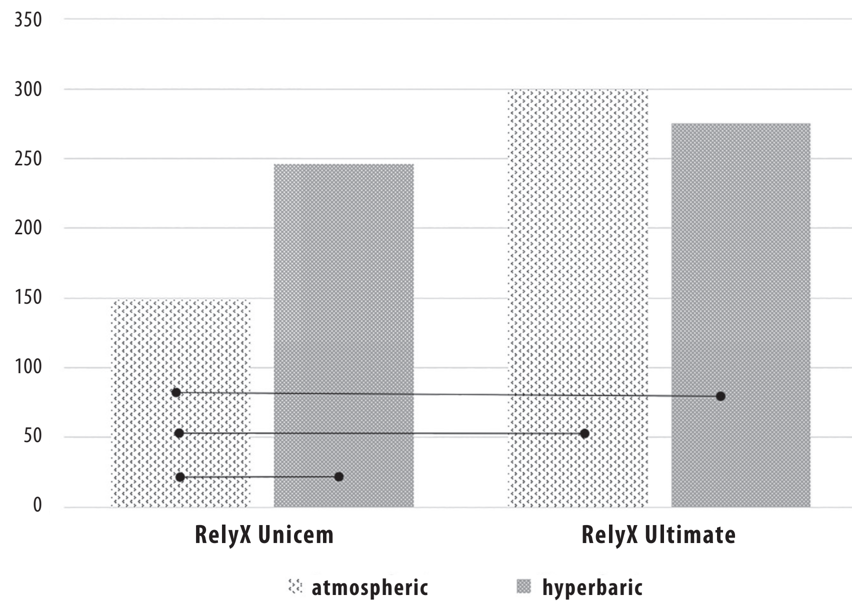
The pull-out bond strengths (N) and standard deviations (SDs) of RelyX Unicem and RelyX Ultimate resin cements in atmospheric and hyperbaric pressure conditions are shown in Table 1. Results revealed that RelyX Ultimate cement provided the highest pull-out strength in every barometric pressure condition. Meanwhile, RelyX Unicem provided the lowest pull-out strength in normal atmospheric pressure and hyperbaric pressure conditions. RelyX Ultimate cement in atmospheric pressure condition showed the highest pull-out strength, which is 299.7 (±77.9) N. However, RelyX Unicem in atmospheric pressure condition had the lowest pullout strength; 148.5 (±35.0) N.

Post hoc analysis with Tukey's honestly significant difference (HSD) test (using α of .05) (Table 2) revealed that mean pull-out bond strength of RelyX Ultimate cement exhibited significant higher than RelyX Unicem cement ($p<0.05$) in the atmospheric pressure condition. There was also significant difference of the mean value of pull-out bond strengths of RelyX Unicem cement in the hyperbaric condition than in the atmospheric pressure condition ($p<0.05$). However, there was no statistically different pull-out bond strength between RelyX Unicem and RelyX Ultimate cement ($p>0.05$) in the hyperbaric condition, nor between the RelyX Ultimate in the atmosphere and RelyX Ultimate in hyperbaric conditions ($p>0.05$) (Figure 3).

DISCUSSION

This in vitro study investigated the effect of hyperbaric pressure (which scuba divers may experience) on pull-out bond strength of fiber posts cemented in a natural root canal with different resin cements. Other researchers performed a similar investigation to simulate the hyperbaric condition using a pressure pot [16]; however, other researchers used a hyperbaric chamber, which is

Figure 3: Mean pull-out bond strength of tested cements in different barometric pressures



Barometric pressures in Newton (N) unit.

Columns linking bars with markers indicate significant differences at $p<0.05$ between groups.

more reliably sealed and provides accurate pressurized condition to simulate diving conditions [18]. Extracted natural teeth and resin blocks have been used in experimenting root filling in vitro. Various tooth factors may have affected the retention of fiber posts, such as the root anatomy and canal length, which reflect the depth of cementation [19]. A resin block enables standardization of the canal length and the amount of the canal surface for bonding. Nevertheless, natural teeth are preferred, as we can assess the bond strength between the dentin, resin cement, and fiber post. In this study single-rooted premolar teeth with root curvature less than 15 degrees were selected, the crown was decoronated at the site 15mm from the tip of the root, and the post space was prepared on a standardized length of 10mm.

According to the results of this study, at normal atmospheric pressure, the RelyX Ultimate resin cement that required an adhesive system (Single Bond Universal Adhesive) to prepare the root dentin prior to cementation has shown higher pull-out bond strength than RelyX Unicem that did not require any extra bonding system. This finding agrees with the results of other studies that compared bond strength produced by self-adhesive resin cement and adhesive resin cement [10,20,21]. The retention of RelyX Unicem cement was lower possibly because no acid conditioning was performed to alter or remove the smear layer inside the root canal before cement application. If some smear layers remained in the canal and occluded the dentinal tubules, they would weaken the bonding effectiveness, especially for the luting system that was not pretreated before cementation. Based on recommendation of the manufacturer, only 2.5-5% NaOCl solution was used as irrigation before cementing fiber posts. However, NaOCl irrigation did not improve post retention because the solution alone did not completely remove the smear layer that formed during canal post preparation [22]. Furthermore, this agent causes deproteinization of the root dentin substance, creates a hydrophilic surface that may hinder the interaction of more hydrophobic materials, and later will cause improper polymerization of resin-based cements [23]. By contrast, other studies have found that the bond strengths of fiber post cementation between self-adhesive and adhesive resin cements are comparable [12,24]. The adhesive systems used in other studies vary. The presence of highly stable acidic primers – i.e., 10-methacryloyloxydecyl dihydrogen phosphate functional monomer – in the single-bond universal adhesive in this study have shown effective bonds with calcium from hydroxyapatite, which may contribute to the high bond strength when compared with other adhesive systems [25].

Results of this study proved that the pull-out bond strength of fiber posts cemented with self-adhesive resin cement significantly improved after simulated diving conditions, but the pull-out bond strength of self-etch resin cement was not significantly different when compared with that under atmospheric pressure conditions. According to Boyle's law, the volume of gas inversely varies with the surrounding pressure at a constant temperature [26], which appropriately explains the increase in bond strengths observed in glass fiber posts cemented with RelyX Unicem under hyperbaric conditions. During the mixing and cementation process, there may be air trapped or voids formed in addition to the smear layer that prevents effective adhesion of the cement to the glass fiber post and root dentin. Under hyperbaric conditions, the air trapped in the free surface between the post and the root dentin wall will contract and result in volumetric contraction. Besides, there was evidence of hygroscopic expansion stress in self-adhesive resin cement after 24 hours of storage in water, but it was not present in the total-etch resin cement [27,28]. In the presence of water, acidic monomers with hydrogen bonding sites in self-adhesive resin will absorb water while displaying its hydrophilic characteristic; eventually, more unattached areas will be covered by the resin cement, which aids the self-sealing at the dentin–cement interface [27].

In the RelyX Ultimate luting cement group, root dentin preparation using self-etching primer prior to cementation will increase the wettability of the dentin surface and remove the smear layer that occludes the dentinal tubule and result in the formation of an effective hybrid layer in the root dentin. When the wettability of the dentin increases and no smear layer prevents adhesion between the cement and dentin, the cement can more easily flow into the dentinal tubules to form micromechnical retention. As a result, the volume of trapped air or voids formed between the post and the root dentin wall reduced. Hybrid layer formation is also considered important to the creation of a strong bonding between resin and root dentin [29]. The hybrid layer has a lower modulus of elasticity than the dentin [30]. Different moduli of elasticity cause the curing stress created in the RelyX Ultimate during polymerization and may be compensated by the elasticity of the hybrid layer during exposure to hyperbaric pressure condition. Similarly, another study did not found significant difference in the pull-out bond strengths of fiber posts cemented with total-etch and self-etch resin cement after exposure to increased pressure conditions [16].

CONCLUSION

This in vitro study did not completely simulate real-world clinical situations, which contributed to the limitation in predicting the success of the material in clinical use. The effect of pressure by clenching while wearing a mouthpiece by the divers was not taken into account. Chewing simulation from horizontal and lateral forces should be performed before simulated diving, and the bond strength test is necessary to simulate the clinical use of the prosthesis.

Within the limitations of this study it can be concluded that self-etch resin cement (RelyX Ultimate) had higher bond strengths in atmospheric condition than self-adhesive resin cement (RelyX Unicem). Hyperbaric pressure cycles demonstrated improved bond strength of self-adhesive resin cement (RelyX Unicem) but did not have significant effect on the bond strength of self-etch resin cement (RelyX Ultimate). Both resin cements have similar pull-out bond strength of glass fiber posts after simulated dives.

Conflict of interest statement

The authors have declared no conflicts of interest.

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