The effect of environmental pressure changes on the retentive strength of cements for orthodontic bands

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Abstract

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Objectives: The purpose of this study was to evaluate the effect of environmental pressure changes on the retentive strength of orthodontic bands cemented with conventional glass ionomer cement or resin-modified glass ionomer cement.

Materials and methods: Stainless steel bands were cemented to 80 extracted first and second molars in two equal groups comprising conventional glass ionomer cement and resin-modified glass ionomer cement. Each group was randomly divided into two sub-groups of 20 samples each, one sub-group to act as a control, and the other to be used experimentally. After seven days of storage, the experimental groups were subjected to simulated dives to 304 kPa for 3 minutes, 15 times in a pressure pot, after which the force required to deband was tested using a universal testing machine. The data were statistically analysed using Student's t-tests, significance being assumed at $P < 0.001$.

Results: The retentive strength of bands cemented with conventional glass ionomer in the pressure-cycled group was statistically significantly less than that in the control group. No statistically significant difference in strength was found between the two groups cemented with resin-modified glass ionomer.

Conclusions: This study showed that the retentive strength of bands cemented with conventional glass ionomer is reduced after pressure cycling. We suggest that dentists should consider using resin-modified glass ionomer cement for cementing orthodontic bands for patients who are divers and thus likely to be exposed to raised-pressure cycling.

Key words

Barotrauma, diving, scuba diving, dental, teeth

Introduction

'Aerodontalgia' was reported for the first time as an in-flight problem early in the 20th Century. In the 1940s, with the advent 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] The term barotrauma is used to describe a physical injury caused by rapid or extreme changes in barometric pressure. Enclosed areas within the body, such as the middle ear, sinuses and lungs, are particularly affected by barotrauma.[2] Barotrauma is associated closely with Boyle's law, which states that, at a given temperature, the volume of a gas is inversely proportional to the ambient pressure, hence its association with both diving and altitude exposure. Problems arise when the enclosed spaces containing gases cannot expand or contract to adjust the internal pressure to correspond to the outer pressure.[3] Carious, inflamed or necrotic teeth and teeth with inadequate restorations develop barotrauma more readily, which manifests itself as tooth or restoration fracture and reduced retention of restorations.[4,5]

In recent years, it has become increasingly popular to holiday at a tropical destination, often with the opportunity to dive, and recreational sports diving generally has become very popular.[6] The importance of sports dentistry has gained increasing recognition from all members of the sports medical team, thus enabling individual sports people to obtain the latest advice on prevention and treatment of orofacial injuries and related topics.[7]

It is inevitable that the dental practitioner will have patients who participate in sports diving and they should be aware of a number of problems that a diver can experience that are associated with the teeth and related structures. There has been a great increase in patients seeking orthodontic treatment in recent years.[8] Most orthodontic treatment is carried out before or during adolescent years, but with an increasing number of options for orthodontic treatment, adult patients now form a significant segment of practice.[9] When a scuba diver is wearing an orthodontic appliance, a potential danger may result from dislodgement of any component during diving. Although this subject is rarely and only briefly discussed in dental textbooks, it is important for a dentist to be aware of the effect of pressure changes on certain dental materials in terms of their retentive strength.[10]

Orthodontics is the branch of dentistry that specialises in the diagnosis, prevention and treatment of dental and facial irregularities. By placing a constant, gentle force in a carefully controlled direction, an orthodontic appliance can slowly move teeth through their supporting bone to a new, more desirable position. Orthodontic appliances usually consist of attached brackets on anterior teeth and bands on molars. Bands are made from stainless steel and are very similar to a ring. Bands are available in different sizes. They are cemented on molars using luting cement, the most popular of which is glass ionomer cement.[11,12] Newly developed resin-modified glass ionomer cements are currently the subject of consideration.[13]

Table 1

Summary characteristics of the two luting cements studied

Cement type	Composition
Conventional glass ionomer cement	Powder: glass powder, pigments, polycarboxylic acid Liquid: tartaric acid, water, conservation agents
Resin-modified glass ionomer cement	Paste A: fluoroaluminosilicate glass, hydroxyethyl methacrylate, dimethacrylate, pigment, initiator Paste B: Polyacrylic acid, distilled water, silica powder, initiator

What effect pressure variations have on the retention of orthodontic bands is still largely unknown. The present study aimed to clarify whether repeated exposure to the pressure variations typically experienced by divers could have a negative influence on the retentive strength of orthodontic bands cemented with different cements, particularly because luting cements easily trap micro-bubbles of air during manual mixing.[14]

Materials and methods

Two types of cements were studied: a conventional glass ionomer cement (Ketac-Cem™, 3M ESPE, Germany) and a resin-modified glass ionomer cement (GC Fuji Ortho Band Paste Pak™, GC Corporation, Japan) (Table 1).

Eighty extracted human first and second molars without caries were collected and cleaned of large debris. All the teeth were decontaminated in 10% formalin. Then they were promptly rinsed and stored in deionized water at room temperature till used for the study. A hole was drilled through the centre of each tooth near the root furcation area and a 0.9 mm stainless steel wire was placed in the hole to resist pulling of the tooth out of embedded medium at debanding. All samples were then mounted in a block of self-curing acrylic resin, below the amelocementum junction with the long axis vertical. The exposed crowns were polished with fluoride-free dental prophylactic paste to remove any fine debris.

Stainless steel orthodontic bands with micro-etched fitting surfaces (3M Unitek) were selected and adapted for best fit to the crown of each tooth. Orthodontic lingual sheets were welded on the buccal and lingual surfaces of the bands. Samples were randomly divided into two equal groups of 40 each according to the type of orthodontic cement used:
Group 1: Conventional glass ionomer cement;
Group 2: Resin-modified glass ionomer cement.

The preparation of the cements was conducted exactly according to the manufacturers' instructions. The cement mix was applied directly to the band-fitting surface, and the bands were seated by using a band pusher with hand pressure. Excess cement was removed from the occlusal and cervical margins of the band so that it would not influence the test results. All the specimens were allowed to bench cure for 5 minutes, and then stored in 0.9% NaCl solution for 7 days at 37^{O}C. Each group was randomly divided into two sub-groups of 20 samples, one sub-group to act as a control and the other to be used experimentally.

All the experimental samples, in open glass containers, were placed in a pressure pot (Puneet Industries, India). During the simulated dives, pressure was changed at a rate of 101 kPa min^{-1} during compression and decompression. The maximum pressure applied was 304 kPa, equivalent to a depth of 30 metres' sea water (msw), and was maintained for 3 minutes. Fifteen pressure cycles were repeated one after the other. This basically corresponds to the activity of a typical recreational diver during a 10-day holiday.[15]

The force necessary to dislodge the orthodontic bands was evaluated using a universal testing machine (Star Testing System, model no STS248). Each specimen was loaded into the inferior vice grip of the universal testing machine and secured in place by tightening adjustable screws to fix the acrylic block in position. Stainless steel loops that engaged through the welded lingual sheaths on the buccal and lingual side of the bands were attached to the superior self-tightening wedge action grip of the universal testing

Figure 1

Retentive strength testing on universal testing machine

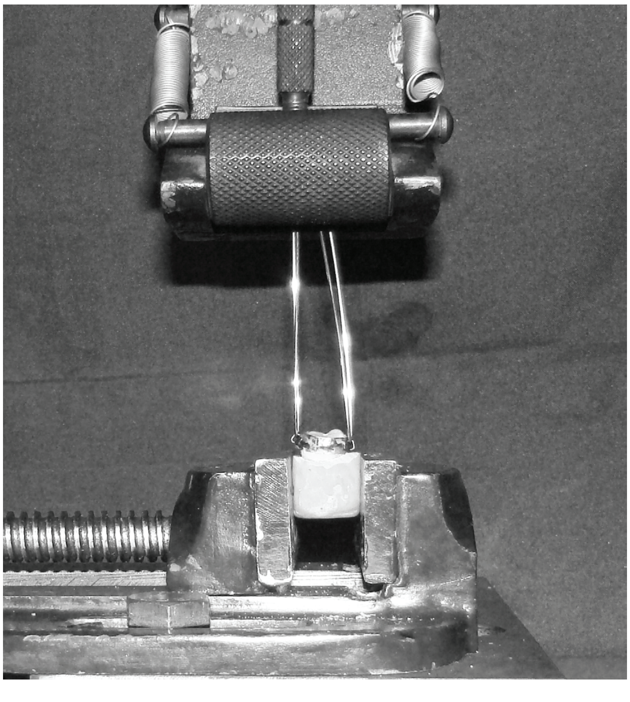

Table 2

Retentive strength of bands cemented with two types of luting cements, for pressure-cycled and control groups (mean (SD))

Cement type	Control group	Pressure-cycled group	*P* value
Conventional glass ionomer cement	1.496 (0.313)	0.975 (0.348)	< 0.001
Resin-modified glass ionomer cement	1.810 (0.392)	1.764 (0.419)	0.722

machine (Figure 1). The universal testing machine was programmed to perform at a crosshead speed of 1 mm min^{-1} and testing proceeded for each sample until the band was removed from the tooth. The maximum debanding force in newtons (N) was interpreted from the stress-strain curve as the maximum force recorded during debanding.

The band was cleaned with a sickle scaler and pumice, cut with a scissor, and laid out flat. Its length and width were measured using vernier calipers and, thus, its area was determined in mm^2. Dividing the debanding force (N) by band area (mm^2) resulted in the band strength expressed in megapascals (MPa).

The statistical analysis was performed using a commercially available software programme SPSS version 1.5. Descriptive statistics that included mean and standard deviation were calculated. Student's t-test was applied to determine whether significant differences existed among the control and experimental sub-groups for both cements. Significance for all statistical tests was predetermined at $P < 0.001$.

Results

A summary of the results of retentive strength of orthodontic bands is presented in Table 2. The retentive strength of bands cemented with conventional glass ionomer in the pressure-cycled group was significantly less than that of the control group ($P < 0.001$), while no significant difference was found between the pressure-cycled group and the control group for bands cemented with resin-modified glass ionomer ($P = 0.722$).

Discussion

It is important for an orthodontist to be aware of the effect of pressure changes on certain dental materials in terms of retentive strength, as the potential danger resulting from dislodgement of orthodontic components during a dive is obvious. This is particularly important for materials that are mixed by hand, such as band cements, as during the mixing process, air may become incorporated into the mixture, forming voids which would be subject to expansion and contraction with environmental pressure changes.[14] No study has examined previously the effect of environmental pressure changes during diving on the retentive strength of orthodontic bands.

In a study examining the long-term effects of barometric pressure changes on the dental health status of German naval personnel, the teeth of personnel working under changed atmospheric pressure (navy divers and frogmen) deteriorated over 10 years at significantly higher rates than did those of personnel working under normal atmospheric pressure (submariners).[16] These findings suggest that sustained exposure to barometric pressure plays a role in dental deterioration.

Previous in vitro studies have shown that pressure changes can affect the retention of restorations and crowns.[15,17,18] Exposure to pressure cycling of full-cast crowns resulted in decreased retentive strength in those cemented with zinc phosphate and conventional glass ionomer cements, whereas no significant effect was found in crowns cemented with resin cement.[19] The authors linked the failure associated with zinc phosphate and conventional glass ionomer cements to porosities that had been generated during mixing and expansion or contraction of these micro-bubbles during pressure cycling, which eventually led to disruption and weakening of the cement layer.[19] In another study, micro-cracks appeared as a result of volumetric contraction in luting cements.[20] When subjected to the effect of pressure cycling, such cracks may produce tensile stresses that exceed the cohesive and adhesive strength of the material, resulting in significant reduction in tensile bond strength.

Although the exact mechanisms of barodontalgia and barotrauma are not known, the air trapped beneath a restoration or in luting cement may be a factor.[3] During diving, dental barotrauma usually occurs while ascending. Upon returning to the surface after completing the dive, the diver may report fracture of teeth or dislodgement of restorations.[4] Differences in the physical properties of the breathing gas mixture used during deep sea diving may contribute to barodontalgia.[17] However, dislodgement of restorations can occur while descending.[3]

Other authors have concentrated on the possible variations in volume in micro-bubbles within insufficiently filled restorations, cements or root canals caused by rapid pressure changes. Trapped air micro-bubbles will be compressed on descent and will expand on ascent.[15,19] Teeth may actually implode during descent or explode upon ascent.[21] It is possible that dislodgement of restorations may develop as a result of micro-leakage following mechanical failure of the luting cement.[18] As military and professional divers are more likely to be subjected to rapid manoeuvres and extreme situations than are civilian divers, it can be assumed that they are more vulnerable to pathological consequences of rapid pressure changes.[4]

In the present study, the retentive strength of bands cemented with resin-modified glass ionomer cement was not significantly affected by pressure cycling to 304 kPa, whereas conventional glass ionomer cement was weakened. This could be attributed to the higher tensile strength, lower elastic modulus and greater amount of plastic deformation that can be sustained before fracture occurs with resin-modified glass ionomer cement compared to conventional glass ionomer cement.[22] The pressure chosen (304 kPa) is equivalent to that to which a scuba diver is subjected at a depth of 30 msw. However, the pressure was held for only 3 minutes, whereas in real life a diver would spend a much longer time underwater. It would be interesting to investigate the behaviour of cements beyond 304 kPa and for longer durations of time.

What effect the pressure variations that divers are exposed to have on the retention of other dental components where luting cements are used is still largely unknown. Also only one brand of each type of cement was tested in this study; further studies with other materials are recommended. Surface details of dislodged bands under scanning electron microscopy could provide better insight into the findings in the present study. Finally, it must be noted that in vitro studies are limited in predicting the success of a material or technique in clinical use.

Conclusions

Resin-modified glass ionomer cement for orthodontic bands retains its strength after pressure cycling to 304 kPa better than conventional glass ionomer cement. Therefore, this type of cement should be used for patients who are exposed to marked variations in environmental pressure, such as recreational and professional divers, balloonists, aviators who fly in unpressurised cabins and mountaineers.

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