Original Article

Effect of Pressure Changes on Fracture Resistance and Micro-leakage of Three Types of Composite Restorations during Simulated Dives and Flights

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Abstract

Background: Pressure changes can affect dental restorations especially in divers. The aim of the present study was to assess the fracture resistance and Micro-leakage of the MOD restorations using three types of composite resins undergoing pressure changes, simulating SCUBA-diving and aviation. **Methods:** For fracture resistance test 90 sound maxillary premolar teeth were randomly assigned to 3 groups of 30 MOD composite restorations using three types of composite resins (nanohybride 3M Z350, microhybride 3M Z250, packable 3M P60) were prepared. Each group was then divided to 3 subgroups of 10 for simulating SCUBA-diving (2 bar pressure cycle), Flight (0.5 bar pressure cycle) and control (atmosphere pressure). The teeth undergone pressure cycles for 1 month and then fracture resistance test was conducted on them using instron testing machine. For Micro-leakage test the same subgroups were made using 90 mandibular premolars (n=10) and using 2% Methylene blue dye for 24 hours Micro-leakage scores were recorded. Data were analyzed statistically. **Result:** In regard of the fracture resistance test packable composite resines had significantly higher scores than nanohybride and microhybride composite resins (p-value<0.05). Control group had significantly higher fracture resistance values in comparison to Dive groups whereas there was no significant difference between control and Flight group. (p-value=0.083). Considering Micro-leakage there was no significant difference between three restorative materials or between three pressure groups. **Conclusion:** Packable composite resins show grater fracture toughness than micro and nanohybride composite resins. Diving pressure cycles demonstrated to have adverse effect on fracture resistance amounts of all three types of composite resins.

Keywords: Micro-leakage; Nanohybride; Fracture resistance; Composite resins

Introduction

With the growing number of scuba divers and aircrew-members dentists will increasingly encounter pressure change-related oral conditions, which require careful attention. [1,2]

These phenomena are mainly related to the law of boyle-mariotte, which states that in a constant temperature and amount of an ideal gas the volume and pressure are inversely proportional. [3,4] Among these oral conditions barodontalgia is known as the toothache that is related to the ambient pressure changes. [5-7]

Odontocrexis is another condition which was first introduced by Calder and Ramsey. [8] To describe the tooth or restoration structure destruction associated with pressure changes. Dental barotrauma is a more general word describing the damages to the tooth structure when pressure changes, which can be with or without pain. This condition is known as a potential cause of incapacitation, which could jeopardize the safety of the scuba diving or flight. [9] Defective dental restorations, leakage and secondary carries are assumed to be most important predisposing factors of dental barotraumas.

In-flight bruxism in aircrew members has also been reported to be the main factor of amalgam restoration failures in World War II By sognnaes. [10,11] Excessive bite forces were also proposed by the USAF symposium of aviation dentistry in 1946 as a predisposing factor for restoration dislodgment. [10] Considering the divers, there is an argument about the effect of clenching on mouthpieces on deterioration of dental restorations. [12] As there is no study examining the effect of pressure changes on properties of composite resin restorations, the aim of the present study was to assess the fracture resistance and Micro-leakage of three types of composite restorations undergoing pressure changes.

Materials and Methods

Specimen preparation

180 sound maxillary and mandibular premolar teeth (90 of each)

How to Cite this Article: Shafigh E, et al. Effect of Pressure Changes on Fracture Resistance and Micro-leakage of Three Types of Composite Restorations during Simulated Dives and Flights. Ann Med Health Sci Res. 2018;8:204-208

– free of any microcracks and caries- extracted for orthodontic reasons within 3-month period were stored in normal saline solution at room temperature. 2 weeks before use, all teeth were immersed in 0.5% Chloramine T trihydrate solution for infection control. 90 maxillary premolar teeth of equal buccolingual dimension were used for fracture resistance test and 90 mandibular premolars were used for Micro-leakage test.

Care was taken that in none of the steps teeth loos moisture.

For each test teeth were randomly divided into 3 groups -leaving 30 teeth in each group- and treated as follows. In group 1, teeth were restored with nanohybride 3M Z350 composite resin (N) and group 2 received microhybride 3M Z250 composite resin restoration (M) while group 3 was restored with packable 3M P60 composite resin (P). Each group were then randomly assigned into 3 subgroups (N=10) for Diving (D) and Flight (F) simulations and a control (C) subgroup.

Standard MOD cavities were prepared using coarse, cylindrical, flat-end diamond burs. Burs were changed per each 10 preparations. Outline of the cavities were first drew on the teeth using a digital caliper. Buccolingual widths of the cavities were considered half the inter-cuspal distance. The gingival margin of the cavities was placed 1 mm above the cementenamel junction (CEJ) with the pulpal floor 2 mm below the central groove. The depth of the axial wall was set at 1.5 mm. Convergence of the buccal and lingual walls toward the occlusal were ensured. The cavosurface angle in all walls was approximately 90degrees.

The teeth were etched for 15 seconds using 37% phosphoric acid, rinsed for 10 seconds with water and air dried until a shiny, hydrated surface of moist dentin was achieved. Adper single bond II (3M ESPE, USA) was applied in two layers with disposable applicators, each layer was air dried for 5 seconds to ensure solvent evaporation and then light cured for 20 seconds with a light intensity of 650 mW/cm^2 by a light-curing unit (Optilux 501, Kerr, Danbury, CT, USA). Then using SS matrix bands and tofflemire, the teeth were restored with A2 shade composite resin. Oblique layering technique was performed with first layer not thicker than 1 mm in gingival and pulpal floors. Following increments were placed in 2 mm thickness having contact with only 2 walls of the cavity. Each increment was light cured for 40 seconds from occlusal surface. After removing the matrix band additional curing was performed from buccal and lingual for 40 seconds each.

24 hours after restoration all groups were finished and polished according to standard methods.

Pressure change simulation

For simulation of pressure changes during dives and flights an experimental chamber was designed having an external monometer attached to in. compressed air was used to increase the chamber pressure and an air vacuum pomp was used to decrease pressure.

The speed of pressure change was set to 1 atm per minute. Diving descent was simulated by increasing the pressure to 2 atm similar to depth of 10 meters under water. Decreasing the pressure to 0.5 bars-like at 5.5 kilometers from sea level altitude- simulated flight ascents.

Each tooth underwent 30 simulated Dives (D) or Flights (F) according to their subgroups. For Dive subgroups the teeth were maintained in 2 atm pressure for 45 minutes each day before returning to 1 atm pressure. For flight subgroups the teeth underwent the same pattern except the chamber pressure, which was 0.5 atm. The control subgroups were stored in 1 atm for one month.

Fracture resistance test

All specimens were mounted in self-cure acrylic resin up to 2 mm below the CEJ. Dental surveyor was employed to ensure uniform alignment of all specimens parallel to the analyzing rod.

All specimens were then placed in a jig, which allowed loading at the central fossa parallel to the long axis of the teeth. Instron universal testing machine (Z010, Zwick GmbH, Ulm, Germany) was used to deliver compressive load at a crosshead speed of 1 mm/min until fracture. The fracture resistance amounts were collected in newtons(N).

Micro-leakage test

The entire tooth surfaces were covered with two layers of nail polish, except for restoration and 1 mm margin around it on tooth surface. The root apices were sealed with sticky wax.

The specimens were then immersed in 2% Methylene blue for 24 hours and rinsed under running water to remove excessive dye. The teeth were subsequently sectioned mesio-distally with a water-cooled low-speed saw.

2 sections of each specimen were examined under stereomicroscope at 16X magnification. Dye penetration was quantified in gingival margins of the restoration using a 0-3 scale system: 0=no dye penetration, 1=dye penetration limited to the enamel of the gingival wall. 2=dye penetration into the dentin in gingival wall. 3=dye penetration past the gingival wall involving the axial wall. The highest scores were recorded.

Data analysis was carried out using SPSS software (SPSS version 18.0, SPSS, Chicago, IL, USA).

Results

Fracture resistance

The mean values of fracture resistance of groups are shown in Table 1.

Results showed that material with p-value<0.001 and pressure change cycles with p-value=0.027 had significant effect of fracture resistance amounts. Packable 3M P60 composite

Table 1: Fracture resistance amounts of different groups (N).

Composite resin type	Dive group	Flight group	Control group
Microhybride	1042.7	1172.6	1219.1
Nanohybride	1003.2	1108.5	1198.3
Packable	1425.7	1748.7	1963.4

Table 2: Experimental groups and sub-groups.

Tests	Groups (n)	Subgroups (abbreviation) (n)
Fracture resistance assessment	Nanohybride 3M Z350	Flight (FNF) (10)
		Diving (FND) (10)
		Control (FNC) (10)
	Microhybride 3M Z250	Flight (FMF) (10)
		Diving (FMD) (10)
		Control (FMC) (10)
	Packable 3m P60	Flight (FPF) (10)
		Diving (FPD) (10)
		Control (FPC) (10)
Micro leakage evaluation	Nanohybride 3M Z350	Flight (MNF) (10)
		Diving (MND) (10)
		Control (MNC) (10)
	Microhybride 3M Z250	Flight (MMF) (10)
		Diving (MMD) (10)
		Control (MMC) (10)
	Packable 3M P60	Flight (MPF) (10)
		Diving (MPD) (10)
		Control (MPC) (10)

Table 3: Distribution of micro leakage scores (0-3) within subgroups of the study micro leakage scores** (n).

Subgroups (n)	0	1	2	3
(MNF)* (10)	2	2	6	0
(MND) (10)	1	0	8	1
(MNC) (10)	2	1	6	1
(MMF) (10)	2	6	1	1
(MMD) (10)	1	4	3	2
(MMC) (10)	3	5	2	0
(MPF) (10)	3	1	6	0
(MPD) (10)	2	2	5	1
(MPC) (10)	2	5	2	1

*The abbreviations represented in Table 2.
**These scores referred to …n

resin group showed significantly higher fracture resistance in comparison to nano and microhybride group (p-value<0.05). Pairwise comparison of the cycles demonstrated that control group had significantly higher fracture resistance values in comparison to Dive groups whereas there was no significant difference between control and Flight group (p-value=0.083) [Table 2].

Micro-leakage

The Micro-leakage scores of different groups are shown in Table 3.

Kruskal-wallis test revealed no significant different in Micro-leakage amounts of 9 subgroups (p-value=0.076). There was also no significant difference between Micro-leakage scores of 3 composite resin groups in different pressure conditions. (p-value=0.341 for packable P60 groups and p=0.228 for microhybride Z250 groups and p=0.247 for nanohybride Z350 groups). Mann-Whitney Test also revealed no significant differences between C, D and F groups.

Discussion

To the knowledge of the authors of the present study, this is the first investigation assessing the effect of pressure changes during flights and dives on mechanical properties of teeth restored with different types of composite resins. Packable, nanohybride and microhybride composite resins were selected because they are the most frequently used composite resins used for restorative treatment among dentists. It is reported by many different authors that among variety of predisposing factors of barodontalia and odontocrexis, leaking restorations rather than carries are of great importance. [6,10] On the other hand excessive bite forces applied to teeth due to clenching and bruxism during flights and dives are also reported to be a crucial factor in tooth destruction. [13-15] Therefor the effect of pressure changes and restorative materials were examined in this study by means of fracture resistance and Micro-leakage.

Regarding the fracture resistance test, the results revealed that teeth restored with packable composite resins were more promising than nano and microhybride groups. In a study by sookhakiyan et al., [16] posterior packable (P60) composite resin showed significantly greater toughness values than 5 types of nanohybride composite resins using hertzion indentation method farmani et al. [17] conclude that nanohybride composite had comparable load bearing capacity with packable resines. Denehy and Torney [18] were the first authors to describe the positive effect of adhesive materials in reinforcing the teeth structures. Morin and others [17] noted significant increase in the fracture resistance of teeth restored with adhesive materials in a group of teeth with MOD preparations as well. On the other hand separate studies have stated that fracture resistance of teeth restored with composite restorations are still significantly lower than intact teeth and composite restorations are not able to fully restore the mechanical properties of teeth. [19,20] Also it is worth mentioning that different clinical conditions like thermocycling can have adverse effect of reinforcement impact of adhesive restorations. [21,22]

Normal biting forces on maxillary premolars have been observed to be 100-300 N. [22] In our study none of the groups showed fracture resistance values lower than this amounts and even the lowest group showed mean fracture resistance values of 622 N. although the clinical conditions and the forces applied to the teeth in oral cavity are different from the design of this study, these numbers can suggest some clinical relevance.

However the concerns are still remaining regarding the patients having clenching or bruxis as occlusal forces have been reported to be as high as 520-800 N. [22] Weakening effect of clenching on tooth structures in pilots and divers has been noted in different studies. [12,13] Researchers have reported aircrew members and divers to have higher prevalence of jaw parafunctional activity.

[6,10] Goldhush et al. estimated that 60-70% of pilots in World War II had suffered from bruxism. Lurie et al. examined the prevalence of bruxism in military environment and found bruxism of clinical importance in 69% of air-crew members. [13] Regarding the SCUBA divers there is an argument that clenching on the mouthpiece during diving, which increases due to cold water and stress may participate in deterioration of dental restoration. [12] Higher prevalence of clenching in SCUBA divers has been reported in other studies. [6,14]

Regarding the effect of pressure change cycles the results of our study showed no significant reduction in fracture resistance values of flight groups in comparison to control groups (p-value>0.05) in all 3 composite resine groups, although flight groups showed a tendency to have reduced fracture resistance. It is of great importance to consider the design of the pressure change cycles when interpreting the data as the cycles were designed to apply desired pressures for 45 minutes each day during 1 month. It is likely to observe more significant differences in longer periods of time. On the other hand Dive groups showed significantly lower fracture resistance amounts in comparison to both control and flight groups (p-value<0.05). The fracture resistance decreased in teeth restored with three types of composite resin groups after pressure cycles with the same pattern. These findings may suggest the effect of pressure changes on fatigue failures of teeth and their adverse effect on tooth structure. This phenomenon can be explained according to the Boyle's law, which states that the volume of a gas at a constant temperature is inversely proportional to the ambient pressure. [23] The air void trapped in a dental restoration expands during each ascend due to the decrease in the pressure and weakens the restoration structure. This has been reported in association of both divers and pilots in previous studies. [8,23]

The significant higher reduction of fracture resistance values in Dive groups can be explained due to the higher range of pressure changes in these groups in comparison to Flight groups (1 bar versus 0.5 bar pressure changes).

Regarding the Micro-leakage test, results of our study showed no statistically significant difference among different groups. In other words neither restorative material nor pressure changes have significant effect on Micro-leakage of restorations. Considering the restorative material results of previous studies are controversial. In a study conducted by Hussain SM and Khan FK, [24] there was no statistically significant difference between Micro-leakage rates in nano filled (Z350) and packable composite resins (P60), Although Z350 showed statistically insignificant better scores. In another study by awliya and El-sahn [25] nano hybrid flowable composite showed higher leakage scores than microhybride type.

Contradictory results reported by different studies may be because of variations in leakage evaluation techniques, test conditions, cavity design and dimensions, restorative materials, type of teeth and observation time. These contrasting results underline the obvious importance of standardized testing parameters of leakage studies. [24]

Regarding the effect of pressure changes the results of our study revealed no significant differences between control and pressure cycle groups. Although after pressure cycles groups showed a tendency toward increasing Micro-leakage but differences were not statistically significant.

Although the pressure changes had effected the restorations in both groups with the same pattern, regarding the results of the present study the use of packable composite resins is suggested in divers and air-crew members as it showed superior fracture resistance values in comparison to nano and microhybride composite resins.

Conclusion

In the end this is worthy to mention that the experimental conditions of this study did not fully mimic the conditions of the oral cavity during diving or flight experiences as teeth are subjected to a mixture of different factors outside the laboratory setting, but still some important clinical relevance can be concluded.

This is the pioneer study investigating the effect of pressure cycles on behavior of different restorative composite resins. The amounts of pressure changes were selected according to the routine diving depths and flight altitudes. Further studies with different pressure cycles, longer durations, different restorative materials and different tests are required to fully understand the effect of ambient pressure changes on restoration and tooth structures.

Conflict of Interest

The authors disclose that they have no conflicts of interest.

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