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# Effect Of Pressure Changes On Fracture Resistance And Fracture PatternsOf Endodontically Treated Premolars With Short Fiber Reinforced Composite Restoration During Simulated Dives and Flight : An in-vitro study

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## ABSTRACT

**Aim :**The present study aims to examine the effect of pressure changes on fracture resistance and fracture patterns of endodontically treated premolarswith short fiber reinforced composite restoration during simulated dives and flight.

**Materials and Methods:** Thirty extracted maxillary premolars were selected and divided into three groups (n=10). All the teeth had endodontic treatment and MOD cavity design with short fiber reinforced composite resins as the final restoration.Group 1 for simulating SCUBA diving pressure(2 ATA), group 2 forflightsimulating pressure (0.37 bar) andthegroup 3 as controlgroup (atsmospheric pressure). All samples were treatedfor 1 monthandfracturetestwasperformedusing a universal testing machine (UTM) with static load was applied at a speed of 0.5 mm/min until fracture occurred and the fracture patterns was observed. Data were statistically analyzed with one-way analysis of variance (ANOVA), while for fracture patterns were tested using Fisher's Test.

**Result :**Therewere statistically significantdifferences in theresultsofthefracturestrength among the groups ($p<0.05$). The controlgroup had thehighestfracturestrength4140,58 N ± 70.33 Ncomparedto flightsimulating group3891.80 N ± 88.43 and SCUBA diving group 3720.76 N ± 43.27. No statistically significant differences ($p>0.05$) observed on the fracture patterns among all groups and all of the fracture were repairable.

**Conclusion:** Diving pressure cycles demonstrated adverse effect on fracture resistance of endodontically treated premolar restoration.Short fiber reinforced composite restoration is suggested in divers and air crew members to increase the fracture resistance of endodontically treated premolar restoration.

**Keyword :**Fracture resistance, fracture patterns, short fiber reinforced composite (SFRC), pressure changes, endodontically treated premolar.

## Introduction

Rapid changes in air pressure can cause discomfort and damage to the teeth and maxillofacial area, unless the pressure in the gas-filled cavity can be balanced with the external air pressure. In addition to these conditions, the most common conditions are barodontalgia (pain caused by trapped gas) and barotrauma (changes in air pressure that cause tooth fractures and restoration fractures) (Mandke et al, 2015).

Barodontalgia has been reported during flights at altitudes of 600–1500 m and dives at depths of 10–25 m. The incidence of this type of dental pain is 0.26 - 8% in flight crews, airplane passengers and divers (Zadik, 2009; Rajpal et al, 2014; Khawalde, 2016). Barotrauma can occur during diving (hyperbaric), flight (hypobaric) or during hyperbaric oxygen therapy.Since the advent of the underwater breathing apparatus (SCUBA) in the mid-20th century, many oral phenomena in flight caused by air pressure have also been reported during diving. Dental barotrauma can appear with or without pain (Zadik, 2009).

Sognnaes reported that the bruxism experienced by flight crews during World War II was a major factor in causing damage to amalgam restorations. His other research also reported about 17 cases of barotrauma in fighter pilots consisting of 6 cases of restoration fracture, 6 cases of loss of restoration and 5 cases of cracks in the restoration. Zadik et al (2009) reported on fractures of the first molars in uncompressed flight at 18,000 feet and restoration fractures at 25,000 feet in simulated chambers.

Endodontically treated teeth experienced a 9% decrease in moisture compared to teeth with vital pulp. The decrease in water content after endodontic treatment results in the shrinkage of the dentinal collagen tissue which favors crack formation and leads to tooth fracture when pressure is applied. The success of restorations in endodontically treated teeth is influenced by several factors, namely the amount of remaining tooth structure, the restorative materials used, the technique used and the interaction of the tooth with the material and the condition of the oral cavity (Segun et al, 2008).

The amount of remaining tooth tissue structure depends on the size of the cavity and is one of the determinants of fracture resistance of the tooth. Tang et al (2010) found that MOD cavities were more likely to fracture than MO or DO cavities. Endodontic procedures reduced the relative stiffness of the tooth cusps by only 5%, whereas in Class I occlusal cavities it reached 20%, while in MOD cavities it reached 63%.

Various conventional techniques and materials are used to restore teeth that have been endodontically treated including using posts and cores, full crowns, onlays, indirect crown restorations with or without cups coverage (Ozsevik et al, 2016). Restoration adhesive systems are believed to have a better ability to distribute functional stresses and can strengthen weak tooth structures (Moosavi et al, 2012).. Modifications in the technique of composite resin restorations to increase fracture resistance include cups coverage.

Composite resin restoration technique using an intermediate layer with Stress Decreasing Resin (SDR) is one of the efforts made to overcome fracture problems. SDR serves to reduce shrinkage volume by modifying pre-polymerized 4-trimethylhexane, urethane dimethacrylate (UDMA) monomer and 65% filler proportion. The thickness of SDR as an intermediate layer will strengthen the fracture resistance of class II composite resin restorations, but does not show a significant difference when applied with a thickness of 2, 3 and 4 mm (Arwin et al, 2020).

Fiber reinforced composite has high flexural strength and fatigue strength, modulus of elasticity close to dentin, good aesthetic properties, does not corrode, is biocompatible and can distribute pressure so as to prevent fracture (Sarabi et al, 2015). Short fiber reinforced composite (Ever X Posterior, GC) is a bulk fill composite resin that has been added with a short glass fiber filler composition as a combination of barium glass and silanated E-glass fiber which is recommended for use in high pressure areas.

**Materials and Methods**

Thirty extracted maxillary premolars were obtained with selection criteria such as intact maxillary premolars, no crown fracture and never restored,no caries, apex completely closed. The teeth were cleaned of calculus and stored in saline solution.All the teeth had endodontic treatment and MOD cavity design with short fiber reinforced composite resins as the final restoration.Group 1 for simulating SCUBA diving pressure(2 ATA), group 2 forflightsimulating pressure (0.37 bar) andthegroup 3 as controlgroup (atsmospheric pressure).

The preparation of the access cavity with an endo access bur and then determine the working length followed by the glide path with K-file no.10 (Dentsply, Switzerland). Furthermore, root canal preparation was carried out with a rotary instrument One Curve (Micromega, France) with a size of 25/ .06 with a crown down technique, irrigation with 2.5% NaOCl for each file entry, activation with ultrasonic (Eighteeth, France), saline irrigation, EDTA 17%, saline, chlorhexidine 2%. The root canals were dried with paper points. The prepared root canals were filled with gutta-percha using the warm vertical compaction technique to 2 mm below the orifice using a resin-based sealer (AH plus, Dentsply) and SDR (Dentsply) 2 mm as aorifice barrier.

The cavity preparation was formed using a high speed handpiece and a diamond bur with continuous water cooling. Class II cavity design MOD cups coverage of maxillary premolars with a buccopalatal cavity width of half the intercuspal distance, 1 mm gingival floor width and 1 mm above the CEJ, 4 mm depth to the floor of the pulp chamber; 2 mm buccal and palatal cusp reduction. Cavity measurement using a digital caliper as a tool for standardization (Mincik et al, 2016; Panahandeh, 2013).

The teeth that had finished endodontic treatment were then immediately restored with the same treatment provided that the results of cavity preparation and application of etching, bonding and exposure time were the same between groups. Etch 15 seconds, bonding 20 seconds, polymerization 20 seconds. Ever X was applied over SDR with a thickness of 2 mm and followed by composite resin to the cups. Then the teeth are finished and polished with a fine bur and a silicon bur. After storage 24 hours in humidity, all sample carried out for a thermocycling process for 200 cycles from 5$^{o}$C to 55$^{o}$C**.**

All samples were planed on gips and divided into three groups (n=10). Group 1 (sampleswas placed into hyperbaric chamber and the air pressure was increased to 2 ATA for 45 minutes every day for 1 month), Group 2 (samples was placed into hypobaric chamber, 0.37 bar for 45 minutes every day for 1 month, Group 3 as control, sample were placed in room temperature and pressure for 1 month.

The root of the tooth was dipped in wax to 1 mm below the CEJ. The wax layer with a thickness of approximately 0.3 mm covers the root of the tooth like the periodontal ligament. The sample was planted on a self-curing acrylic using a 10 ml syringe. The inside of the syringe is smeared with Vaseline first and the sample is planted at a 90$^o$ position to a limit of 1 mm below the CEJ to resemble the position on the alveolar bone.The implanted sample was removed from the acrylic mold and the wax was cleaned. After the sample was cleaned of wax, then the sample was replanted into an acrylic cylinder mold that had been formed with the root of the sample given a thin layer of elastomeric impression material used to imitate the role of the periodontal ligament which can reduce the occlusal pressure exerted on the sample.

The sample was then tested using UTM with a load with a crosshead speed of 0.5 mm/min until fracture occurred and fracture pattern was observed with using a stereomicroscope with a magnification of 12x.

The classification of fracture patterns used (Garoushi, 2021) and (Frater, 2021) are:

**Type I**: delamination or chipping of composite resin( Repairable)
**Type II**: fracture of the restoration without affecting the tooth structure( Repairable)
**Type III**: fracture of the restoration and involving the tooth structure above the CEJ ( Repairable)
**Type IV**: fracture of the restoration and involves the tooth structure below the CEJ (Irrepairable)

The data obtained were analyzed statistically using ANOVA test with a level of significance ($\alpha = 0.05$ ) to determine wheter significant different exist among tested group then followed by ofLeast Significant Differences (LSD) test. Fisher's test to see differences in fracture patterns between groups.

**Result**

**Fracture Resistance**

Fracture resistance of direct restoration class II MOD cups coverage with the addition of short fiber reinforced composite, the highest mean value was in the control group which did not get a change in air pressure with a value of 4140,581 N ± 70,38. The lowest fracture resistance value was seen in the diving group with a fracture resistance value of 3720,760 N ± 43,27 (Table 1).

Table 1. Average and Standard Deviation Value of Direct Restoration Fracture Resistance Class II MOD Cups Coverage with Short Fiber Reinforced Composite

| Group | Fracture Resistance (N) | | |
|---|---|---|---|
| | n | X ± SD | p |
| **Dive** | 10 | 3720.760 ± 43.2773 | .000 |
| **Flight** | 10 | 3891.810 ± 88.4312 | |
| **Control** | 10 | 4140.581 ± 70.3833 | |

Table 2. LSD Test for Fracture Resistance

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Control | dive | 419.8210* | 31.2483 | .000 | 355.705 | 483.937 |
| | flight | 248.7710* | 31.2483 | .000 | 184.655 | 312.887 |
| Dive | control | -419.8210* | 31.2483 | .000 | -483.937 | -355.705 |
| | flight | -171.0500* | 31.2483 | .000 | -235.166 | -106.934 |
| Flight | control | -248.7710* | 31.2483 | .000 | -312.887 | -184.655 |
| | dive | 171.0500* | 31.2483 | .000 | 106.934 | 235.166 |

*. The mean difference is significant at the 0.05 level.

The Least Significance Difference (LSD) test in the table above shows that there is a significant difference between the three sample groups in this study with p = 0.000 ($p < 0.05$).

## Fracture Pattern

Observation of the fracture pattern was carried out after the fracture resistance test by observing the location of the fracture fracture in all samples. The location of the fracture pattern is divided into two categories, Repairable if only delamination / chipping occurs in the composite resin restoration or fracture occurs in the restoration without affecting the tooth structure or affecting the tooth structure. Fractures were categorized as Irrepairable for fracture patterns to the root below the cervix and vertical cracks that extended to the root.

Table 3. Fracture Pattern after fracture resistance test

| **Group** | **n** | ***Repairable ( %)*** | | | | ***Irrepairable ( %)*** | |
|---|---|---|---|---|---|---|---|
| | | **Delamination/ Chippingon restoration (Tipe I)** | **Fractureoftherestorationwithoutaffectingthetooth(Tipe II)** | **Fractureoftherestorationandtoothstructureabovethe CEJ(Tipe III)** | **Total** | **Fractureoftherestorationandtoothstructurebelowthe CEJ(Tipe IV)** | **Total** |
| Dive | 10 | - | 60 | 40 | 100 | - | - |
| Flight | 10 | - | 70 | 30 | 100 | - | - |
| Control | 10 | - | 70 | 30 | 100 | - | - |

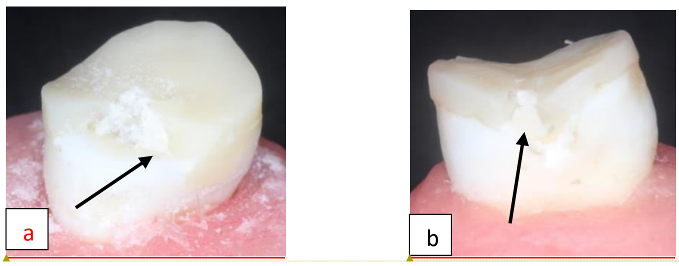
Table 3 shows the percentage of fracture patterns in each group. In the Dive group, 60% of the samples had fractures in the composite restoration alone and 40% fractures in the composite restoration and tooth structure above the CEJ. Flight and control groups, respectively, 70% of the fracture samples were seen in the composite restoration alone and 30% fracture in the composite restoration and the tooth structure above the CEJ. All of the sample, there was no fracture pattern affecting the composite restoration and tooth structure below the CEJ, which means that the Irrepairable fracture pattern category was not found in this study.

Table 4. Fisher's test to observed the differences in fracture patterns

| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | .300[a] | 2 | .861 | 1.000 | | |
| Likelihood Ratio | .296 | 2 | .862 | 1.000 | | |
| Fisher's Exact Test | .418 | | | 1.000 | | |
| Linear-by-Linear Association | .218[b] | 1 | .641 | .817 | .408 | .165 |
| N of Valid Cases | 30 | | | | | |

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is 3.33.
b. The standardized statistic is -.466.

Table 4 show no significant difference between all groups. The descriptive data show that all the fracture patterns of the samples in this study were repairable.




(a) Type II (fracture of the restoration without affecting the tooth structure),
(b) Type III (fracture of the restoration and involving the tooth structure above the CEJ)



**Discussion**

Based on table 1, the results obtained after the compression test process was carried out on the three groups in this study, descriptively obtained the mean value of the dive group that received a pressure change of 2 ATA had the smallest fracture resistance of 3720.7 N then followed by the flight group which received the change in pressure was 0.37

ATM of 3891.8 N. The highest average fracture resistance was found in the control group that did not receive a change in air pressure with a value of 4140.5 N. Statistically this result showed a significant difference between groups. This is indicated by the results of the One way ANOVA test in the three sample groups with $p < 0.05$. There is an effect of differences in air pressure on the fracture resistance of post-endodontic premolars with direct restorations class II MOD cups coverage with short fiber reinforced composite resin and there is a difference in fracture resistance of post-endodontic premolars with direct restorations class II MOD cups coverage with the addition of short fiber reinforced to changes in air pressure during flight compared to diving.

The results of this study are in line with Shafiq's research which examined the effect of changes in air pressure on fracture resistance and microleakage of three types of composite resins in diving and flight simulations and found that the fracture resistance of the restoration was weakest in the Diving group, followed by the Flight and control groups. This can be caused by the influence of air changes that can cause fatigue failures in the teeth.

This is in accordance with Boyle's law, which states that at a constant temperature, the pressure of a gas will be inversely proportional to its volume. As air pressure increases, the volume of gas will decrease. Air bubbles or gases trapped in dental restorations expand every time there is a decrease in air pressure and vice versa so that if this happens repeatedly it can weaken the restoration structure. Even with the use of a sealer that has good mechanical properties, microleakage and trapped gas will still be found in root canal fillings (Von See et al, 2012). This is what can trigger the initial crack that can cause restoration fractures in the teeth of divers and pilots. This study also simulates changes in air pressure in divers and pilots for 1 month which means the gas expansion cycle occurs for 30 times and this weakens the restoration in the sample group.

The fracture resistance in the diving group had the weakest resistance compared to the flight group, also due to the large difference in air pressure between the diving group (2 ATA) and the aviation group (0.37 ATM). The Dive Group got a difference in air pressure of 2 ATA with a depth of 10 m. Air pressure 2 ATA is absolute pressure which is the sum of atmospheric pressure plus hydrostatic pressure, so that the pressure received by the Diving sample group in this study is greater than the flight group.

Normal biting force is 222 N – 445 N for maxillary premolars. When biting, occlusal forces are observed to be around 520 – 800 N (L.Gulec et al, 2017). When biting or chewing, the mandibular premolar fossa will come into contact with the mandibular premolar protrusion. This is in accordance with the compression test simulation in this study where the zig load position was placed on the sample tooth fossa to mimic the position of the load received by the maxillary premolars.

In this study, there was no sample group that showed fracture resistance that was lower than the normal biting strength value, even in the Diving sample group which had the smallest fracture resistance. This is because in this study a modified composite resin was used, namely short fiber reinforced composite (Ever X post) and as an intermediate layer SDR was used where the restoration was carried out with cuspal coverage (Moosavi et al, 2012). These results are in line with previous studies that examined the effect of dairek class II MOD cuspal coverage short fiber reinforced restorations on post-endodontic tooth fracture resistance. group added with polyethylene fiber reinforced ribbon or restoration with GIC and conventional composite resin (Pusparani et al, 2021).

Glass fiber has advantages in high tensile strength and excellent compression, this is due to the good adhesion factor between glass fiber and polymer matrix through a silane coupling agent. As is well known, hardness is defined as the resistance of a material to mechanical forces of indentation or penetration (Yap, 2000). Ever X which contains E-glass fiber has excellent mechanical resistance when receiving mechanical forces that occur. The addition of fibers to a methacrylate-based matrix produces compositions with comparable or superior mechanical properties compared to other materials.

Elayouti, et al study found that endodontically treated premolars and restored all cusps with composite resin increased fracture resistance. Reducing the entire cusp surface of the premolars by 2 mm and restoring it with composite resin can be a suitable restoration option for restoring posterior teeth, especially in the premolar area.

**Limitation**

The results in this study indicate that there is no sample group that shows fracture resistance lower than the normal biting strength value even in the diving sample group that has the smallest fracture resistance, this can also be caused because in this study did not use saliva which can cause degradation. composite resin caused by salivary pH. Composite resin restorative materials are in contact with various salivary pH, both acidic and basic, which can affect changes in the physical properties of the composite resin. One of the factors that can cause damage to the resin filler composite is the effect of low salivary pH (Pribadi, et al,2011). The release of this filler can cause porosity so that it can weaken the composite resin structure.

The fracture resistance in the flight group was higher than in the diving group and there was a significant difference between the two groups.This is because the change in air pressure in the flight group is not as large as the pressure change in diving, so that the volume of gas undergoing expansion and vice versa, is not as large as the volume of gas contained in the diver group, so that the potential for cracks due to accumulation of gas expansion is not as large as in the diver group.

The control group has the highest fracture resistance of all other groups, this is because the control group is not affected by changes in air pressure so that the potential for cracks caused by accumulation of gas expansion does not occur in this group.

The addition of a fiber layer to the restoration can increase strength and can prevent crack propagation from the restoration to the tooth. When a layer of fiber is placed on a composite resin, the fibers act as crack stoppers, reinforcement, and have the ability to resist further cracking. Small cracks in the area of interwoven fibers will inhibit their development into small dimensions. When the crack reaches the fiber surface, the path becomes blunt and propagates causing a change in direction (Belli , 2006).

The fracture patterns in the three groups had almost the same fracture pattern, namely type II (fracture of the restoration without affecting the tooth structure) and type III (fracture of the restoration and affecting the tooth structure but still above the CEJ) where both types were included in the category of repairable fracture patterns. which means that catastrophic failure is avoided and restoration repairs are possible. The random position and orientation of the fibers also affects the stress received by the restorative material, where the position of the fiber between the CEJ and the occlusal plane is more effective in preventing tooth fracture below the CEJ or root fracture (Monaco et al, 2016).

The sample in the diving group had a slightly higher percentage of type III fracture pattern (40%) than the percentage of type III fracture pattern in the flight and control groups (30%). This is possible due to variations in the size of the crown of the teeth sampled in this study, thus affecting the thickness of the tooth wall. Another factor that can be the cause is that the change in air pressure in the diving group is greater than that of the flight and control groups, so that the volume of gas that experiences expansion and vice versa is greater in the diver group, so that the potential for cracks due to accumulation of gas expansion is also greater.

**Conclusion**

This study also showed that direct class II MOD cups coverage restorations with the addition of short fiber reinforced composites can be used as an option for post-endodontic dental restorations in divers and pilots who are often exposed to different air pressures so that the restoration can last a long time in the mouth.
In this study, there was no difference in the fracture pattern that occurred in direct class II MOD cups coverage restorations with short fiber reinforced composite resin on post-endodontic teeth and given different changes in air pressure with the result that all restorations had a repairable fracture pattern.

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