Original Article

Effect of hyperbaric oxygen profiles on the bond strength of repaired composite resin

Hossam Mossa, Essam ElKhatat[1], Ahmed M. Hassan, Kusai Baroudi[1], Khaled Beshr

Departments of Restorative Dental Sciences and [1]Preventive Dental Sciences, Alfarabi Colleges, Riyadh, Saudi Arabia

Corresponding author (email: <hossammf@yahoo.com>)
Dr. Hossam Mossa, Department of Restorative Dental Science, Alfarabi Colleges, Riyadh - 11691, Kingdom of Saudi Arabia.

Received: 16-12-15 Accepted: 06-04-16 Published: 26-04-16

Abstract

Objective: This study was performed to evaluate the bond strength of repaired three types of composite resins under various hyperbaric oxygen (HBO) profiles with various session numbers. **Materials and Methods:** Sixty specimens of three types of composite resin (nanofilled composite, nanohybrid composite and microfilled composite) each type of composite was divided into four group according to various profiles of HBO treatment (control, 2bar, 3 bar and 5 bar). Then, the specimens were repaired; thermocycled, the tensile bond strength were measured. Then the data were analyzed by One-way ANOVA followed by Tukey's *post hoc* test ($\alpha = 0.05$). **Results:** The highest bond strength was obtained for the repaired nanofilled composite resin specimens while; the lowest bond strength was obtained for the repaired microfilled composite resin specimens. The highest tensile bond strength was recorded for the specimens who treated with the highest pressure of HBO. **Conclusion:** The bond strength of repaired nanofilled composite resins is better than the other types of composite resin. The highest pressure of HBO, the highest bond strength of repaired composite resins.

Key words: *Bond strength, hyperbaric oxygen, repaired composite resin.*

INTRODUCTION

One of the most frequent requirements of today's dentistry is bonding of new composite resin to an aged one. It has been estimated that half of a general practitioner's time is spent on replacement dentistry, with the consequent increase in time and expense.[1] Therefore, the repair of composite restorations by their partial replacement is a minimally invasive[2,3] and less time-consuming[4] alternative to the complete replacement; moreover, it increases their longevity.[5]

The oxygen inhibition layer (OIL) that forms on the surface of methacrylate-based resins cured in the presence of oxygen has received significant attention in the literature. OIL forms as a result of the increased affinity of free radicals toward oxygen, which is greater than their affinity toward the methacrylate carbon–carbon double bonds, thus, retarding the formation of a polymer.[6,7] The effect of oxygen-inhibited layer on composite–composite bond strength is controversial.[8,9]

Özcan *et al*.[10] found that the composite–composite bond strength varied in accordance with the specific particulate filler and composite resin as well as the different surface conditioning methods used. Several methods have been suggested to improve the composite–composite adhesion, such as roughening,

Access this article online	
Quick Response Code:	Website: www.jispcd.org
	DOI: 10.4103/2231-0762.181189

How to cite this article: Mossa H, ElKhatat E, Hassan AM, Baroudi K, Beshr K. Effect of hyperbaric oxygen profiles on the bond strength of repaired composite resin. J Int Soc Prevent Communit Dent 2016;6:S70-4.

etching the substrate surface with acidulated phosphate fluoride[11] of hydrofluoric acid gel,[10] air-born particle abrasion,[12] or using silanes and intermediate adhesive resins.[13]

Hyperbaric oxygen (HBO) therapy is defined by the Undersea and Hyperbaric Medical Society (UHMS) as a treatment in which a patient intermittently breathes 100% oxygen while the treatment chamber is pressurized to a pressure greater than sea level (1 atmosphere absolute, ATA).[14] Despite over a century of use in medical settings, HBO remains a controversial therapy. The last 20 years have seen a clarification of the mechanism of action of hyperbaric therapy and a greater understanding of its potential benefit. However, HBO may have a therapeutic effect in certain carefully defined disease states. For example, in dentistry, HBO therapy is used in osteoradionecrosis, osteomyelitis of jaws, aggressive periodontitis, and adjunctive therapy for the placement of implants in irradiated jaws.[15]

The aim of the study

This study was performed to evaluate the bond strength of three types of composite resins under various profiles of HBO treatment.

MATERIALS AND METHODS

Sixty cylindrical specimens of visible–light–activated composite resin were prepared from three types of resins (20 each). The first type was prepared from Durafill (Microfilled, Heraeus-Kulzer GmbH, Wehrheim, Germany) whereas the second type was prepared from Filtek Z250XT (Nanohybrid universal restorative, 3M ESPE, St. Paul, MN, USA, Batch N515291). The third type was prepared from FILTEK Z350XT (Nanofilled universal restorative, 3M ESPE, St. Paul, MN, USA, Batch 775645). Composite resin specimens were prepared by condensing the composite resin into split Teflon mold (5 mm in diameter and 2 mm thickness). The visible–light–activated composite resin (single paste) was obtained in a screw-driven syringe suitable for injection into the molds against a glass slab in a bulk technique. Thin glass plates were forced against all of the specimens with heavy weights to smoothen their top surfaces as well as to prevent air inhibition during curing. The specimens were cured using visible-light cured unit (Heliolux II Vivadent, Australia), which was applied to the specimen, with the curing light transmitted through the glass plate. Approximately ten exposures of 20 s each were applied at various positions on the top surface of each specimen. This process was repeated immediately after with the plate removal. All cures were done at room temperature. Then, the specimens were stored at 37°C for 24 h.[16]

Each type of composite specimens was treated with HBO and was randomly assigned into four groups (5 each) according to the different types of HBO profiles, which depended on the pressure of HBO used; the first group was the control group, which was not treated with HBO; the second group was tested under HBO at 2 bar. Each profile had a duration of 96 min and consisted of a compression phase (18 min), hold phase at 2 bar oxygen breathing (60 min), and decompression phase (18 min). The third and fourth had the same duration except that the holding phases were either 3 or 5 bar.

Then, the cylindrical composite resin specimens (5 × 2 mm thickness) were reinserted into the Teflon split mold (5 mm in diameter and 4 mm thickness). The specimens were treated in a dimension lab under fixed temperature and oxygen gas environment and under various adjusted pressure levels (2 bar, 3 bar, and 5 bar). The top surface of the specimens was etched with 35% phosphoric acid gel (Contac 37% Phosphoric Acid. FGM Products Odontológicos LTDA. Batch 260614). Then, the etchant was washed thoroughly using for 30 s with copious amounts of water and dried under air.

SL Bond (Swiss TECColtèneAG, Switzerland. Batch F30451) was used with Durafill composite whereas Single bond universal adhesive (3M Gmbh Dental products, Germany. Batch 514472) was used for both nanohybrid and nanofilled composite. A thin layer of the adhesive bond was spread and dried with a gentle blast of clean dry air and then cured for 20 s with visible light cured unit. Afterward, a second layer of bonding was applied and cured. The etching and bonding procedures were carried out in accordance with the manufacturer's instruction according to each type of composite, and were carried out by the same operator throughout the experiments. Then, the mold was filled with composite resin using an incremental technique and light-cured for 30 s with the visible-light cure, multidirected from the top surface to each increment. After removal of the mold, an additional 20 s irradiation was applied from each proximal side of the specimens. All tested specimens were thermocycled (100 cycles, 5-55°C). After storage period (one month), the tensile bond strength (Mpa) of the repaired specimens was tested on Universal Instron testing machine. The load was applied with a cross-head speed of 0.5 mm/min until failure.

Statistical analysis

Data were statistically analyzed by one-way ANOVA followed by Tukey's *post hoc* test at the significance level of $\alpha = 0.05$.

RESULTS

The mean values and standard deviation of tensile bond strength of the tested groups are illustrated in Table 1 and graphically in Figure 1. The microfilled composite resin groups recorded the lowest tensile bond strength than that of the nanohybrid or nanofilled composite resin groups. Nanofilled composite resin groups recorded the highest tensile bond strength followed by the nanohybrid and microfilled composite resin groups. The control group recorded the lowest tensile bond strength whereas the composite resin specimens repaired under 5 bar recorded the highest tensile bond strength for all types of repaired composite resin. There was a significant difference of bond strength between the repaired microfilled specimens and the other repaired composite resins ($P < 0.05$). There was a significant difference of bond strength between the specimens repaired under 2.0 bar and the specimens repaired under 3 or 5 bar ($P < 0.05$). There was a significant difference of bond strength between the repaired composite resin of control specimens and the specimens repaired under 3 and 5 bar ($P < 0.05$).

DISCUSSION

Adhesion between two composite layers is achieved in the presence of an oxygen-inhibited layer of unpolymerized resin.[17] An OIL develops on surfaces exposed to air during polymerization of particulate filling composite.[18] Reports on how the oxygen-inhibited layer affects the bond strength have been inconsistent. Studies have demonstrated an ideal bonding of two composite resin layers in the presence of an oxygen-inhibited layer.[19,20] A few studies reported that the presence of an oxygen-inhibited layer made no significant differences to the bond strength.[21,22] Water storage is considered to have detrimental effects on the composite resin surface due to hydrolysis and release of filler particles as well as water uptake in the resin matrix.[23,24] Continuous application of mechanical and environmental loads eventually leads to progressive degradation and crack initiation and growth, resulting in catastrophic failure of dental restorations. This process is further assisted by pre-existing voids introduced during material processing, imperfect interfaces, and residual stresses, making resistance to crack initiation and growth an important consideration for a reliable assessment of dental restorations.[25]

The surfaces of the aged composite resins need to be refreshed somehow. The use of an intermediate low-viscosity resin can be considered a necessary step in composite resin repair to enhance the bond by promoting chemical coupling to the resin matrix, bonding to the exposed fillers, or micromechanical retention through monomer penetration into the matrix microcracks.[26]

The control group recorded the least bond strength for the repaired composite specimens, which may be because of lack of air-inhibited layer on the surface, the degree of unreacted carbon double bond is lower, and chemical bonding between fresh and aged composite is not a reliable bond.[27]

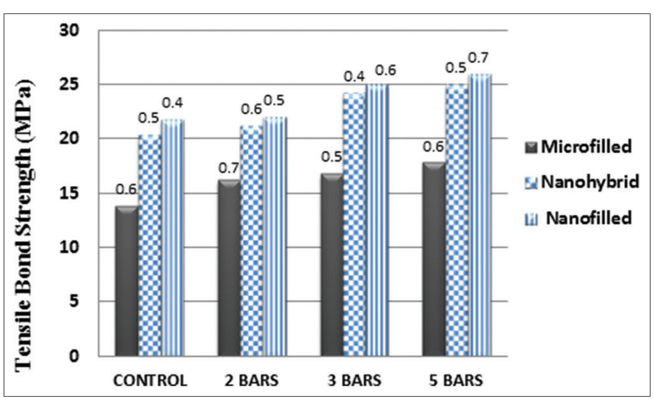

Figure 1: Histogram of mean values of tensile bond strength for different types of composite resin under various types of hyperbaric oxygen profilesunder various profiles modes of hyperbaric oxygen

Table 1: The mean score of tensile bond strength and standard deviation of three repaired composite resin specimens under various profill modes of hyperbaric oxygen

Repaired composite Hyperbaric oxygen profile		Durafill	Filtek Z250XT	Filtek Z350
Control	X	16.8	20.4	21.8
	SD	0.6	0.5	0.4
Profill 1	X	16.2	21.2	22
	SD	0.7	0.6	0.5
Profill 2	X	16.8	24.2	25
	SD	0.5	0.4	0.6
Profill 3	X	17.8	25	26
	SD	0.6	0.5	0.7

X=mean score of tensile bond strength for 5 specimens, SD=standard deviation

The hybrid type of composite is better than microfilled composite, possibly due to the presence of filler, which increases the strength of the composite.[28,29]

The nanofilled composite resin recorded the highest result in comparison to the other groups, which may be due to the shape and size of the particles. This suggests that the entanglement between the resin components and the nanofillers is better for nanofilled composite and enhancing the three-dimensional microstructure of the composite as well as improving its mechanical strength. Kim *et al.*[30] have reported that composites with round particles may exhibit increased mechanical strength. This is further evidence that nanohybrids may not behave similar to Nanofills.[31]

The specimens subjected to 5 bar recorded the highest bond strength than that of the other groups. This might be due to the trapped air voids which is present in the microcracks that form between the filler of the composite due to the hydrolytic effect of the water. There is an inverse relationship between the pressure and the volume of minute trapped air bubbles, according to the Boyle's law, which states that at a given temperature the volume of a gas is inversely proportional to the ambient pressure.[32] When ascending, the trapped air voids decreased in volume and water entered into the microcracks; on the other hand, when descending, the trapped air voids increased in volume and water exited the microcracks, which led to increased hydrolytic effect and increased roughness, and thus, the depth of the crack became larger. When dentin adhesive is applied, it can penetrate deeper under the highest pressure applied (5 bar), which may lead to the highest bond strength.

CONCLUSION

The bond strength of the repaired nanofilled composite resins is better than the other types of composite resins. It was observed that higher the pressure of hyperbaric oxygen, the higher the bond strength of the repaired composite resins.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Tyas MJ, Anusavice KJ, Frencken JE, Mount GJ. Minimal intervention dentistry - A review. FDI Commission Project 1-97. Int Dent J 2000;50:1-12.
2. Gordan VV, Shen C, Riley J 3rd, Mjör IA. Two-year clinical evaluation of repair versus replacement of composite restorations. J Esthet Restor Dent 2006;18:144-53.
3. Moncada G, Martin J, Fernandez E, Hempel MC, Mjör IA, Gordon VV. Sealing, refurbishment and repair of Class I and Class II defective restorations: A three-year clinical trial. J Am Dent Assoc 2009;140:25-432.
4. Krejci I, Lieber CM, Lutz F. Time required to remove totally bonded tooth-colored posterior restorations and related tooth substance loss. Dent Mater 1995;11:34-40.
5. Fernandez E, Martin J, Vildosola P, Oliveira Junior OB, Gordan V, Mjör IA. Can repair increase the longevity of composite resins? Results of a 10-year clinical trial. J Dent 2015;43:279-86.
6. vonBeetzen M, Li J, Nicander I, Sundström F. Factors influencing shear strength of incrementally cured composite resins. Acta Odontol Scand 1996;54:275-8.
7. Dall'Oca S, Papacchini F, Goracci C, Cury AH, Suh BI, Tay FR, *et al*. Effect of oxygen inhibition on composite repair strength over time. J Biomed Mater Res B Appl Biomater 2007;81:493-8.
8. Sehgal A, Rao YM, Joshua M, Narayanan LL. Evaluation of the effects of the oxygen-inhibited layer on shear bond strength of two resin composites. J Conserv Dent 2008;11:159-61.
9. Shawkat ES, Shortall AC, Addison O, Palin WM. Oxygen inhibition and incremental layer bond strengths of resin composites. Dent Mater 2009;25:1338-46.
10. Özcan M, Alander P, Vallittu PK, Huysmans MC, Kalk W. Effect of three surface conditioning methods to improve bond strength of particulate filler resin composites. J Mater Sci Mater Med 2005;16:21-7.
11. Ohara N, Koizumi H, Matsumoto Y, Nakayama D, Ogino T, Matsumura H. Surface roughness and gloss of indirect composites etched with acidulated phosphate fluoride solution. Acta Odontol Scand 2009;67:313-20.
12. Hemadri M, Saritha G, Rajasekhar V, Pachlag KA, Purushotham R, Reddy VK. Shear bond strength of repaired composites using surface treatments and repair materials: An *in vitro* study. J Int Oral Health 2014;6:22-5.
13. Rinastiti M, Özcan M, Siswomihardjo W, Busscher HJ. Effects of surface conditioning on repair bond strengths of non-aged and aged microhybrid, nanohybrid, and nanofilled composite resins. Clin Oral Investig 2011;15:625-33.
14. Hampson NB. Hyperbaric Oxygen Therapy: 1999 Committee report. Undersea and Hyperbaric Medical Society, 1999.
15. Devaraj D and Srisakthi D. Hyperbaric oxygen therapy - Can it be the new era in dentistry? J Clin Diagn Res 2014;8:263-5.
16. Dionysopoulos D, Papadopoulos C, Koliniotou-Koumpia E. Effect of temperature, curing time, and filler composition on surface microhardness of composite resins. J Conserv Dent 2015;18:114-8.
17. Özcan M, Kojima AN, Pekkan G, Mesquita AM, Bottino MA. Adhesion of substrate-adherent combinations for early composite repairs: Effect of intermediate adhesive resin application. Int J Adh Adhes 2014;49:97-102.
18. Bijelic-Donova J, Garoushi S, Lassila LV, Vallittu PK. Oxygen inhibition layer of composite resins: Effects of layer thickness and surface layer treatment on the interlayer bond strength. Eur J Oral Sci 2015;123:53-60.
19. Li J. Effects of surface properties on bond strength between layers of newly cured dental composites. J Oral Rehabil 1997;24:358-60.

20. Suh BI. Oxygen-inhibited layer in adhesion dentistry. J Esthet Resto Dent 2004; 16:316-23.
21. Sehgal A, Rao YM, Joshua M, Narayanan LL. Evaluation of the effects of the oxygen-inhibited layer on shear bond strength of two resin composites. J Conserv Dent 2008;11:159-61.
22. Finger WJ, Lee KS, Podszun W. Monomers with low oxygen inhibition as enamel/dentin adhesives. Dent Mater 1996;12:256-61.
23. Nassoohi N, Kazemi H, Sadaghiani M, Mansouri M, Rakhshan V. Effects of three surface conditioning techniques on repair bond strength of nanohybrid and nanofilled composites. Dent Res J (Isfahan) 2015;12:554-61.
24. Kaleem M, Khan AS, Rehman IU, Wong FS. Effect of beverages on viscoelastic properties of resin-based dental composites. Materials 2015;8:2863-72.
25. Drummond JL. Degradation, fatigue, and failure of resin dental composite materials. J Dent Res 2008;87:710-19.
26. Kupiec KA, Barkmeier WW. Laboratory evaluation of surface treatments for composite repair. Oper Dent 1996;21:59-62.
27. Kula K, Nelson S, Kula T, Thompson V. *In vitro* effect of acidulated phosphate fluoride gel on the surface of composites with different filler particles. J Prosthet Dent 1986;56:161-9.
28. Tay FR, Gwinnett JA, Wei SH. Micromorphological spectrum from overdrying to overwetting acid-conditioned dentin in water-free acetone based, single-bottle primer/adhesives. Dent Mater 1996;12:236-44.
29. Özcan M, Corazza PH, Marocho SM, Barbosa SH, Bottino MA. Repair bond strength of microhybrid, nanohybrid and nanofilled resin composites: Effect of substrate resin type, surface conditioning and ageing. Clin Oral Investig 2013;17:1751-8.
30. Kim KH, Ong JL, Okuno O. The effect of filler loading and morphology on the mechanical properties of contemporary composites. J Prosthet Dent 2002;87:642-9.
31. de Moraes RR, Gonçalves Lde S, Lancellotti AC, Consani S, Correr-Sobrinho L, Sinhoreti MA. Nanohybrid resin composites: Nanofiller loaded materials or traditional microhybrid resins? Oper Dent 2009;34:551-7.
32. Kieser JD. Holborow D. The prevention and management of oral barotraumas. N Z Dent J 1997;93:114-6.