Mechanical properties of fiber-reinforced composite resin exposed to alcoholic beverage

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Abstract. Addition of fiber to dental bridgework was thought to be more efficient comparing to porcelain-fused to metalwork. In other side, some patients consumed alcoholic beverage in their daily life. This study aimed to determine mechanical properties of fiber-reinforced composite (FRC) exposed to alcoholic beverage. The materials used were dental resin (i-FLOW i-dental, Lithuania), polyethylene fiber (Vactrise, USA), and 4 alcoholic beverages. FRC samples (40) were divided into 10 groups (n=4, control:aquades). Each Sample was soaked in beverage for 5 s followed by 5 s in aquades for each cycle (10 cycles daily for 4 wk). Mechanical properties were examined for hardness and flexural strength. The result showed the mean values for hardness (KHN) were: 98.70±6.03 (aquades), 99.01±4.92 (Beer), 87.65±7.83 (Vermouth), 80.23±5.22 (Rum), 78.20±3.70 (Tequila); while for flexural strength (MPa) were: 336.00±25.05 (aquades), 308.25±10.39 (Beer), 215.07±34.86 (Vermouth), 194.89±27.69 (Rum), 175.48±33.58 (Tequila). The ANOVA revealed significant differences in hardness and flexural strength ($p<0.05$). The LSD showed no significant difference in hardness and flexural strength of FRC soaked in aquades and Beer, while for other groups and aquades the differences were significant. In conclusion, FRCs soaked in different concentration of alcoholic beverages affected the decrease of hardness and flexural strength properties.
Keywords: Alcohol beverage, flexural strength, FRC, hardness

1 Introduction

It is known among the dentists that teeth do not have the ability to regenerate as other tissues in the body. As a result, when teeth are lost, there must be replacement material to substitute the lost substance and function. The missing teeth may influence someone appearance, speech, and eruption of remaining teeth [1].

One of the treatments for missing teeth is fixed partial denture (FPD) restoration. The most popular material used for FPD is porcelain-fused to metal (PFM). The PFM is known to have the properties of good aesthetic appearance, high strength, and cost expensive [2]. The PFM restoration needs extensive remaining tooth removal for the placement of alloy frame and also several patient visitings to the dental clinic [3]. Regarding to the time efficiency of patients visiting the clinic and also the time reqired by the dentist to make FPD, there is an alternative of PFM restoration lately by the use of fiber-reinforced composite resin (FRC) restoration. The materials used for FRC restoration are flowable dental composite (mostly contain bis-GMA and filler), fiber (glass or polyetylene), and coupling agent [4]. The FRC restoration was reported to have the properties of better viscoelastic, similar strength, less cost than the PFM restoration [5]. The FRC restoration even can be finished by the dentist in one single visit of patient to the dental clinic (therefore it is also called chairside work [6].

Ultra-high molecular weight polyethylene (UHMWPE) fiber was often used by the dentist as fibers to be reinforced in resin matrix for FPD bridgework. Polyethylene fiber was chosen as it had the properties of good physical and mechanical characteristic, chemically inert, resistent to wear and abrasion, and also resistent to impact [7]. Other study reported that UHMWPE fibers resisted to corrosive chemicals, very low moisture absorption, self-lubricating, odorless, tasteless, and nontoxic [8]. Reinforcement of UHMWPE fibers to dental composite resin gave flexural values of approximately 200 MPa [9].

It is known in dentistry, there are various types of polymer degradation in the oral cavity, for instance as a result of mechanical, thermal, and passive hydrolisis. The material degradation mechanism is related to the polymer erosion that influences the substance losses. Dental erosion becomes a risk factor for oral health related to patients eating and drinking habit in their daily lifestyle. Some patients consume alcoholic beverages in their daily life. It is seen that the alcoholic beverage consumption as boon for both body and soul [10]. Previous study reported that every drinking of 25 mL of alcoholic beverage, the tooth surface contacted with the beverage for 5 s before it washed away by the saliva [11]. Previous study [12] reported that alcoholic beverage can induce erosion on the surface of dental

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composite resin. The alcohol that is contained in the beverages diffuses into dental resin matrices resulting plasticising polymer then reducing the mechanical and physical properties such as surface hardness and roughness [13]. It was reported that the ratio of alcohol-water by 50-50 (volume based) showed the highest impact on flexural strength of resin dental composite material [14]. However, there is no studies related to the effect of alcoholic concentration contained in commercial beverages towards mechanical properties of polyethylene fiber-reinforced dental composite resin.

2 Materials and methods

2.1 Materials

The materials used in this research were as Table 1. The instruments used for research were : surgical stainless steel scissors, forceps, light curing unit (LED, Woodpecker, USA), brass split mold for flexural and hardness test, glass slide, syringe, celluloid strip, load of 500 g, aluminum foil, tweezers, water bath, universal testing machine, microhardness tester.

Table 1. Material used in current study

Material	Manufacturer	Composition
Fiber	Vactrise, USA	Ultra-high molecular weight polyethylene
Flowable dental composite resin	i-FLOW i-dental, Lithuania	Bis-GMA
Beer	Bintang, Indonesia	Alcohol 4.5 %
Vermouth	Martini, Italy	Alcohol 15 %
Rum	Malibu, Barbados	Alcohol 21 %
Tequila	Camino, Mexico	Alcohol 40 %

2.2 Fiber preparation

The UHMWPE fibers were kept in desiccator for 24 h before used. This process was aimed to make the fibers humidity homogeny. The fibers were cut into (2 × 2 × 25) mm by surgical stainless steel scissors for flexural strength measurement and (2 × 2 × 25) mm for hardness test. The fibers then wrapped in aluminum foil, placed in petridish, then kept in refrigerator before used.

2.3 Specimen preparation

Specimens preparation were based on ISO 9917-2. Specimens were made for each group 4 (n=4). The brass split mould for flexural strength was placed on a glass plate. The inner mould of the brass was marked at the height of 0.9 mm from the mould base by marker pen. The dental resin composite was injected using a syringe until the mark in the mould. The polyethylene fiber was lied on the surface of the flowable composite resin. The fiber was then covered by another layer of composite resin by injecting the composite resin until the mould was fulfilled. A layer of celluloid strip was then placed on the top of composite resin surface. A glass slide was then placed on the top of the celluloid strips and also a load of 500 g to obtain smooth and flat surface of the specimen. The sample was then light cured by LED light curing unit for 20 s. As the diameter of the tip of the light curing was 8 mm, therefore 4 curing process for the length of 25 mm flexural test specimen was needed. The aluminum foil was used to cover the parts that were not intend to cure. The specimens made for hardness test were similar in preparation to the flexural measurement except for the sample size of (2 × 2 × 25) mm.

2.4 Immersion of the specimens

Various alcoholic beverage (4 brands) as in table I were used for specimen’s immersion. The control for specimen immersion solution was aquades. It was prepared 25 mL of each beverages brand which was placed in a beaker glass instead of each having 25 mL of aquades which was prepared in another beaker glass. The beakers then were placed in the waterbath with a constant temperature of 37 °C to simulate the oral temperature. Four strips of FRC samples were used for each beverage. The beverages control group in this research was aquades. Each complete cycle was started by soaking one of the specimens in respective beverage solution for 5 s and then it was taken out using a tweezers, dried it with a filter paper then soaked in aquades for 5 s. The cycle was repeated for 10 times and ended with the soaking in aquades for 24 h before the next 10 cycles of treatment. The process was repeated for 10 cycles for each solution to simulate the drinking pattern of patient in daily life during 28 d. After 28 d of the immersion in the solution and aquades, the samples were then dried with filter paper before the flexural strength and hardness measurement were done.

2.5 Measurement of flexural strength

The flexural strength measurement was based on ISO 10477 part 7. The test was carried out using the universal testing machine with the cross-head speed of 2 mm min^{-1}. The supporting rods (2 mm in diameter) was mounted paralel with 20 mm between the centers while the third rod (2 mm diameter) was placed in the centre parallel to the other two. The combination of the three rods can use to give a three point loading to the specimen. Each specimen was given a line in the middle and was placed in the testing machine. The machine was activated until the specimen fractured. The maximum force in Newton (N) can be gained withstand by the specimen right before it fractured was displayed. The force displayed was calculated using the following formula [15]:

$$\sigma = 3 \text{ PI} / 2 \text{ bd}^2 \quad (1)$$

Where:
Σ = flexural strength (MPa)
P = maximum load at the point of fracture (N)
I = distance between the supports (mm)
b = width of the specimen (mm)
d = depth of thickness of the specimen (mm)

2.6 Hardness measurement

Samples for hardness tester were prepared according to ISO 6507-2. Leitz microhardness instrument (Leitz Inc, USA) and leicaQGo software program (Leica, Germany) were used to carry out the measurement and calculate the hardness value. A load of 0.245 N and a loading duration of 20 s were used in this research. The materials used showed viscoelastic in property, therefore time delay from applying the indenter to determination of the hardness value was standardized to 10 seconds.

3 Results and discussion

The result of flexural strength measurements and hardness were as Table 2. It was seen from the table that the flexural strength and surface hardness properties of polyethylene FRCs exposed to higher percentage of alcoholic beverage were decreased. The control immersion solution of aquades provided higher FRC flexural strength value than the FRC exposed to commercial alcoholic beverages. By this result it can be stated the concentration of alcohol in alcoholic beverages influence the decrease of flexural strength of FRC. Previous research reported that when ethanol penetrated through the polymer matrix, it would remove the unreacted monomers, oligomonomers, and linear polymer from the polymer structure and then causing the softening effect to the polymer [16].

Previous research [17] reported that higher alcohol concentration gave higher softening effect to composite resin matrix. It was found that wine (9 volume percentage alcohol) had greater composite resin wear effect compared to beer (5 volume percentage alcohol). By this finding therefore it was concluded that the higher concentration of alcohol, the higher the rate of elution, causing more damage to the polymer matrix and resulting lower flexural strength.

Table 2. Mean of flexural and hardness test value

Alcoholic beverage (% of alcohol)	Flexural strength (MPa)	Hardness (KHN)
Aquades (0 %, control)	336.00±25.05	98.70±6.03
Beer (4.5 %)	308.25±10.39	99.01±4.92
Vermouth (15 %)	215.07±34.86	87.65±7.83
Rum (21 %)	194.89±27.69	80.23±5.22
Tequila (40 %)	175.48±33.58	78.20±3.70

The normality test of the data for flexural strength was determined by Shapiro Wilk Test with the Saphiro Wilk statistical value of 0.916, p=0.067. The Levene test to verify the homogenity of the data showed statistical value of 2.130, p=0.127. By the data, it can be concluded that the data had normal distribution and the variance was homogeny. By this parameter, the data can be analyzed parametrically by using analysis of variance (ANOVA). The result of the ANOVA was as Table 2.

Table 3. ANOVA for flexural strength value

	df	F	Sig
Between groups	4		
Within groups	15	26.68	0.001
Total	19		

Table 3 showed there was a statistically significant difference on the flexural strength of polyethylene FRC after immersed in various alcoholic beverages. The result exhibited that the more percentages of alcohol content in the beverages indeed significantly decreased the flexural strength of FRC. In order to identify which groups differed from each other therefore Least Significant Difference (LSD) test was used. The result of the LSD as in Table 4.

Statistical result of LSD post hoc showed that the mean flexural strength of Aquades vs Beer, Vermouth vs Rum, Vermouth vs Tequila, and Rum vs Tequila revealed no significant difference. It showed from the research that the exposed of FRC in alcoholic beverages decrease the flexural strength but further decrease in flexural strength after 15 % alcohol concentration were not statistically significant. The explanation of this fact was likely to be the addition of polyethylene fibers to be reinforced to the polymer matrix. According to previous study [18, 19], the fuse of high-performance UHMWPE fibers into acrylic resin base brought about a reduction in water sorption. Polyethylene fibers were hydrophobic and they replaced the hydrophylic resin with hydrophobic fiber brought about the high modulus fibers and the quality of the fiber interface controlled the dimensional changes of the resin. By this process, the degradation of FRC did not happen in a great degree to the point that mechanical properties of FRC were influenced.

Table 4. LSD for flexural strength test

Group Comparison	Mean different	p
Aquades vs Beer	27.75	0.177
Aquades vs Vermouth	120.94	0.001
Aquades vs Rum	141.12	0.001
Aquades vs Tequila	160.52	0.001
Beer vs Vermouth	93.19	0.001
Beer vs Rum	113.37	0.001
Beer vs Tequila	132.77	0.001
Vermouth vs Rum	20.18	0.320
Vermouth vs Tequila	39.59	0.062
Rum vs Tequila	19.40	0.338

Statistical calculation for hardness value normality test by Shapiro Wilk revealed the value of 0.992, p= 0.970. The homogeny test of Levene showed statistical value of 1.802, p=0.220. By the data, it can be concluded that the hardness value showed normal distribution and the variance was homogeny. By this parameter, the data can be analyzed parametrically by using analysis of variance (ANOVA). The result of the ANOVA for hardness properties was as Table 5.

Table 5. ANOVA for hardness value

	df	F	Sig
Between groups Within groups Total	4 15 19	222.68	0.001

Table 5 revealed significant difference among hardness value of polyethylene FRC exposed to various commercial alcoholic beverages. Further analysis by LSD was done to know further the groups which were differed each other. The result of the LSD for hardness value test was as in Table 6.

Table 6 revealed that there was not any significant difference of hardness property between aquades and beer immersion of polyethylene FRC. This fact may be caused by the reinforcement of polyethylene fiber to the resin. Polyethylene fiber had the property of relatively chemically inert, therefore such lower alcohol exposure (5 %) did not impact significantly to the hardness value of FRC. This result was in agreement with previous study that found no statistically different in dental composite wear between beer and water after 14 d of immersion treatment [17].

Table 6. LSD for hardness value

Group Comparison	Mean different	p
Aquades vs Beer	10.33	0.150
Aquades vs Vermouth	113.74	0.001
Aquades vs Rum	197.09	0.001
Aquades vs Tequila	142.14	0.001
Beer vs Vermouth	126.07	0.001
Beer vs Rum	107.32	0.001
Beer vs Tequila	120.51	0.001
Vermouth vs Rum	31.45	0.284
Vermouth vs Tequila	27.62	0.170
Rum vs Tequila	15.93	0.253

Clinically, the effects of alcoholic beverages on dental restoration may be influence by many factors. Saliva in the oral cavity may dilute or buffer the alcoholic beverage thus reducing the softening effect. To predict the behaviour effect of FRC related to food and beverage consumption in daily life need knowledge of sorption and solubility properties of this material.

4 Conclusion

The result of this study showed that polyethylene FRC soaked in higher concentration of alcohol from commercially alcoholic beverages revealed the mechanical decrease properties including the flexural strength and surface hardness. The immersion of FRC in Vermouth with the alcohol concentration of 15 % caused a significant decrease in flexural strength and hardness value but beer (4.5 %) was not enough to cause a significant decrease both in flexural strength and hardness properties. Further study can be carried out on the minimum concentration of alcohol to cause a significant decrease in mechanical properties in 28 d of immersion.

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