Effect of Different Contamination on Microhardness of Resin Composite

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Abstract

This study aims to evaluate the effect of contamination on surface microhardness of resin composite in comparison to resin composite without contamination group. Vickers microhardness was used to determine the effectiveness of polymerization on the contaminated surface of resin composite. Resin composite was filled into a disc-shaped metallic split mold (2 mm depth). Then, the resin composite specimens were contaminated by contaminants include a bonding agent, hemostatic agent, plumber tape, powdered gloves and alcohol then light cured for 40 seconds. Specimens were divided into 2 groups (unpolished and polished groups). Each specimen was tested by Vickers microhardness tester. The data were analyzed statistically by independent t-test and paired t-test using SPSS. The results revealed contamination by a bonding agent and plumber tape in unpolished groups was significantly lower than uncontaminated group ($p < 0.05$). There were no significant differences between uncontaminated group and 5 contaminated in polished groups ($p > 0.05$). The surface hardness of the polished specimens increased in 5 contaminated groups compared to the values from the uncontaminated group and all of the polished groups were significantly higher than the unpolished groups ($p < 0.05$). In conclusion, contamination by a bonding agent and plumber tape were effect by the polymerization of resin composite. However, after the polishing procedure, the microhardness value of resin composite increased because the polishing procedure may have removed the incomplete polymerization layer caused by surface contamination.

Keywords*: contamination, polymerization, resin composite, surface hardness, Vickers microhardness*

1. Introduction

Resin composites are used worldwide in dentistry, mainly because of their aesthetic quality and good physical properties. Since resin composite was first developed, many efforts have been made to improve the clinical behavior of this restorative material. Several studies have demonstrated that the surface hardness of resin composite depends on many parameters such as curing techniques, depth of cure, curing time, and polishing procedures. Some contamination such as water maybe inhibit polymerization reaction that effect surface hardness but no evidence about this issue (AlShaafi, 2017).

The polymerization reaction is one factor that effect surface hardness. Adequate polymerization all over composite resin restorations is one of the main important factors influencing their clinical success. The degree of conversion is an important tool to estimate the physical, mechanical and biological properties of composite resin restorations (Galvão, Caldas, Bagnato, de Souza Rastelli, & de Andrade, 2013; Cekic-Nagas, Egilmez, & Ergun, 2010). Higher degree of conversion is an essential factor for obtaining superior physical and mechanical properties (Cekic- Nagas et al., 2010; Yoon, Lee, Lim, & Kim, 2002). Inadequate polymerization might lead to marginal microleakage (Kusgoz et al., 2011), discoloration (Aguiar et al., 2011) and decreased bonding strength (Dalli'Magro et al., 2008) of resin composite restorations. The incomplete curing of composite resins is associated to a reduction in their mechanical properties and biocompatibility, increased content of residual monomers and altered clinical performance due to esthetic impairment, with high tendency to surface staining and the possibility of marginal leakage (Camargo, Moreschi, Baseggio, Cury, & Pascotto, 2009). A lower degree of conversion might also cause increase in the amount of released unreacted monomer, leading to less biocompatible restorations (Yap, Soh, Han, &

Siow, 2004; Yap, Wong, & Siow, 2003). In addition, uncured functional groups can act as plasticizers, producing restorations with inferior mechanical properties (Alonso et al., 2013; Asmussen & Peutzfeldt, 2001). Furthermore, discoloration and accelerated wear were caused by residual monomer trapped in the restoration (Tanaka, Taira, Shintani, Wakasa, & Yamaki, 1991).

If resin composite is exposed to air during the polymerization process which is induced by free radicals, the polymerization of resin composite will be interfered with or delayed and decrease the surface hardness of resin composite. So, after curing resin composite, the most effective way to increase the surface hardness of resin composite is polishing (Park & Lee, 2011). The significant increase surface hardness occurs by removing the oxygen induce layer from the surface of restorative material (Strnad, Kovacs, Andras, & Beresescu, 2015). The polishing influenced hardness of the tested resin composite, significantly increasing these values. Although a smooth surface can be obtained after polymerization, the superficial layer is essentially composed by organic matrix, being hence, less dense than the underlying layer. Thus, the removal of this layer by polishing procedures increases the surface resistance (Chinelatti, Chimello, Ramos, & Palma-Dibb, 2006).

Hardness is defined as the resistance to permanent indentation or penetration. Hardness is commonly correlated with mechanical strength, rigidity, and resistance to intraoral softening (Uhl, Mills, & Jandt, 2003). There are many factors that influenced the hardness of resin composites such as organic matrix composition, type and amount of filler particles and degree of conversion (Correr, Sinhoreti, Correr, Tango, Schneider, & Consani, 2005). Morover, the physical and mechanical properties of dental composites are directly related by the degree of conversion during the polymerization process (Moraes et al., 2008). Decrease in surface hardness would adversely affect mechanical properties and marginal integrity of resin composite restoration (Obici, Sinhoreti, Correr, Góes, Consani, 2004). Several direct and indirect methods can be used to evaluate the degree of polymerization of resin composites. The surface hardness was used to verify indirectly the degree of polymerization of resins composite (Ferracane, 1985). In direct methods, infrared spectroscopy and electron resonance can directly quantify the percentage of double carbon links converted into simple links during polymerization reactions (Koda et al., 1995). However, these methods are complex, time consuming and costly (Rueggeberg & Craig, 1988). Therefore, the indirect methods, the use of hardness tests has become very popular due to there are more simple techniques and reliability of the obtained results (Ferracane, 1985). In addition, the hardness values show a positive correlation with degree of conversions (Rueggeberg and Craig, 1988; Bouschlicher, Rueggeberg, & Wilson, 2004). Hardness testing has been widely used in the study of optimum cure of composite resins and includes Knoop and Vickers hardness testing. The Knoop and Vickers tests are classified as microhardness tests (Anusavice, 1996). When the Knoop and Vickers hardness methods were compared in a study on placement techniques of composites, it was reported that both the Knoop and Vickers hardness measurements showed statistically similar results and good correlation (Poskus, Placido, & Cardoso, 2004). Both tests can be used for the indirect evaluation of degree of polymerization of composites (Poskus et al., 2004) and the Vickers hardness method is an appropriate indirect test to use to evaluate the degree of cure of composites (Lodhi, 2006).

Surface hardness of the tested materials a study was assessed using Vicker's hardness test as it is easy to apply and the data obtained was reliable (Galvão et al., 2013). The knop diamond indenter used in the procedure does not deform over time and is reportedly suitable for measurement of the hardness of fragile brittle materials (Wang, D'Alpino, Lopes, & Pereira, 2003). Surface hardness is a good predictor for resin conversion as it is especially sensitive to small changes in polymer cross-linking in areas of high conversion (Souza et al., 2010). Surface hardness tests furthermore allows for measurements at specific locations within the sample while its simplicity allows evaluation of large number of specimens (Dietschi,

Marrett and Krejci, 2003).

The result of previous studies revealed about contamination of saliva, blood and powdered glove that effect mechanical properties of resin composite. The presence of powder in the gloves seems to be more damaging for the diametral tensile strength, flexural strength, flexural modulus and incremental layer bond strength than the presence of saliva (Martins et al., 2015). Blood contamination significantly reduced the bond strengths between resin composite increments (Eiriksson, Pereira, Swift, Heymann, & Sigurdsson, 2004). However, the present studies do not address the effect of contamination from hemostatic agent, bonding agent, alcohol, powdered glove and plumber tape that are commonly used in clinical procedures for resin composite manipulation. In addition, there is no evidence about the effect of surface contamination effectiveness of resin composite polymerization.

The aim of this study was to evaluate the influence of surface contamination, include alcohol, bonding agent, plumber tape, powdered gloves and hemostatic agent, on surface microhardness of resin composite. Vickers microhardness was used to determine the effectiveness of polymerization on the contaminated surface of resin composite.

2. Objectives

The objective of this study is to investigate the surface hardness of contaminated surface of resin composite. To compare the surface hardness of contaminated resin composite between unpolished and polished groups

3. Materials and methods

Specimen preparation

A total of 120 specimens of disc-shaped resin composite (Premise, Kerr Corp, Orange, CA, USA, B1, Lot No.5361110) were prepared from metallic split mold (Ø 4 mm, thickness 2 mm). The specimens were divided into 6 groups depending on the type of contamination and each group was divided into 2 subgroups (Figure 1).

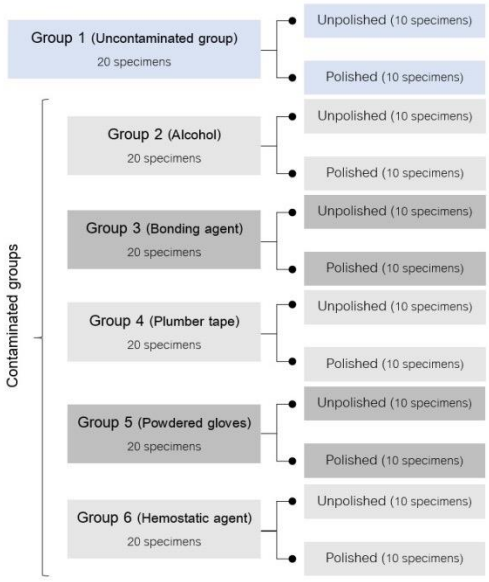

Figure 1 Schematic illustrations of experimental groups

Group 1 (Uncontaminated group): 20 specimens were prepared by placement of resin composite shade B1 into a metallic split mold. The material was placed in one bulk with adequate compaction. The top of the mold was covered with a celluloid matrix strip (0.05 mm thick, Hawe Striproll, KerrHawe SA, Bioggio, Switzerland, Lot No.2547813) and glass slide (1 mm thick); the excess material was removed by pressing a glass slide against the strip. The mold was covered with a specifically designed light tip alignment cover. The cover enabled the light tip (turbo curve tip diameter of 8 mm unit, Kerr Corp, Orange, CA, USA) of curing unit (Demiplus, Kerr Corp, Orange, CA, USA) to be positioned centrally and perpendicularly to the top of the slot and contact the glass slide. The material was light-cured from the top surface for 40 seconds and checked with a radiometer (Model L.E.D. RADIOMETER, sds Kerr, Middleton, WI, USA) to calibrate the power density of 1,100- 1,300 mW/cm2.

Group 2-6 (Contaminated groups): 20 specimens of each group were prepared by placement resin composite into a metallic split mold. The material was placed in one bulk with adequate compaction. In 2 to 6 experimental group, the top surface of the composite resin were contaminated with alcohol, bonding agent, plumber tape, powdered gloves and hemostatic agent respectively.

Group 2, 3 and 6, one drop (0.05 ml) of each contaminate agent were applied on the resin composite surface by using a microbrush with a brushing motion, 5 times per specimen and air-dry by triple syringe.

Group 4 and 5, plumber tape and powdered gloves (Sri Trang GlovesTM, Songkhla, Thailand) were cutting into a piece size 1 × 2 cm. and then applied on the surface by a rubbing motion, 5 times per specimen.

The top of the mold was covered with a celluloid matrix strip and a glass slide, and the excess material was removed by pressing a glass slide against the strip. The remaining steps were similar to those described for group 1.

In addition, each group was divided into 2 subgroups (Figure 1). Subgroup 1: After polymerization of each subgroup, the mold was removed and 10 specimens of each group were tested by Vickers hardness testera. (FM-810, FUTURE-TECH, Japan). Subgroup 2: 10 specimens remaining were sequentially polished with Optidisc™ (Kerr, Bioggio, Switzerland). For standardization, polishing was performed by the same operator using Optidisc in decreasing abrasive following the manufacturer's recommendation [coarse (40 micrometers), fine (20 micrometers), extra fine (10 micrometers) respectively], each one with a single-use to polish under dry condition for 5 times.

Every step of the procedure was performed by one person, in a room with fluorescent light during specimen preparation and curing. After specimen the preparation step, all specimens were tested by Vickers hardness tester. However, void in resin composite, crack or fracture specimen was excluded from the experiment.

Microhardness evaluation

For each indentation, surface hardness was measured with a Vickers microhardness tester (FM-810, FUTURE-TECH, Japan) using a load of 50 grams for 15 seconds. To reduce measurement errors among different areas within a specimen, the surface hardness of five points per specimen were measured and averaged to produce the representative value for that specimen. The first indentation was made at the center of sample. Four other indentations apart from the first indentation 1.5 mm. to left, right, up and down were made.

Data analysis

The normal distributions were tested by Kolmogorov-Smirnov test. Means of microhardness, in each contaminated group (unpolished), were compared to uncontaminated group (unpolished) by

independent two-tailed t-test. In addition, all contaminated groups (polished) were compared to uncontaminated groups (polished) by independent two-tailed t-test. Moreover, all contaminated groups (unpolished) were compared to uncontaminated and contaminated groups (polished) by paired t-test. Because the contamination was controlled and specimen's preparations were made with the same experimenter paired t-test were used in this study. All statistical tests were performed at a significant level of 0.05.

4. Results and Discussion Results

The means of microhardness values of unpolished resin composite contaminated by alcohol, bonding agent, hemostatic agent, plumber tape and powdered glove were 44.30 kg/mm^2 , 38.89 kg/mm^2, 43.10 kg/mm^2, 41.51 kg/mm^2 and 43.49 kg/mm^2 (respectively). Microhardness values of unpolished resin composite contaminated by bonding agent and plumber tape were significantly lower than unpolished uncontaminated group ($p < 0.05$) as shown in Table 1.

Table 1 Comparison of Vickers microhardness (mean) between uncontaminated and contaminated group (unpolished)

	Mean (SD) kg/mm^2		Mean (SD) kg/mm^2	p-value
Uncontaminated	44.52(1.84)	Alcohol	44.30(1.72)	0.787
		Bonding	38.89(3.61)	0.001*
		Hemostatic agent	43.10(1.7)	0.091
		Plumber tape	41.51(2.12)	0.003*
		Powdered glove	43.49(2.1)	0.261

*indicates significant difference between uncontaminated group and contaminants, independent t-test at significant level 0.05

Means of microhardness values between each polished contaminated groups and polished uncontaminated group were shown in Table 2. The means of microhardness values of polished groups range from 51.86 kg/mm^2 to 52.52 kg/mm^2. There was no significant difference, compared between each contaminated groups and uncontaminated group (polished) (p 0.05).

Table 2 Comparison of Vickers microhardness (mean) between uncontaminated and contaminated group (polished)

	Mean (SD) kg/mm^2		Mean (SD) kg/mm^2	t-test	p-value
Uncontaminated	52.19 (1.15)	Alcohol	51.91 (1.57)	0.460	0.651
		Bonding	52.52 (1.39)	0.569	0.576
		Hemostatic agent	52.07 (1.04)	0.255	0.802
		Plumber tape	51.86 (1.11)	0.651	0.523
		Powdered glove	52.24 (0.76)	0.103	0.919

*Independent t-test at significant level 0.05

By microhardness method, the means of microhardness values between unpolished and polished groups were shown in Table 3. There was significant difference ($p < 0.05$), compared between unpolished and polished groups in each group ($p < 0.05$).

Table 3 Comparison of Vickers microhardness (mean) between unpolished and polished groups (mean (SD), n=10)

	Unpolished kg/mm^2	Polished kg/mm^2	t-test	p-value
Uncontaminated	44.52 (1.84)	52.19 (1.15)	9.777	0.000*
Alcohol	44.30 (1.72)	51.91 (1.57)	7.675	0.000*
Bonding	38.89 (3.61)	52.52 (1.39)	10.289	0.000*
Hemostatic agent	43.10 (1.70)	52.07 (1.04)	15.498	0.000*
Plumber tape	41.51 (2.12)	51.86 (1.11)	12.792	0.000*
Powdered glove	43.49 (2.1)	52.24 (0.76)	14.991	0.000*

*indicates significant difference between unpolished and polished group, paired t-test at significant level 0.05

5. Discussion

The microhardness test can evaluate the degree of polymerization of resin composite as an indirect method. Degree of polymerization reaction effect directly to the properties of a restorative material (Yap, Sau, & Lye, 1998). The effectiveness of material curing may be assessed directly or indirectly. Direct method, spectroscopy is one of more frequently used methods to determine monomer to polymer conversion. In general, it is the use of light, sound or particle emission to study the properties of matter. Spectroscopic methods have been increasingly used in studying monomer conversion into polymer of resin composite (Ruyter & Svendsen, 1978).

The percentage of converted monomer into polymer does indicate degree of conversion, but does not indicate the actual amount of converted aliphatic C=C double bonds in the resulting polymer (Emami & Soderholm 2003), but direct method can indicate percentage of incomplete polymerization. However, this study just needs to investigate the effect of contamination to effectiveness of polymerization. Therefore, the indirect method was used in this study. The measurement of surface microhardness is one indirect method that commonly is used because of convenience. Our study used surface microhardness measurements to estimate the quality of resin curing under contamination.

In the present study, we found that contamination with a bonding agent and plumber tape significantly decreases the surface hardness compared with uncontaminated group which can be indicated that contamination from these 2 materials effects effectiveness of resin composite polymerization and there were remaining of unpolymerized monomers. For a bonding agent, the components of a bonding agent include less fillers load and more matrix that also is the reason of decreased surface hardness. For plumber tape, it may be attached by any foreign materials or its own components that effect polymerization of resin composite. This is a definite limitation of our study and should be investigated in future research.

Many factors affect the degree of polymerization of resin composite, including the shade, light curing duration, increment thickness, light unit system used, cavity diameter, cavity location, light curing tip distance from the curing resin composite surface, substrate through which the light is cured **(e.g.**, curing through ceramic, enamel, or dentin**)**, filler type, and temperature (AlShaafi, 2017). In this study, these factors were controlled in each experimental group. Oxygen inhibited layer will occur on the top of resin composite surface. Oxygen is a powerful inhibitor which retards or even terminates polymerization (Park, & Lee, 2011). The most effective way to increase the surface hardness of resin composite is polishing after curing (Park, & Lee, 2011). The significant increase surface hardness occurs by removing the oxygen induce layer from the surface of restorative material (Strnad, G., *et al*, 2015). But in the present study, celluloid strip and glass slide were used in specimen preparation procedure so oxygen inhibited layer will not occur on the restoration surface

In the polishing procedure, the capacity is related to their ability of equally removing particles and organic matrix (Ritter, 2001). Polishing influenced hardness of the tested resin composite, significantly increasing these values (Chinelatti et al., 2006). This study used Optidisc with Coarse (40 micrometers), fine (20 micrometers) and extra fine (10 micrometers), disc that was impregnated with aluminum oxide particles. Our result was consistent with a previous study, in which polishing influenced surface hardness of resin composite, significantly increasing these values. In addition, mean thickness of each specimen before and after polishing was measured. There was a significant difference of 0.04 mm.

Recently, a manufacturer has developed resin composite materials that improved the physical properties and better in clinical use than the first generation resin composite. Contamination during resin composite restorative procedures is still the critical problems that we should avoid. For future studies, SEM should be used to evaluate remaining contaminated agent on specimens after the preparation procedure and polishing procedure and also to evaluate the depth of contamination.

6. Conclusion

Contamination from a bonding agent and plumber tape alters the results of the effectiveness of resin composite polymerization that may cause significantly decreased surface hardness by measurement of microhardness value. From our study the contamination only inhibited polymerization and reduced hardness at the resin surface which can be removed by routine polishing resulting in hardness that was similar to the uncontaminated resin. Although, other materials do not affect the polymerization of resin composite but awareness of manipulation on resin composite in clinical work is required.

7. Acknowledgement

This study was financially supported by the Faculty of Dental Medicine, Rangsit University

8. References

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