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Effect of Different Light Curing Systems on Surface Hardness of Composite Resins

SUMMARY

Aim: *The purpose of this study was to evaluate the effect of different light curing systems on surface hardness of composites.*

Materials and Methods: *Composite samples (2 mm thick, 6 mm in diameter, n=10) were prepared in a teflon mould using different light curing systems. Group 1: Hybrid composite samples Filtek Z250 (3M ESPE, St. Paul MN, USA) were polymerized with halogen light source (PolyLUX II, KaVo, Germany) for 20 seconds. Group 2: Hybrid composite Filtek Z250 samples were polymerized with halogen light source for 20 seconds, then additional polymerization was performed in Colténe D.I.-500 oven. Group 3: Composite samples Filtek Z250 were polymerized with LED light source (Elipar FreeLight 2, 3M ESPE, St. Paul MN, USA) for 20 seconds. Group 4: Composite samples Filtek Z250 were polymerized with LED light source for 20 seconds, then additional polymerization was performed in Colténe D.I.-500 oven. Group 5: Tescera indirect composite samples were polymerized in Tescera ATL (Bisco, Inc. Schaumburg, IL, USA). The hardness test was performed using a digital microhardness tester (Buehler, Lake Bluff, Illinois, USA) with load of 500 g and dwell time of 15 seconds. The hardness was measured from the top and the bottom of the composite discs. Data were analyzed by using Student t-test, 1-Way ANOVA and Tukey's tests ($p<0.05$).*

Results: *The mean values and standard deviations were as follows: Group 1 (top = 66.50 ± 1.28; bottom = 64.81 ± 1.45); Group 2 (top = 68.06 ± 1.76; bottom = 66.71 ± 2.27); Group 3 (top = 69.80 ± 0.97; bottom = 67.01 ± 2.16); Group 4 (top = 69.85 ± 0.92; bottom = 68.05 ± 0.81); Group 5 (top = 71.05 ± 1.46; bottom = 71.33 ± 1.08).*

Conclusion: *Tescera ATL system exhibited the highest microhardness values. The group in which halogen lamp and additional polymerization was used, showed significantly higher hardness values than the group in which only halogen lamp was used. However, additional polymerization did not affect the values when LED systems were used.*

Keywords: Hybrid Composite; Polymerization, techniques; Microhardness

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Introduction

Composite materials have changed over the past decade. The new developments, along with an increase in patient aesthetic awareness, have led many practitioners to use composites to restore posterior teeth. But, inadequate polymerization can cause some clinical problems such as discoloration, pulpal irritation, postoperative sensitivity or failure of the restoration[1].

The degree of conversion of a resin material may affect physical properties, such as compressive strength, wear and hardness[2]. Highly polymerized composites characterized by increased cross-link density and low residual monomer have been shown to exhibit greater wear resistance, hardness and flexural strength[3-6]. Hardness, which is defined as the resistance of a material to indentation, cutting, stratching or abrasion, can be used as one indicator for the completeness of polymerization since the hardness of a polymer is directly related to its degree of cure[7].

Many different light curing systems have been demonstrated in response to dramatic rise in the use of composite restorations over the past few years. Most of these systems purpose at decreasing polymerization shrinkage or reducing curing time[8-11]. There are various technologies used for curing lights, which range from conventional halogen bulbs to more expensive systems using lasers, plasma arc and LEDs (light-emitting diodes). Nowadays, halogen-based light curing units are the most widely used light curing units in dentistry[12]. LEDs hold several advantages over halogen-based units, including having longer lifetimes of several thousand hours, converting electricity to light more efficiently, producing less heat, not requiring filters and resistance to shock and vibration[13]. Rather than a hot filament, as used in halogen lamps, LED uses junctions of doped semiconductor to generate blue light[14]. LEDs operate around 470 nm, which falls conveniently within the camphorquinone absorption spectrum[15-17]. Blue LEDs present spectral purity for highly efficient curing of dental resins. Moreover, LEDs have an effective lifetime of more than 10.000 hours and do not present significant degradation of light emission over time[17].

An adequate curing of resin composites may influence the mechanical properties and clinical optimization of these materials. Microhardness is a typical parameter for indicating the degree of polymerization of resin composites. However, adequate surface hardness does not ensure proper polymerization throughout the restoration. Therefore, hardness analysis must also be performed on the bottom surface of the samples, since insufficient polymerization of this area may increase the risk of bulk and marginal fracture[18].

There is a relationship between polymerization shrinkage and microhardness of resin composite. Less polymerization shrinkage causes higher microhardness levels. Recently, in order to reduce polymerization shrinkage, soft-start and low-intensity curing systems have been utilized in restorative dentistry[10,11,19-23].

A positive correlation has been established between composite hardness and inorganic filler content[24,25]. Curing light irradiance exposure duration and composite light transmission are variables significantly affecting hardness and conversion profiles with sample depth[26,27] .

Bottom to top hardness ratios ranging from 0.80-0.90 have been used as criteria for adequate conversion at a specific sample depth[28] .

Developments in the organic matrices and a better polymerization increase their mechanical and physical properties[29]. Oxygen inhibits the polymerization of resins by reacting with free radicals so that they are not available to induce the polymerization reaction[7,30-32]. This inhibition can be significant. It is hypothesized that air mixed into the composite during packing may not only increase the porosity, but also inhibits polymerization of composite resins, both of which can lead to a reduction in the composite's hardness[30].

The purpose of this study was to evaluate the effect of different light curing systems on surface hardness of composites.

Material and Methods

A hybrid composite - Filtek Z250 (3MESPE, St. Paul MN, USA) was used in this study. Test specimens, 2 mm in thickness and 6 mm in diameter, were prepared. Specimens were randomly divided into 5 groups (n=10). *Group 1*: Hybrid composite samples - Filtek Z250 (3M ESPE, St. Paul MN, USA) were polymerized with halogen light source (PolyLUX II, KaVo, Germany) for 20 seconds; *Group 2*: Hybrid composite (Filtek Z250) samples were polymerized with halogen light source for 20 seconds, then additional polymerization was performed in Colténe D.I.-500 oven; *Group 3*: Composite samples (Filtek Z250) were polymerized with LED light source (Elipar FreeLight 2, 3M ESPE, St. Paul MN, USA) for 20 seconds; *Group 4*: Composite samples (Filtek Z250) were polymerized with LED light source for 20 seconds, then additional polymerization was performed in Colténe D.I.-500 oven; *Group 5*: Tescera indirect composite samples were polymerized in Tescera ATL (Bisco, Inc. Schaumburg, IL, USA).

The hardness test was performed using a digital microhardness tester (Buehler, Lake Bluff, Illinois, USA) - load: 500 g; dwell time: 15 seconds). All samples were measured from the top and the bottom of the composite discs.

Statisticall analysis was performed using Student t-test, 1-Way ANOVA and Tukey's tests ($p<0.05$).

Results

When compared with the top and bottom surface roughness values, Groups 1 and 3 showed statistically significant difference. However, there was no statistically significant difference between the top and the bottom roughness values of Groups 2, 4 and 5 (Tab. 1). The highest surface roughness value was observed in Group 5 and the lowest value was observed in Group 1.

Table 1. The mean values and standard deviations (S.D)

Groups	Mean and S.D. (Top Surface)	Mean and S.D. (Bottom Surface)
Group 1	66.50 ± 1.28	64.81 ± 1.45
Group 2	68.06 ± 1.76	66.71 ± 2.27
Group 3	69.80 ± 0.97	67.01 ± 2.16
Group 4	69.85 ± 0.92	68.05 ± 0.81
Group 5	71.05 ± 1.46	71.33 ± 1.08

There was a significant difference between Groups 1-3, 1-4, 1-5, 2-3, 2-4 and 2-5. No significant difference was observed between Groups 1-2, 3-4, 3-5 and 4-5.

Discussion

One of the most significant factors affecting the longevity of restorative materials is their surface hardness and subsequent resistance to abrasive forces. While it is expected that all materials posses sufficient resistance in the dynamic oral environment in terms of surface hardness, this criteria is specifically important for the restorative materials in the posterior region. Therefore; in the present study, "Filtek Z 250", a microhybrid composite was used in the posterior region, and "Tescera" an indirect restorative material was selected as a control material. This study evaluated the effect of additional heat application to 2 different systems in which only light curing is accomplished. Tescera, which requires both light and heat curing application was therefore taken as a control group.

The results indicated that samples polymerised with halogen light source reached significantly higher surface hardness values when an additional heat polymerization was used. On the other hand, surface hardness values were not affected by additional heat polymerization when LED light application was used (Tab. 1). This shows that LED light source is more effective compared to halogen light system and minimizes the amount of residuel monomers, resulting in a highly qualified polymerization level. The high-quality polymerization capacity of LED system has also been reported by other researchers[17,33-35].

However, it seems more appropriate to make this comment for the top surfaces of the samples rather than the base ones. Because the light penetration to the base surfaces is less in light-polymerised samples, the hardness values show a drop in these regions for all groups in this investigation (Groups 1-4). In previous studies, the same results were obtained[36,37]. In case a halogen lamp is used, the difference between top and base surface hardness values in the group with no heat application is approximately the same with the group with heat application. On the other hand, in the LED group, the difference between top and base hardness values in the heat applied group is less than the group where no heat application was used. As a result, even though, LED provides an effective polymerization on surfaces it directly penetrates; if an additional heat polymerization has been used, it is evident that it is unable to reach the base surfaces efficiently.

Within limitations of this study, it can be concluded that in LED systems with direct light exposure, high surface hardness values were obtained as if additional heat has been applied. However, the inclusion of additional heat polymerization to the procedure can still be recommended to enhance the mechanical and surface properties of the bottom of composite restorations and render this area comparable to the top.

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