Original Article

Effect of Different Curing Modes on the Degree of Conversion and Vickers Microhardness of Commercial Composites

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ABSTRACT

Objective: The aim of this study was to evaluate and compare the effect of different curing modes (soft start, ramped and delayed polymerization modes) on the degree of conversion and Vickers micro hardness of commercial composites.

Study Design: Experimental study

Place and Duration of Study: This study was conducted at COMSAT, Lahore in October 2015 till April 2016 for a period of six months.

Materials and Methods: Two commercially available hybrid and nano-hybrid composite i.e. Te-Econom plus (Ivoclar vivadent, Liechtenstein) and Coltene NT Premium (Whaladent, Altstätten, Switzerland) respectively were evaluated. All samples were prepared in brass molds by using three different modes of polymerization. Degree of conversion and Vickers micro hardness of the samples was evaluated by FTIR (Thermo Nicolet P6700 USA) technique and Vicker's hardness indentor (MicroMet 6040, Buehler, Germany).

Results: Degree of conversion and Vickers microhardness of both dental composites showed the sequence, delayed curing > ramped curing > soft start curing. However, Coltene NT Premium showed better results comparatively.

Conclusion: Delayed mode of curing showed better degree of conversion and Vickers micro hardness comparatively. However, there was insignificant difference between the findings of both composites.

Key Words: Dental Composites, Degree of conversion, Vickers microhardness, Modes of curing

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INTRODUCTION

In restorative dentistry, light-cured composite resins have been regarded a material of key importance owing to their aesthetic properties. However, several factors, mainly polymerization shrinkage and stress are the main issues that reduce the longevity of the restoration. Researchers have focused on bringing up novel composites based on changing the chemistry of organic matrix (hyperbranched resins and ring opening polymers) and by throwing light on different curing techniques that decreased the polymerization shrinkage and stress to a significant level [1-3]. Three main phases *i.e.* pre-gel, gel point, and post-gel take place in the curing process of composite resins. During the pre-gel phase, there is a prevalence of linear polymer chains and the material may flow and undergo molecular readjustment to compensate for the shrinkages forces. Following pre-gel phase, the gel point of resin material is established during which the resin passes from the flow state (pre-gel) to the viscous state (post-gel) and movement of molecules is no longer possible. Thereafter, in the post-gel phase, the resin loses its flowing ability presenting a high modulus of elasticity and predominance of cross-linked polymeric structure. At this stage, the stress generated by polymerization shrinkage is transmitted to tooth-restoration interface [4, 5].

In the past, various studies have demonstrated that curing technique may influence the polymerization shrinkage of resin based composite materials [6, 7]. The clinical performance of composite resins is directly related to the degree of monomer conversion after photopolymerization and incomplete curing may lead to reduction in hardness, biocompatibility, bond strength between tooth and restoration and increased possibility of marginal leakage, pulpal damage, solubility and

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water sorption[8,9]. Therefore, different curing techniques have been suggested to minimize the effects of polymerization contraction especially sensitivity and marginal leakage [6, 10].

The techniques used in this study were step technique, soft start or ramped curing, and pulse-delay technique. In step technique (2 stages), exposure of low light intensity is given for a determined period followed by exposure with high light intensity for a certain additional period [11]. The soft start or ramp technique (progressive) has low initial intensity in the first few seconds, which is gradually increased for a certain period until it reaches a high final value that is maintained for the remaining curing time [12], whereas, in pulse-delay technique (delayed pulse) a short exposure of low light intensity is given for a certain period, followed by a period without exposure and then final curing step is performed [13]. The aim of these techniques is to decrease the shrinkage stress by allowing the occurrence of a more prolonged pre-gel phase, which as a result would allow the material to maintain its plasticity and flow for an extended period, thereby, reducing internal stresses and providing good marginal adaptation. Complete curing or a proper degree of conversion at the final stage of these techniques with high light intensity would provide satisfactory physical and mechanical properties [14].

The measurement of microhardness (MH) is an indicator of physical, mechanical, and biological properties of a restorative material and the degree of curing of a material can be indicated indirectly by the hardness test [11, 15]. Vickers hardness test (VHS) has been considered a valid tool for evaluating the hardness, viscoelastic properties, and other responses of rigid polymers [16].

Fourier transformed infrared spectroscopy (FTIR) is a direct method used to measure the degree of conversion (DC). It utilizes molecular vibrations to quantify the ration of monomer conversion into polymers by determining specific band positions to compare the unpolymerized aliphatic C=C stretching band at 1640 cm^{-1} to the aromatic C=C stretching band at 1610 cm^{-1} [13].

The aim of the present study was to determine and compare the in vitro effects of different curing techniques on the depth of cure by VH testing and measuring DC by using two different resin composites and to find out if a different composite material would respond differently under the same curing technique.

MATERIALS AND METHODS

Total 52 samples were prepared in a disc shaped brass mold, out of which 36 samples of dimension 8×4 mm were prepared for hardness testing, 18 samples of dimension 8×2 mm for degree of conversion evaluation. The mold was placed on glass slab and each sample was poured in a mold carefully. Single increment layer of 2mm was cured from both sides using high intensity blue light (LED, Woodpecker) for 60s at the constant distance of 1mm by applying three different modes of curing. The samples were removed carefully from the mold and were polished with different sized grit papers and further processed for testing.

Fourier Transform Infrared Spectroscopy (FTIR) was conducted before and after curing of all samples to evaluate the degree of conversion using the FTIR (Thermo Nicolet 6700, USA). The spectra were collected over the region 4000–400 cm^{-1} at a resolution of 8 cm^{-1} and averaging 256 scans. The data was analyzed by using OMINIC software and degree of conversion was calculated by using the following formula:

DC % = 100 × [1 − (Rpolymerised/Runpolymerised)]

Where, DC denotes degree of conversion and R is the ratio of peak height of polymerized aliphatic to polymerized aromatic and unpolymerized aliphatic to unpolymerized aromatic groups of samples. DC was calculated by analyzing the changes in the ratio of the absorbance intensities of aliphatic C=C peak at 1638 cm^{-1} and that of an aromatic C=C at 1608 cm^{-1} of the uncured and cured samples[3].

Vicker's hardness was measured by applying 200 gf load for 10 s by Vicker's hardness indentor (MicroMet 6040, Buehler, Germany). Three indentations were made on each specimen; the mean values of all three indentations were calculated. The HV values will be calculated according to ASTM E384-11e1 by using following formula:

$$VH = 1.854\ F/\ d_o$$

Where VH denotes Vicker's hardness number, F denotes indentation load and d_o denotes indentation diagonal[3].

The mean and standard deviation values were calculated and One-way ANOVA analysis was performed for all characterizations by using SPSS version 24. The result was considered significant with p-value ≤ 0.05.

RESULTS

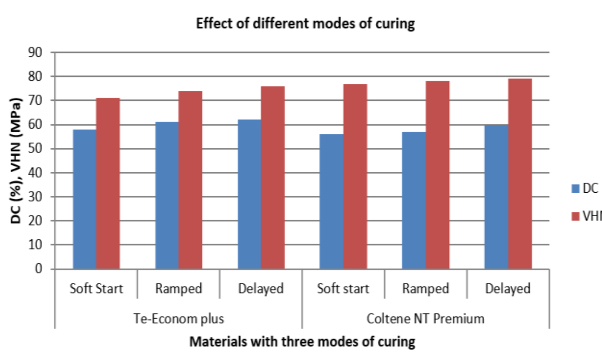

Figure No.1 Graphical presentation of degree of conversion and Vickers microhardness values

No statistical difference was observed between degrees of conversion and micro hardness of both materials. However, delayed curing mode showed better results than ramped and soft start curing modes. Vickers microhardness showed high values for Coltene NT Premium.

Two commercially available dental composites of A1 shade were used in the study. Description of the composites has been elaborated in Table 1.

Table No.1: Composition of the materials

Materials	Composition (Wt %)
Te-Econom plus (Ivoclar vivadent, Liechtenstein)	A1 Shade Hybrid resin based dental composite[17] Dimethacrylate based resins (BisGMA, UDMA, TEGDMA – 22 wt %), Filler (Barium glass, Ytterbium trifluoride, silicon dioxide -78 wt %)
Coltene NT Premium (Whaladent, Altstätten, Switzerland)	A1 Shade Nanohybrid resin based dental composite[18] Dimethacrylate based resins (BisGMA, BisEMA, TEGDMA – 25 wt %) Filler (Silica nanoparticles & aluminosilicate glass – 75-80 wt %)

Table No.2: Degree of conversion and Vickers microhardness values

Materials	Modes	Degree of Conversion	Vickers microhardness
Te-Econom plus	Soft Start	58%	71 ± 1.5
	Ramped	61%	74 ± 0.9
	Delayed	62%	76 ± 3.7
Coltene NT Premium	Soft start	56%	77 ± 3.9
	Ramped	57%	78 ± 0.5
	Delayed	60%	79 ± 2.0

DISCUSSION

In this study effect of different modes of curing on degree of conversion (DC) and hardness of two commercially available composites was evaluated. Results showed insignificant difference in hardness as well degree of conversion of both the tested RBC's and these results are in accordance with previous studies done by[19] and [20] in which the authors reported no statistically significant difference in hardness and degree of conversion of a commercially available dental composite after curing with different modes of polymerization. However, as the Coltene NT Premium has more filler loading by weight %, it showed high values of micro hardness comparatively.

DC is a very important parameter of resin based composites (RBC's) as final mechanical, physical and biological properties are influenced by it and are greatly enhanced by increased DC[21,22]. A low degree of conversion may affect the longevity of restorations by RBC's as unreacted monomers may dissolve in wet environment due to incomplete conversion and also act plasticizers consequently reducing mechanical properties[23]. Moreover, the degradation of material might take place due to oxidation or hydrolyzation as the double bonds present in uncured resin are reactive[24]. The minimum DC required for clinically acceptable restoration has not been established precisely[25]. The DC of commercially available RBC's reported in literature is found to be in range of 50% to 75%[26]. The findings showed that both composites in all the tested modes had DC within that range. In delayed mode both the DC and hardness was more by ramped mode and soft start mode respectively. The difference in DC and hardness as a result of different curing modes made be due to difference in cross linking of monomers and setting reactions within RBC's[27]. Delayed curing had positively impacted degree of conversion by allowing monomers ease of settlement & reaction[23]. The more DC and hardness by pulse delay mode may be due to fact that this mode provides higher amount of energy to RBC's every time because according to[28] the maximum intensity by light source is achieved at 0.55 s and then decreases significantly as time progresses. As in pulse delay mode the material is given intermittent light and dark cycles[29], so it is supplied with maximum energy every time which increased both DC and hardness as both are dependent on supply of energy for conversion of double bonds to single[30].

The lower DC and hardness of RBC's in soft start mode may be due to fact that a lower intensity of energy is supplied at the start which results in less polymerization rate. Moreover, viscosity of RBC's is increased in initial soft start curing which interrupts supply of free radicals and consequently polymerization is limited in the end although supply of energy is increased[31,32]. In another study[33] also evaluated the effect of different cures modes on hardness and DC and results showed maximum hardness and DC was shown by Delayed mode, followed by ramped mode and soft start which are accordance with this study.

CONCLUSION

Based on the results of the study, it is concluded that different curing modes affect degree of conversion and micro hardness slightly. No significant difference was observed between two materials however delayed curing showed better results than ramped curing followed by soft start mode. Clinicians prefer technique based on several factors and literature has mixed findings in report.

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Author's Contribution:

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