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Original Article

Effect of composite shade, curing time and mode on temperature rise of silorane and methacrylate- based composite resins

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Abstract

Introduction: The present study was performed to evaluate the effects of light-curing modes and shades of methacrylate and silorane-based composite resins on temperature rise during polymerization of composite resins.

Materials &Methods: In this in vitro study, ninety composite samples with two types of composite resin - methacrylate-based and a low-shrinkage silorane-based were prepared, in 3 groups (30 samples in each group), Group 1: Filtek Z250 (shade A3), Group 2: Filtek Z250 (shade B2) and Group 3: Filtek P90 (shade A3). To evaluate temperature changes, 15 samples and the other half were light-cured using the standard and soft start curing modes for 40 seconds, respectively. A k-type thermocouple was used to recorded temperature changes.

Results: Temperature rise in the silorane-based composite resin group (group 3) was higher than that in the methacrylate-based one (group 1) ($P<0.001$). Temperature rise with the darker shade (group 1) was higher than that with lighter shade (group 2) ($P<0.001$). Standard curing resulted in more temperature rise compared to soft start curing; however, the difference was only significant in group 2 ($P<0.001$). In all groups, temperature increased with an increase in curing time and the temperature rise pattern during the first 10 seconds with the soft start curing was not consistent with the standard curing (in group 2 and 3); the temperature rise pattern was milder than the soft start curing ($P<0.001$).

Conclusion: Factors such as composite resin type, shade and curing mode affected temperature changes in composite resins evaluated in the present study.

Keywords: LED dental curing lights, Composite resins, Polymerization, Filtek p90, Filtek z250

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اثر رنگ کامپوزیت، مدت زمان و شیوه نوردهی بر افزایش دمای رزین کامپوزیت های با پایه سایلوران و متاکریلات

سید مصطفی موسوی نسب، آرمان صالحی*، نگار صالحی

چکیده

مقدمه: مطالعه حاضر با هدف بررسی اثر شیوه نوردهی و رنگ کامپوزیت های با پایه متاکریلات و پایه سایلوران بر افزایش دما حین پلیمریزاسیون رزین کامپوزیت ها انجام شد.

مواد و روش ها: در این مطالعه آزمایشگاهی ۹۰ نمونه از دو نوع کامپوزیت، با پایه متاکریلات و کامپوزیت با درصد انقباض پایین با پایه سایلوران در سه گروه، گروه۱: Filtek Z250 (رنگ A3)، گروه ۲: Filtek Z250 (رنگ B2) وگروه ۳: Filtek P90 (رنگ A3) استفاده شد. برای ارزیابی تغییرات حرارتی ۱۵ نمونه به روش standard و ۱۵ نمونه به روش soft start به مدت ۴۰ ثانیه نوردهی شدند. برای ثبت تغییرات حرارتی از یک ترموکوپل نوع K استفاده شد.

یافته ها: افزایش دما در کامپوزیت سایلوران بیس (گروه ۳) نسبت به کامپوزیت متاکریلات بیس (گروه ۱) بیشتر بود ($P<0.001$). افزایش دما در رنگ روشن تر (گروه ۲) بیشتر از رنگ تیره تر (گروه ۱) بود ($P<0.001$). شیوه نوردهی standard بیشتر از شیوه نوردهی soft start موجب افزایش دما شد، که این تفاوت تنها در گروه ۲ آشکار بود ($P<0.001$). در تمامی گروه ها افزایش زمان نوردهی موجب افزایش دما شد و الگوی افزایش دما در طول ۱۰ ثانیه ابتدایی پلیمریزاسیون در مورد شیوه نوردهی soft start در مقایسه با شیوه نوردهی standard در گروه ۲ و ۳ همخوانی نداشت; الگوی افزایش دما در مورد شیوه نوردهی soft start ملایم تر بود($P<0.001$).

نتیجه گیری: نتایج نشان داد که فاکتورهای نوع و رنگ کامپوزیت و همچنین شیوه نوردهی بر تغییرات حرارتی کامپوزیت های مورد بررسی در مطالعه حاضر اثر گذار هستند.

واژگان کلیدی: دستگاه ساطع کننده نور، رزین کامپوزیت، پلیمریزاسیون،Filtek p90 ، Filtek z250

Introduction

The dental pulp is a highly vascular tissue whose vitality is influenced during preparation of cavities and restorative procedures. Photo-polymerization exotherm of the resin-based restorative materials and the heat of irradiation of dental light curing units are sources of temperature rise in the tooth cavity which may consequently damage the pulp.[1] The most amount of temperature rise occurs with the use of direct composite resin restorations during light curing.[2,3] The heat produced during photo-polymerization might theoretically damage gingival and the pulp tissues.[4] The dentin has been reported to be an ideal thermal barrier although in deep cavities the thin remaining dentin might pose problems.[5] Several authors have reported a 5.5ºC threshold for irreversible changes in the pulp tissue; however, this temperature rise threshold is still a matter of controversy.[6, 7] Although the pulpal tissue is sensitive to thermal changes, the amount of thermal trauma which can be tolerated by the pulp is still unknown. However, some studies have reported low sensitivity of pulp cells to heat and it appears that heat is not a major factor in cellular damage, particularly in the short term.[8]

Various factors influence the temperature rise during polymerization, which are generally divided into three categories,[9,10] first category: factors related to the light sources such as the duration of light curing [11] and light intensity;[12] second category: factors related to the composite resin shade and its chemical content;[4, 13, 14] and third category: factors related to the tooth structure, such as the thickness of the remaining dentin and its quality,[15, 16] pulp status and its regenerative potential.[9] Despite the introduction of LED light-curing units which are expected to result in less temperature rise and less tissue injury, the problem still persists in deep cavities and at close proximity to the pulp because new generations of LED light-curing units with high powers reach output energy levels of 2000 mW/cm^2 and up to 93% of the total output energy is converted to heat.[17]

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Therefore, some manufacturers have recommended curing modes with lower energy levels for adhesives and the first layers in cavities in which the dentinal floor is placed deeply near the pulp. It has been shown that darker shades result in more temperature rise within the composite resin.[4, 13] When darker shades are polymerized with QTH light-curing units, there is more temperature rise in tooth structure due to lower ability of light to pass through; however, it appears LED light-curing units pose less problems.[10,18,19] The present study was undertaken to evaluate and compare the amount of heat transfer between two different resin-based materials (methacrylate-based and silorane-based) at different curing times and with different shades with the use of a diode (LED) light-curing unit.

The null hypothesis of this study stated that there was no difference in heat transfer between methacrylate-based and silorane-based composite resins at different irradiation times and with the use of different shades.

Materials&Methods

The materials used in the present in vitro study consisted of a methacrylate-based (Filtek Z250, 3M ESPE) and a silorane-based (Filtek P90, 3M ESPE) composite resin which is a new type of composite resins developed to decrease polymerization shrinkage (Table 1). A Bluephase LED light-curing unit (Ivoclar Vivadent, Schann and Lichtenstein) containing three curing modes -low, soft start and standard- was used for photo-polymerization. In the present study the soft start and standard curing modes were used. The unit functions at two wavelengths of 470 and 500 nm. The output energy of the unit during the study was checked by a radiometer (LED Radiometer, Kerr, USA). Soft start curing mode output energy was 200mW/cm^2 during the first 5 seconds, which increased to 750 mW/cm^2.

This curing mode is used to increase the degree of conversion (DC) and achieve better properties for the material and decrease the internal stresses, which result in better marginal adaptation in bonded composite resin restorations.[20] In the standard mode, the output energy was 750 mW/cm^2. To evaluate temperature changes, ninety composite samples were prepared in 3 groups (30 samples in each group) that 15 samples were light-cured using the standard curing mode and 15 samples were light-cured using the soft start curing mode for 40 seconds (Table 2).

Table 1. Materials and their composition used in the study

Type	Material	Content	Manufacturer
Filtek Z250	Methacrylate-based composite	Matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA Filler: zirconia, Silica (0.01-3.5 µm), 78 wt%, 60 vol%	3M ESPE, St. Paul, MN, USA
Filtek P90	Silorane-based composite	Matrix: 3,4 Epoxycyclohexyl ethyl cyclopoly-methylsiloxane, bis-3,4 epoxycyclohexyl-ethyl-phenyl-methylsilane Filler: Silanized, quartz, Yttrium fluoride (0.04 - 1.7 µm), 76 wt%, 55 vol%	

Bis-GMA, Bisphenol A glycidyl dimethacrylate; Bis-EMA, Ethoxylated Bisphenol A dimethacrylate; UDMA, Urethane dimethacrylate; TEGDMA, Triethylene glycol dimethacrylate.

Table 2. The number of samples and the study groups.

Group	Resin Composite Type	Shade	Curing Mode	Samples 90
I	Filtek Z250 (Methacrylate-based)	A3	Standard curing	15
			Soft start curing	15
II	Filtek Z250 (Methacrylate-based)	B2	Standard curing	15
			Soft start curing	15
III	Filtek P90 (Silorane-based)	A3	Standard curing	15

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Evaluation of thermal changes: A dark-colored Teflon (PTFE) cylindrical mold with 5 cm in height and 10 cm in diameter was prepared. The dark color of the mold prevented the heat of the environment from reaching the thermocouple during photo-polymerization of the restorative material, which might have resulted in errors. The mold consisted of two upper and lower halves. At the center of the upper half of the mold, a cylindrical space with 2 mm in height and 6 mm in diameter was created for the placement of composite resin material and at the upper part of the space there was a wider area with 1 mm in height and 8 mm in diameter for the placement of the tip of the light-curing unit so that the tip would be fixed in that area without any movement.

In addition, in lower half of the mold a hole was created for the placement of the arch wire of the k-type thermocouple with a diameter of 0.1 cm (ST-8891 E, Standard Instruments Co., Kowloon, Hong Kong). For measuring the thermal changes, a piece of composite resin with 2 mm in thickness was placed at the center of the mold and was packed using a special composite resin spatula. Then a piece of Mylar matrix band was placed over it and the tip of the light-curing unit was placed in contact with the matrix band over the composite resin material. Then polymerization was carried out for 40 seconds during which the thermal changes were transferred by the thermocouple to a data logger (Standard, ST-8891E, Taiwan) (Figure 1).

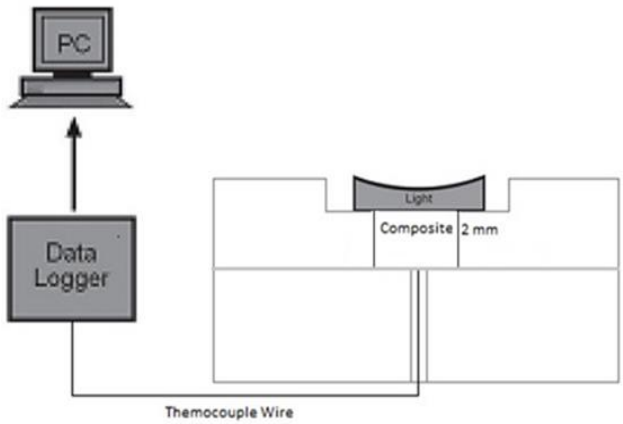

Figure1. Schematic representation of the temperature rise measurement during polymerization of the composite resin material

The data logger recorded temperature changes from the start of light-curing to almost 120–180 seconds until the temperature decreased. Data were saved in a computer. Data were analyzed using SPSS 20 (SPSS Inc., Chicago, IL, USA). $P<0.05$ was statistically considered significant. Data were reported using descriptive statistics (means and standard deviations) in each group. One-way ANOVA, repeated-measures ANOVA and post hoc (Tukey) test were used to compare thermal changes in different groups and at different time intervals.

Results

Table 3 presents the mean thermal changes in the study groups in terms of the curing time and the curing mode (soft start and standard curing). In all groups, temperature increased with an increase in curing time and the thermal changes were significant in general and in each study group ($P<0.001$).

In order to compare the effects of composite resin shade on temperature rise, comparisons were made between group 1 and 2 with similar composite resin base with different shades. The mean temperature changes in group 1 (with darker shade: A3) and group 2 (with lighter shade: B2) were 12.6 and 11.6ºC, which were statistically significant ($P<0.001$). However, the difference between groups 1 and 2 was significant with the standard curing mode ($P<0.001$) but it was not significant with using the soft start curing mode ($P=0.366$). In addition, to compare the effects of composite resin type on temperature rise, comparisons were made between groups 1 and 3, which had similar shade. The mean temperature changes in group 1 with methacrylate-based and in group 3 with silorane-based composite resins were 11.6 and 13.1ºC, respectively, which were significant ($P<0.001$).

Moreover, the difference was still significant by considering the curing mode ($P<0.001$). Figure 2 presents thermal change patterns in terms of curing modes (standard and soft start). Curing mode in groups 1 and 3 had no significant effect on thermal changes ($P=0.365$ and $P=0.085$, respectively) but in group 2, standard curing mode resulted in more temperature rise ($P<0.001$). In addition, comparison of thermal changes at different time intervals (the first 5 seconds, the first 10 seconds, 20–30 seconds, 30–40 seconds and the total 40 seconds) showed that the differences in temperature rises were different between soft start and standard curing modes during the first 5 and 10 second intervals in group 2 (methacrylate-based, B2) and group 3 (silorane-based, A3) ($P<0.001$).

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Table 3. The mean thermal changes in the study groups in terms of mode and time of curing

Group	Curing Mode	Curing Time 0 (s) mean	0 (s) SD	5 (s) mean	5 (s) SD	10 (s) mean	10 (s) SD	20 (s) mean	20 (s) SD	30 (s) mean	30 (s) SD	40 (s) mean	40 (s) SD	
I	Soft start	22.3	2.86	23.7	1.16	27.4	1.48	30.8	1.48	32.7	1.52	33.5	1.71	
	Standard	23.9	1.20	27.9	0.84	30.8	0.96	33.8	1.00	36.2	1.03	37.9	1.19	P-VALUE
II	Soft start	22.3	2.86	23.7	1.16	27.4	1.48	30.8	1.48	32.7	1.52	33.5	1.71	(<0.001)
	Standard	23.9	1.20	27.9	0.84	30.8	0.96	33.8	1.00	36.2	1.03	37.9	1.19	
III	Soft start	22.1	0.84	22.5	.762	29.6	0.49	35.2	0.45	36.3	0.67	36.5	0.86	
	Standard	22.3	1.26	27.3	1.49	30.1	7.96	35.1	1.19	36.1	1.10	36.4	1.14	

Group I: Methacrylate-based resin composite (Filtek Z250, 3M ESPE), shade A3

Group II: Methacrylate-based resin composite (Filtek Z250, 3M ESPE), shade B2

Group III: Silorane-based resin composite (Filtek P90,3M ESPE), shade A3

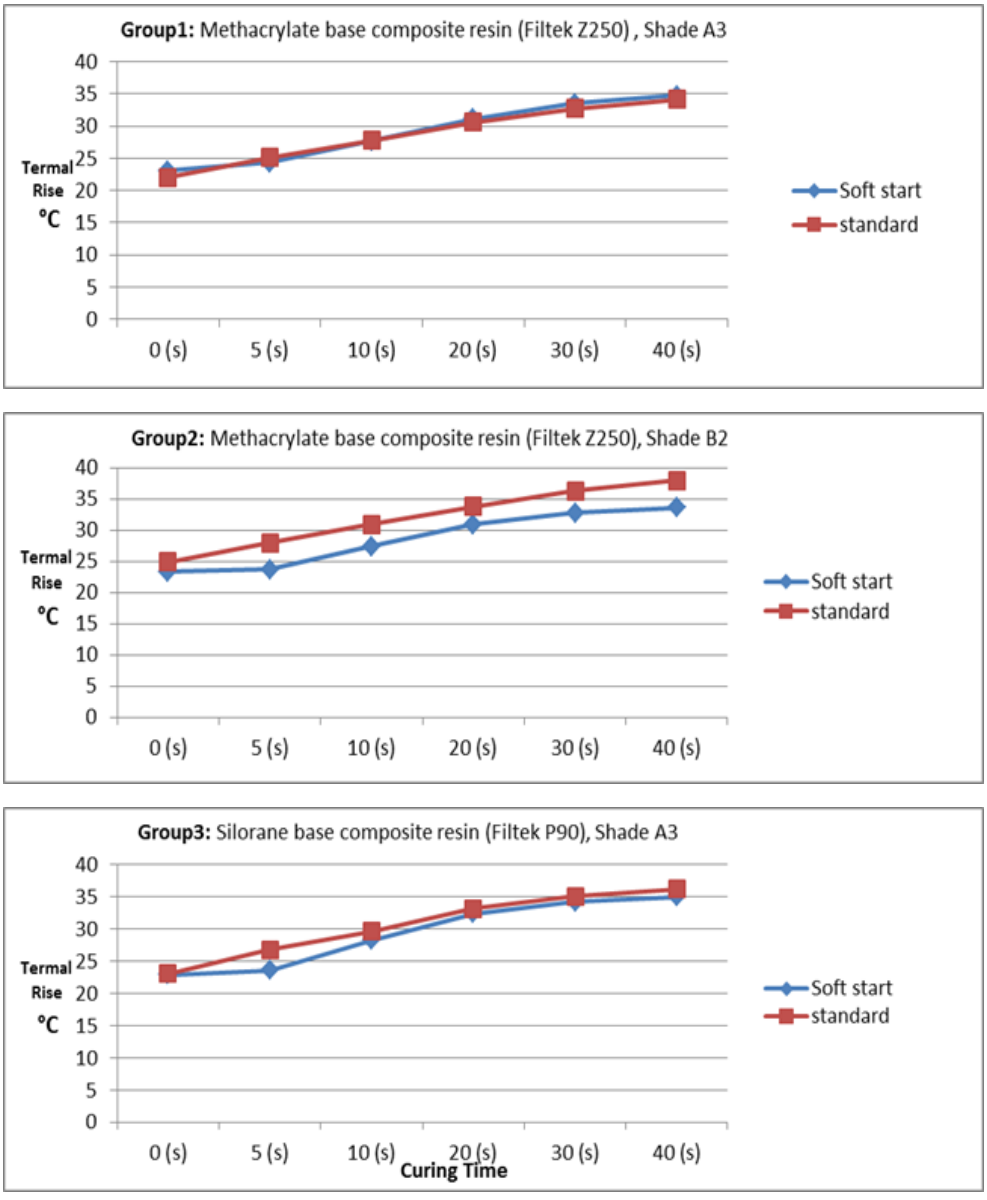

Figure 2. Thermal change patterns during curing time intervals in terms of curing modes (standard and soft start)

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Discussion

Temperature rise during light-curing of composite resins is under the influence of two factors: exothermic polymerization reaction of composite resin and the heat produced by the light-curing unit.[21] Also, other factors including the type of composite resin and its thickness and shade, the duration of curing and the distance from the light source influence on the temperature rise.[22] The results of the current study indicated that darker shades and silorane-based composite resins had higher temperature rise during polymerization. However, the curing mode had no significant effect on thermal changes, except for the B2 shade of methacrylate-based composite resin. However, the temperature rise pattern during the first 10 seconds in soft start curing mode was not consistent with standard curing mode, the pattern showed milder temperature rise than the soft start curing mode. Findings reject the null hypothesis of this study.

There are several ways to classify composite resins in terms of their shade. If classification is based on the degree of brightness, then the different shades of composite resins from bright to dark will be as follows: B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4 and C4.[23] In the present study, shade B2 was used as a lighter shade and shade A3 as a darker shade. The results of the present study showed increase in temperature during the 40-second curing with both A3 and B2 shades, the darker shade (A3) indicated more temperature rise. The difference might be attributed to the type and amount of dark pigments which retain more heat.[23] Furthermore, it has been shown that darker shades need more irradiation compared to lighter shades to reach the same curing depth.[24] Therefore, when a large amount of monomer and free radicals remain, the polymerization is lengthened, which might have a role in temperature rise. These results are with the same as the results of a study conducted by Al-Qudah et al.[23] who stated that darker composite resins (A4 and B3) dissipate the heat produced by polymerization later than lighter composite resins.

The higher temperature rise during polymerization of silorane-based composite resins (Filtek P90) might be attributed to different polymerization shrinkage process of this material, which relies on silorane and oxirane and the polymerization reaction is mediated through a ring-opening cationic reaction.[25] This reaction takes place in the oxirane component and optical pyrometry studies have shown that the ring-opening cationic polymerization reaction in the oxirane is a very exothermic reaction, and the temperature increases 100°C compared to the room temperature in a few seconds.[26] Moreover, the amount of heat produced during the cationic polymerization is directly proportional to the number of initiators produced by light.[27]

In a study performed by Miletic et al., Filtek LS (silorane-based) exhibited more temperature rise compared to two other methacrylate-based Admira and Herculite XRV composite resins.[28] In addition, Filtek P90 (silorane-based) composite resin exhibited more temperature rise compared to Ceram X and Beautiful II in a study of Miletic et al. The results of the above studies and other similar studies are similar to the results of the current study.[28, 29]

One of the interesting findings of the present study was the fact that in contrary to expectations the curing mode (soft start or standard) had no significant effect on thermal changes in group 1 (methacrylate-based) and group 3 (silorane-based) composite resins with the A3 (darker) shade; however, in relation to group 2 with B2 (lighter) shade, the standard curing mode resulted in more temperature rise compared to the soft start curing mode. Hannig et al. reported a higher temperature rise with the use of standard curing mode (6.9°C) compared to the soft start curing mode (6.1°C) during light-curing of composite resin, which is consistent with the results of the present study (group 2).[12] However, as discussed above, the milder difference in the effect between the curing modes on temperature changes of darker shades of composite resin results from the fact that darker shades allow less light to pass through and possibly its pigments more than the lighter shades decrease the intensity of light.

Comparison of thermal changes at different time intervals indicated conspicuously milder temperature rise pattern during the first 10 seconds with the soft start curing mode compared to the standard curing mode, which is considered one of the advantages of soft start curing mode because it prevents sudden temperature rise. These findings are consistent with the results of Knezevic et al. who showed the greatest temperature changes occurred during the first 10 seconds (13+1.2) through tetric ceram composite resin with the standard curing mode, but the least temperature changes took place with the soft start curing mode (5.2+1.9).[14] Clinical experience in relation to the use of light-curing units shows that the dental pulp properly recovers from the deleterious effects of light curing. However, Zach

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and Cohen reported that if the pulp temperature increases up to 5.5°C, 15% of monkey tooth pulps undergo necrosis.[6] These findings, along with the findings of Pohto et al. indicated that the threshold temperature for irreversible pulpal changes begins at 42 to 42.5°C.[30] By considering this threshold temperature, the recorded temperature rises were critical in all study groups with both curing modes in the present study. However, previous studies have shown that this temperature rise may last for a short time.[1, 12] Therefore, despite a significant rise in temperature due to polymerization and by considering the output energy of the light-curing unit, the short duration of this temperature rise might not result in pulpal damage.

Furthermore, it should be taken into account that in the present study, the increase in composite resin temperature was recorded without paying attention to tooth tissues and structures and the recorded thermal changes cannot be directly considered equal to those in clinical situations. In clinical situations the dentin with low thermal conductivity can prevent temperature rise in the dental pulp to some extent. In addition, the pulp chamber circulatory flow and fluid movement within the dentinal tubules were not taken into account in this in vitro study. A temperature rise to higher than 43°C results in increased blood flow, which is an effective factor involved in decreasing the pulp chamber temperature.[31]

Nonetheless, clinicians should be aware of the possible negative effects of light curing on the health of the pulp in deep cavities because the pulp injury potential increases in deep cavities due to thin residual dentin and increased tubular surface area.[32] It has been suggested that in deep cavities, at first, a 2-mm glass-ionomer layer be placed to decrease these risks. This thickness of glass-ionomer can decrease the pulp chamber temperature rise during polymerization.[33] However, since the use of glass-ionomer decreases the bond between the composite resin and dentin, this technique should be confined to deep cavities. In addition, a decrease in curing time, a decrease in the thickness of composite resin to be cured and use of soft start curing mode can decrease temperature rise during polymerization.

Conclusion

The aim of this in vitro study was to evaluate the effects of light-curing modes and shades on temperature rise during polymerization of composite resins. The following conclusions were drawn: temperature rise in the silorane-based composite resin group was higher than that in the methacrylate-based composite resin group. Temperature rise with the darker shade was higher than that with lighter shade.

Standard curing resulted in more temperature rise compared to soft start curing. In all groups, temperature increased with an increase in curing time and the temperature rise pattern during the first 10 seconds with the soft start curing was not consistent with the standard curing and the temperature rise pattern was milder than the soft start curing.

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Conflict of interest disclosure: The authors state that they have no conflict of interest.

Authors' Contributions

The study was designed by Sayed-Mostafa Mousavinasab and Arman Salehi. The study data were collected by Arman Salehi. Results were evaluated by Sayed-Mostafa Mousavinasab and Arman Salehi. Analysis and interpretation of data, drafting of the manuscript and critical revision of the manuscript for important intellectual content were preformed by Arman Salehi and Negar Salehi, study supervision was performed by Sayed-Mostafa Mousavinasab.

References

1. Atai M, Motevasselian F. Temperature rise and degree of photopolymerization conversion of nanocomposites and conventional dental composites. Clin Oral Investig 2009; 13:309-16.
2. Daronch Mr, Rueggeberg FA, Hall G, De Goes MF. Effect of composite temperature on in vitro intrapulpal temperature rise. Dent Mater 2007; 23:1283-8.
3. Piplani A, Suresh Sajjan M C, Ramaraju AV, Tanwani T, Sushma G, Ganathipathi G, et al. An in-

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[DOI: 10.22088/cjdr.5.2.50]

vitro study to compare the temperature rise in the pulp chamber by direct method using three different provisional restorative materials. J Indian Prosthodont Soc 2016;16:36-41.
4. Knezevic A, Tarle Z, Meniga A, Sutalo J, Pichler G, Ristic M. Degree of conversion and temperature rise during polymerization of composite resinsamples with blue diodes. J Oral Rehabil 2001; 28:586-91.
5. Murray PE, About I, Lumley PJ, Smith G, Franquin JC, Smith AJ. Postoperative pulpal and repair responses. J Am Dent Assoc 2000; 131:321-9.
6. Zach L, Cohen G. Pulp Response to Externally Applied Heat. Oral Surg Oral Med Oral Pathol 1965; 19:515-30.
7. Dogan A, Hubbezoglu I, Dogan OM, Bolayir G, Demir H. Temperature rise induced by various light curing units through human dentin. Dent Mater J 2009; 28:253-60.
8. Stewardson DA, Shortall AC, Harrington E, Lumley PJ. Thermal changes and cure depths associated with a high intensity light activation unit. J Dent 2004; 32:643-51.
9. Millen C, Ormond M, Richardson G, Santini A, Miletic V, Kew P. A study of temperature rise in the pulp chamber during composite polymerization with different light-curing units. J Contemp Dent Pract 2007; 8:29-37.
10. Kim R, Yi A, Eo S-H, Lee IB, Seo DG. Temperature changes in bulk-fill resin composite during photopolymerization. Am J Dent2015;28:241-4.
11. Murchison DF, Moore BK. Influence of curing time and distance on microhardness of eight light-cured liners. Oper Dent 1992; 17:135-41.
12. Hannig M, Bott B. In-vitro pulp chamber temperature rise during composite resin polymerization with various light-curing sources. Dent Mater 1999; 15:275-81.
13. Weerakoon AT, Meyers IA, Symons AL ,Walsh LJ. Pulpal heat changes with newly developed resin photopolymerisation systems. Aust Endod J 2002;28:108-11.
14. Knezevic A, Tarle Z, Meniga A, Sutalo J, Pichler G. Influence of light intensity from different curing units upon composite temperature rise. J Oral Rehabil 2005; 32:362-7.
15. Shortall AC, Harrington E. Temperature rise during polymerization of light-activated resin composites. J Oral Rehabil 1998; 25:908-13.
16. Yazici AR, Muftu A, Kugel G, Perry RD. Comparison of temperature changes in the pulp chamber induced by various light curing units, in vitro. Oper Dent 2006; 31:261-5.
17. Asmussen E, Peutzfeldt A. Temperature rise induced by some light emitting diode and quartz-tungsten-halogen curing units. Eur J Oral Sci 2005; 113:96-8.
18. Martins GR, Cavalcanti BN, Rode SM. Increases in intrapulpal temperature during polymerization of composite resin. J Prosthet Dent 2006; 96:328-31.
19. Park SH, Roulet JF, Heintze SD. Parameters influencing increase in pulp chamber temperature with light-curing devices: curing lights and pulpal flow rates. Oper Dent 2010;35:353-61.
20. Kramer N, Lohbauer U, Garcia-Godoy F, Frankenberger R. Light curing of resin-based composites in the LED era. Am J Dent 2008; 21:135-42.
21. Smail SR, Patterson CJ, McLundie AC, Strang R. In vitro temperature rises during visible-light curing of a lining material and a posterior composite. J Oral Rehabil 1988; 15:361-6.
22. Masutani S, Setcos JC, Schnell RJ, Phillips RW. Temperature rise during polymerization of visible light-activated composite resins. Dent Mater 1988; 4:174-8.
23. Al-Qudah AA, Mitchell CA, Biagioni PA, Hussey DL. Effect of composite shade, increment thickness and curing light on temperature rise during photocuring. J Dent 2007; 35:238-45.
24. Swartz ML, Phillips RW, Rhodes B. Visible light-activated resins--depth of cure. JAm Dent Assoc 1983; 106:634-7.
25. Boaro LC, Goncalves F, Guimaraes TC, Ferracane JL, Versluis A, Braga RR. Polymerization stress, shrinkage and elastic modulus of current low-shrinkage restorative composites. Dent Mater 2010; 26:1144-50.
26. Crivello J, Falk B, Zonca M. Photoinduced cationic ring-opening frontal polymerizations of oxetanes and oxiranes. J Polym Sci Part A: Polym Chem 2004; 42:1630-46.
27. Weinmann W, Thalacker C, Guggenberger R. Siloranes in dental composites. Dent Mater 2005; 21:68-74.
28. Miletic V, Ivanovic V, Dzeletovic B, Lezaja M. Temperature changes in silorane-, ormocer-, and dimethacrylate-based composites and pulp chamber

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roof during light-curing. J Esthet Restor Dent 2009; 21:122-31.
29. Guiraldo RD, Consani S, Consani RL, Berger SB, Correr AB, Sinhoreti MA, et al. Comparison of silorane and methacrylate-based composites on the polymerization heat generated with different light-curing units and dentin thicknesses. Braz Dent J 2013; 24:258-62.
30. Pohto M, Scheinin A. Microscopic observations on living dental pulp II. The effect of thermal irritants on the circulation of the pulp in the lower rat incisor. Acta Odontol1958; 16:315-27.
31. Raab WH. Temperature related changes in pulpal microcirculation. Proc Finn Dent Soc 1992; 88(Suppl 1):469-79.
32. Santini A, Watterson C, Miletic V. Temperature rise within the pulp chamber during composite resin polymerisation using three different light sources. Open Dent J 2008; 2:137-41.
33. Hansen EK, Asmussen E. Correlation between depth of cure and temperature rise of a light-activated resin. Scand J Dent Res 1993; 101:76-9.

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