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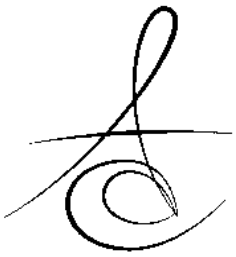

THERMAL CONDUCTIVITY OF DIFFERENT COMPOSITE RESIN MATERIALS IN DIFFERENT POLYMERIZATION TIMES AND MODES

FARKLI KOMPOZIT REZIN MATERYALLERIN FARKLI KÜRLEME SÜRELERINDE VE MODLARINDA TERMAL ILETKENLIKLERI

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ABSTRACT

Aim: The current study investigated the thermal conductivity of dimethacrylate**-** and silorane-based composite resins at different polymerization times and modes.

Materials and Method: Forty dentin discs (8 mm diameter, 1.5 mm thick) were obtained from caries-free human molar teeth. Filtek Silorane (3M ESPE, Minnesota, USA) and Filtek Z550 (3M ESPE, Minnesota, USA) composite were polymerized with a LED (Light-Emitting-Diode) curing device (Valo, Ultradent Products Inc., Utah, USA)**,** in two modes in different times (xtra power mode, 3200 mW/cm^2; 3-, 6-, 9-, 12-, +2 s / standard mode 1000 mW/cm^2, 10-, 20-, 30-, 40-, +2 s)(n=10). Temperature changes in the dentin discs were measured with a K-type thermocouple (E-680, Elimko Co., Ankara, Turkey) and recorded. Data were statistically analyzed using Analysis of variance and independent sample t test (α=0.05)

Results: Mean temperature changes were significantly different among polymerization times and modes ($p<0.05$). Temperature change of Filtek Silorane were significantly higher than Filtek Z550 for each time interval and curing mode ($p<0.05$).

Conclusion: As the polymerization time increases, the temperature increase in the dentin may adversely affect to the pulp health.

Key Words: Thermal conductivity, dental composite resin, LED curing unit, polymerization time

ÖZ

Amaç: Bu çalışmada siloran-esaslı ve dimetakrilat-esaslı kompozitlerin farklı polimerizasyon sürelerinde ve modlarında termal iletkenlikleri değerlendirildi

Gereç ve Yöntem: Sağlam insan üçüncü molar dişlerinden 40 dentin disk (8 mm çap, 1.5 mm kalınlık) hazırlandı. Filtek Silorane (3M ESPE Dental Ürünleri, Minnesota, ABD) ve Filtek Z550 (3M ESPE Dental Ürünleri, Minnesota, ABD) kompozit örnekleri, led ışık cihazı ile (Valo, Ultradent Products Inc., Utah, ABD) iki farklı modda ve farklı sürelerde (xtra power mod, 3200 mW/cm^2; 3, 6, 9, 12 +2 sn / standard mod 1000 mW/cm^2, 10, 20, 30, 40, +2 sn) polimerize edildi. Dentin örneklerindeki sıcaklık artışı, K tipi termokapıl (E-680, Elimko Co., Ankara, Türkiye) kullanılarak ölçüldü. Her zaman aralığı arasındaki ölçüm farkları (ΔT) kaydedildi. Veriler ANOVA ve bağımsız örneklem t-testi ile analiz edildi. (α = 0.05)

Bulgular: Farklı polimerizasyon süreleri ve modları arasında ortalama sıcaklık artışları açısından anlamlı farklılıklar tespit edildi ($p <0.05$). Filtek Silorane kompozitin polimerizasyonu sırasında tüm modlar ve zaman aralıklarında Filtek Z550'ye kıyasla anlamlı derecede daha yüksek sıcaklık artışı görüldü ($p <0.05$).

Sonuç: Polimerizasyon süresi arttıkça dentindeki ısı artışı pulpa sağlığını olumsuz etkileyebilir.

Anahtar Kelimeler: Termal iletkenlik, dental komozit rezin, LED ışık cihazı, Polimerizasyon süresi.

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INTRODUCTION

Dental composite resins polymerize with free - radical polymerization under irradiation with visible light, using wavelength of 400-500 nm.[1] Light emitting diode (LED) technology was proposed in 1995 for polymerization of dental composite resins.[2,3] LEDs are more powerful when polymerizing resin-based materials. This is explained by the emission spectra of the LED being better matched to the absorption spectrum of the camphorquione than the broad spectrum of the halogen units.[4] Because of its longer life-span (over 10.000 hours) and more consistent light output, LEDs uses too much in dental applications.[5, 6]

The polymerization of the composite resins produces a temperature increase, caused by the energy absorbed and exothermic reaction during polymerization.[7] The polymerisation of composite resins and the irradiation temperature of the LCUs are sources of temperature increase in the tooth cavities and may damage the inner tissues, especially the pulp.[8] It suggested that external heating may enhance the mobility of reactive species and the conversion kinetics of resin composites during polymerization.[9] Temperature increase during polymerization is affected by factors like composition and transmission properties of the composite resins, intensity of light, type of light source, duration of light exposure and depth of the cavity or restoration. [10, 11]

Pulp is a vascularized tissue, so, during dental procedures, the pulp temperature may not exceed normal. [12] Previous studies have shown that the pulp results in significant damage and 15% loss of viability for temperature rise of 5,5 ºC and 100% for temperature rise of 16,6 ºC of the monkey teeth.[13, 14]

When heat is applied to a solid material, the temperature rise proceeds from the high temperature zone into the low temperature zone in the material. This is called thermal conductivity.[15] There are 2 methods used to measure thermal conductivity: steady state and non-steady state. In steady state measurement methods, the sample is subjected to a constant temperature increase which does not change over time. After reaching equilibrium, thermal conductivity is determined by measuring the heat flow rate per unit area.[16] There are several studies comparing various physical and mechanical properties of silorane-based composites and traditional methacrylate-based composites.[17-19] However, there are not enough studies comparing the thermal conductivity of these composites. Therefore, the aim of the current study was to measure temperature rise in silorane- (Filtek Silorane, 3M ESPE Dental Products) and dimethacrylate**-**based (Filtek Z550, 3M ESPE Dental Products) composite resins during polymerization with VALO LED unit (Ultradent, Utah, USA) at standard mode and xtra power mode.

MATERIALS AND METHODS

Forty dentin disc samples were obtained from caries- and crack-free human third molars after obtaining informed consent from patients under a protocol approved by the local Ethics Committee Review Board (2018/77) for this research. In the literature, 7-10 samples are prepared from each material in order to measure the thermal conductivity of dental materials. We have prepared 10 samples from each group in our study.[14, 20, 21] Dentin specimens were composed of 8 mm diameter – 1.5 mm thick, by using a low speed saw (Isomet, Buehler, Illinois, USA). In the current study a silorane-based composite resin (Filtek Silorane, 3M ESPE, Minnesota, USA) and a dimethacrylate-based composite resin (Filtek Z550, 3M ESPE, Minnesota, USA) were used. Property of materials that used in this study was shown in Table 1.

Table 1. Brand, matrix, filler type, material type, manufacturer and lot of composite resin materials used in this study

Material	Matrix	Filler Type	Material Type	Manufacturer	Lot
Filtek Silorane	Epoxycyclohexylethylcyclopolymethylsiloxane, bis-3,4-epoxycyclohexylethylphenylmethylsilane	Silanized quartz, yittriumflorür	Microhybrid, silorane-based composite resin	3M ESPE, St. Paul, MN, USA	N428339
Filtek Z550	Bis-GMA, UDMA, Bis-EMA	Zirconia, silica	Nanohybrid, dimethacrylate-based composite resin	3M ESPE, St. Paul, MN, USA	N295825

Two adhesive systems and composite resins applied up to dentin discs 2 mm thickness and accordance with the manufacturer's instructions.

Composite specimens divided in two subgroups (n=10) and each subgroup polymerized with Valo LED light curing unit (Ultradent, Utah, USA)(LCU) in standard mode and xtra power mode.(Table 2) During polymerization, temperature rise of the pulpal side of dentin disc samples under composite resins was moniterized with a K-type thermocouple (E-680, Elimko Co., Ankara, Turkey). A silicon mold was used as a supporting structure for the samples. (Figure 1) The thermocouple was placed under dentin discs and thermocouple was coupled with a data logger. The specimens were polymerized and temperature rise was moniterized with respect to time. Temperature change recorded approximately 40 s in normal mode and 12 s in xtra power mode. Data were analyzed using One-way ANOVA and independent sample t test (α=0.05).

Table 2. Brand, type of mode, output of the light tip, polymerization time and manufacturer of LED unit

Brand	**Type of mode**	**Output of the light tip (mW/cm$^{2)}$**	**Polymerization time (s)**	**Manufacturer**
Valo LCU	Standard	1000	10	Ultradent Products Inc., South Jordan, UT, USA
	Xtra power	3000	3	

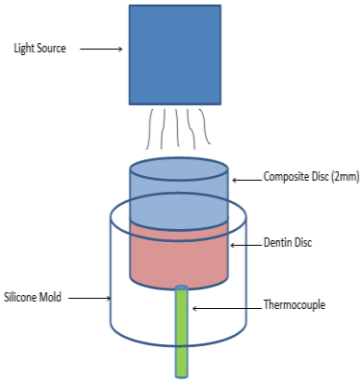

Figure 1. Apparatus for measuring temperature changes.

RESULTS

Table 3 is showing the mean temperature increase with silorane- and dimethacrylate-based composites in different cure modes. Different curing modes and curing times lead to significant differences in terms of temperature increase ($p<0.05$).

Polymerisation of silorane based composite (Silorane) with LED curing device resulted in significantly higher mean temperature increase than dimethacrylate based composite (Z550) for each polymerization time and mode ($p<0.05$). Statistical analysis showed differences among the curing modes. The temperature increase was observed as the polymerization time of the composites increased ($p<0.05$).

Table 3. Measurement times and temperature increase of composite samples.

Mode	Duration	Δt - Z 550	Δt - Silorane	
Standart mode	10 s	2.74 ± 0.68 ^{a,A}	3.93 ± 0.98 ^{b,AB}	P<0.05
	20 s	4.06 ± 0.52 ^{a,C}	4.38 ± 0.63 ^{b,B}	
	30 s	4.66 ± 0.54 ^{a,D}	5.95 ± 0.63 ^{b,C}	
	40 s	4.80 ± 0.53 ^{a,D}	6.07 ± 0.52 ^{b,CD}	
Xtra power mode	3 s	2.51 ± 0.42 ^{a,A}	3.47 ± 1.16 ^{b,A}	P<0.05
	6 s	3.25 ± 3.45 ^{a,B}	4.57 ± 1.21 ^{b,B}	
	9 s	3.86 ± 0.50 ^{a,BC}	5.48 ± 1.40 ^{b,C}	
	12 s	4.23 ± 0.49 ^{a,C}	5.84 ± 1.48 ^{b,C}	

Means followed by different lowercase letters in the rows and uppercase letters in the columns differed statistically at the independent sample t test 5% level

DISCUSSION

In this study thermal conductivity of two different resin composites that placed on 1.5 mm thickness dentin and effect of heat generation af two different curing mode was compared. A K-type thermocouple was used in our study since the thermocouples were determined as reliable instruments for temperature change measurement in the literature. External heat may damage to the pulp tissue.[22] Uses of high density light sources may cause heat that dangerous for pulpal health. During polymerization of resin composites there is two important factors causes increase of heat; exothermic reaction of polymerization and heat from LCU.[23] Masutomi and et al.[8] found that exothermic reaction is more important than light source type, while Strang et al.[24] defended otherwise.

Previous studies have shown that increased temperature during polymerization leads to necrosis in pulp cells and causes irreversible reactions in the pulp.[25, 26] These reactions, which start with a 5.5 °C heat increase in the pulp, can turn completely necrose over 16.5 °C.[22] In our study, the average temperature increase in the methacrylate-based composite specimens in any group did not reach the limits that would cause irreversible reaction for pulp cells. However, when the silorane-based composite specimens polymerized with standard mode LCU for 30 s or more and xtra-power mode LCU for 9 s or more, the temperature increase in the dentin samples was over 5.5 °C. On the other hand, these curing times were higher than those specified in the manufacturer's instructions. In the standard curing times, which determined by the manufacturers of the composite resins, the temperature increase in both composite specimens did not reach a dangerous level for pulp health.

It has been reported that the temperature rise decreases as the resin filler content of a dental material increase, because fillers are chemically inert and do not affect the heat of reaction.[11] However, as the fillers temperature increases, the temperature of the resin matrix also increases. Fillers have the ability to absorb the external energy. This energy may cause heat increase in the composite resin matrix. So, the filler structure of the composite resin may play an indirect role in the increase in temperature.[27]

A molecule called 'Siloran' is obtained by the combination of siloxane and oxirane molecules, which polymerize with cationic ring opening reaction.[28] This reaction is induced by photoactivation of the camphorquinone. The oxirane molecules interacts with iodonium salts and the reaction spread from active centers.[29] Some studies in the literature showed that silorane-based composites cause significant temperature increases than the dimethacrylate-based composites.[30,31] Researchers thought that this was due to different heat patterns caused by the cationic ring opening reaction. [32] Moreover, the cationic ring opening reactions of the oxiranes are quite an exothermic reaction and causes heat increase. [33] According to this informations the higher thermal conductivity of the silorane-based composite resin in this study can be explained by its chemical structure.

In this study different ligth energy influence the heat produced during composite photo activation. The highest temperature change is measured for standard mode. Xtra power mode showed lower temperature rise than standard mode. When the Valo LCU is used in Xtra power mode, it creates light intensities close to the Plasma Arc devices. Thus, Valo LCU has shortened exposure time because of its high power (3200 mW/cm^2). Previous studies have showed that plasma arch lights occur more temperature rise than LED.[34-36] But in our study xtra power mode caused less temperature rise. Manufacturer recommend a tree-second polymerization time for the universal hybrit composites. If used in more times xtra power mode may produce more head. Due to its low polymerization time and lower heat exposure time it caused lower temperature rise from standard mode.

Comparison of temperature changes in different composites and curing modes of this study shows that silorane-based composite materials has higher thermal conductivy because of its chemical structure. Again, according to this study plasma mode of LCU occur almost same heats with normal mode during polymerization. The light device used in the study also leads to an increase in heat. The polymerization of the two composites were done under the same conditions and the temperature increase due to the light device became the standard for all samples. Thus, the thermal conductivity of composites could be compared on equal terms. However, the increase in temperature caused by the light device may affect the total heat increase affecting the pulp health. Therefore, the temperature increase caused by the light device used in the clinic should be considered.

CONCLUSION

The temperature increase resulting from the long polymerization time can reach a level that adversely affects the pulp health. So, the polymerization of the composite resin should be made according to the LCUs manufacturer's instructions.

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KAYNAKLAR

1. Uhl A, Volpel A, Sigusch BW. Influence of heat from light curing units and dental composite polymerization on cells in vitro. J Dent 2006; 34: 298-306.
2. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. Br Dent J 1999; 186: 388-91.
3. Leung MK, Chang CC, Wu MH, Chuang KH, Lee JH, Shieh SJ, Lin SC, Chiu CF. 6-N,N-diphenylaminobenzofuran-derived pyran containing fluorescent dyes: a new class of high-brightness red-light-emitting dopants for OLED. Org Lett 2006, 8: 2623-6.
4. Yondem I, Altintas SH, Usumez A. Temperature rise during resin composite polymerization under different ceramic restorations. Eur J Dent 2011; 5: 305-9.
5. Dunn WJ, Taloumis LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. Am J Orthod Dentofac Orthop 2002; 122: 236-41.
6. Karataş Ö, Türel V, İlday N, Seven N. Anterior mine hipoplazisinin kompozit restorasyonlarla tedavisi: İki olgu sunumu. J Dent Fac Atatürk Uni 2013; 22: 371-4.
7. Nammour S, Zeinoun T, Bogaerts I, Lamy M, Geerts SO, Bou Saba S, Lamard L, Peremans A, Limme M. Evaluation of dental pulp temperature rise during photo-activated decontamination (PAD) of caries: an in vitro study. Lasers Med Sci 2010; 25: 651-4.
8. Masutani S, Setcos JC, Schnell RJ, Phillips RW. Temperature rise during polymerization of visible light-activated composite resins. Dent Mater 1988; 4: 174-8.
9. Peutzfeldt A. Resin composites in dentistry: the monomer systems. Eur J Oral Sci 1997; 105: 97-116.
10. Goodis HE, White JM, Andrews J, Watanabe LG. Measurement of temperature generated by visible-light-cure lamps in an in vitro model. Dent Mater 1989; 5: 230-4.
11. Atai M, Motevasselian F. Temperature rise and degree of photopolymerization conversion of nanocomposites and conventional dental composites. Clin Oral Investig, 2009, 13: 309-316.
12. Hussey DL, Biagioni PA, Lamey PJ. Thermographic measurement of temperature change during resin composite polymerization in vivo. J Dent 1995; 23: 267-71.
13. Ilday NO, Sagsoz O, Karatas O, Bayindir YZ, Celik N. Temperature changes caused by light curing of fiber-reinforced composite resins. J Conserv Dent 2015; 18: 223-226.
14. Karatas O, Turel V, Bayindir YZ. Temperature rise during polymerization of different cavity liners and composite resins. J Conserv Dent 2015; 18: 431-5.
15. Horai KI, Simmons G, Kanamori H, Wones D. Thermal diffusivity and conductivity of lunar material. Science 1970, 167: 730-1.
16. Guler C, Keles A, Guler MS, Karagoz S, Cora ON, Keskin G. Thermal conductivity of different colored compomers. J Appl Biomater Funct Mater 2017; 15: e362-8.
17. Santos PJ, Silva MS, Alonso RC, D'Alpino PH. Hydrolytic degradation of silorane- and methacrylate-based composite restorations: Evaluation of push-out strength and marginal adaptation. Acta Odontol Scand 2013; 71: 1273-9.
18. Mohammadi N, Shakur Shahabi M, Kimyai S, Pournagi Azar F, Ebrahimi Chaharom ME. Shear Bond Strengths of Methacrylate- and Silorane-based Composite Resins to Feldspathic Porcelain using Different Adhesive Systems. J Dent Res Dent Clin Dent Prospect 2015; 9: 181-7.
19. Mahmoud SH, Al-Wakeel Eel S. Marginal adaptation of ormocer-, silorane-, and methacrylate-based composite restorative systems bonded to dentin cavities after water storage. Quintessence Int 2011; 42: e131-9.
20. Little PA, Wood DJ, Bubb NL, Maskill SA, Mair LH, Youngson CC. Thermal conductivity through various restorative lining materials. J Dent 2005; 33: 585-91.
21. Kul E, Aladag LI, Yesildal R. Evaluation of thermal conductivity and flexural strength properties of poly(methyl methacrylate) denture base material reinforced with different fillers. J Prosthet Dent 2016; 116: 803-10.
22. Zach L, Cohen G. Pulp Response to Externally Applied Heat. Oral Surg Oral Med Oral Pathol 1965; 19: 515-30.

23. 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.
24. Strang R, Patterson CJ, McLundie AC, Cummings A, Smail SR. In vitro temperature rises produced by five polymerising light sources. Restorative Dent 1988; 4: 33-5.
25. Secilmis A, Bulbul M, Sari T, Usumez A. Effects of different dentin thicknesses and air cooling on pulpal temperature rise during laser welding. Lasers Med Sci 2013; 28: 167-70.
26. Aguiar FH, Barros GK, Lima DA, Ambrosano GM, Lovadino JR. Effect of composite resin polymerization modes on temperature rise in human dentin of different thicknesses: an in vitro study. Biomed Mater 2006; 1: 140-3.
27. da Silva EM, Penelas AG, Simao MS, Filho JD, Poskus LT, Guimaraes JG. Influence of the degree of dentine mineralization on pulp chamber temperature increase during resin-based composite (RBC) light-activation. J Dent 2010; 38: 336-42.
28. Weinmann W, Thalacker C, Guggenberger R. Siloranes in dental composites. Dent Mater 2005; 21: 68-74.
29. Knezevic A, Tarle Z, Meniga A, Sutalo J, Pichler G, Ristic M. Degree of conversion and temperature rise during polymerization of composite resin samples with blue diodes. J Oral Rehabil 2001; 28: 586-91.
30. Miletic V, Ivanovic V, Dzeletovic B, Lezaja M. Temperature changes in silorane-, ormocer-, and dimethacrylate-based composites and pulp chamber roof during light-curing. J Esthet Restor Dent 2009; 21: 122-31.
31. Mousavinasab SM, Khoroushi M, Moharreri M. Temperature rise during primer, adhesive, and composite resin photopolymerization of a low-shrinkage composite resin under caries-like dentin lesions. ISRN Dent 2012; 2012: 198351.
32. Gao BT, Lin H, Zheng G, Xu YX, Yang JL. Comparison between a silorane-based composite and methacrylate-based composites: shrinkage characteristics, thermal properties, gel point and vitrification point. Dent Mater J 2012; 31: 76-85.
33. Loney RW, Price RB. Temperature transmission of high-output light-curing units through dentin. Oper Dent 2001; 26: 516-20.
34. Ozturk B, Ozturk AN, Usumez A, Usumez S, Ozer F. Temperature rise during adhesive and resin composite polymerization with various light curing sources. Oper Dent 2004; 29: 325-32.
35. Nomoto R, McCabe JF, Hirano S. Comparison of halogen, plasma and LED curing units. Oper Dent 2004; 29: 287-294.
36. Price RB, Ehrnford L, Andreou P, Felix CA. Comparison of quartz-tungsten-halogen, light-emitting diode, and plasma arc curing lights. J Adhes Dent 2003; 5: 193-207.

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