

Evaluation of the Degree Conversion of Dental Composite Nanoparticles as an Effect on the Variation of Initial Temperature Treatment

Subhaini Jakfar ^{1*}, Sri Fitriyani ¹, Evita Mutiara Peron ¹, Diana Setya Ningsih ¹, Iin Sundari ¹, Viona Diansari ¹, Basri A. Gani ²

¹Dental Material Department of Dentistry Faculty, Universitas Syiah Kuala (USK), Darussalam, Banda Aceh, Indonesia, 23111

²Oral Biology Department of Dentistry Faculty, Universitas Syiah Kuala (USK), Darussalam, Banda Aceh, Indonesia, 23111

Abstract:- The degree of conversion in photo-activated resin composites can be affected by temperature. A new type of composite, called nanoparticle resin composite, has been developed for dentistry. This study aimed to investigate how temperature variation of the nanoparticle Ceram-X™ Duo resin composite before polymerization affects the degree of conversion. The study used 30 cylindrical specimens, each 6mm in diameter and 3mm in thickness, divided into three treatment groups: 5°C, 25°C, and 60°C. Each group contained five polymerized specimens and five unpolymerized specimens. The degree of conversion was measured using FTIR with 45 scans, a resolution of 4 [1/cm], and an analyzed wavelength of 500-4000 [1/cm]. Statistical analysis was performed using the One-Way ANOVA test and Tukey. The results showed that temperature significantly influenced the degree of conversion. The highest degree of conversion was observed at 60°C, with a value of 21.38%, compared to 14.94% at 5°C and 7.24% at 25°C. In conclusion, this study demonstrates that temperature variation before polymerization impacts the degree of conversion of dental nano particle resin composites.

Keywords:- Temperature; Degree of Conversion; Nanoparticle Resin Composite.

I. INTRODUCTION

The use of composite resins as restorative materials in dentistry is increasing rapidly; that composite resin has better physical, mechanical, and esthetic properties when compared to other filling materials those are previously discovered, such as silicate or acrylic resin [1]. Currently, composite resin can be applied for several purposes, such as restoration of anterior and posterior teeth caused by the caries process, adjustment of occlusion, cementation for indirect restorations, and bonding of orthodontic brackets [2].

However, some dentist practitioners claim that the composite resins have several weaknesses, including being able to experience volume reduction (shrinkage) during polymerization, which is followed by the emergence of stress on the bond between the tooth and the restoration [3, 4]. This stress can break the bonding or cause deflection around the tooth structure. The magnitude of this stress contraction is related to the restoration configuration, for example, the degree of conversion of composites and their conversion rate.

As a result, it could reduce the longevity of the restoration [5, 6].

The degree of conversion of the composite resins is related to the conversion of monomer carbon-carbon double bonds to polymeric carbon-carbon single bonds [7]. Lovell, et al. reported that increased conversion would result in increased surface hardness, flexural strength, flexural modulus, fracture resistance, diametral strength, and wearability [8]. Many factors can affect the value of the degree of conversion, namely the color and thickness of the resin, type of filler, type and quality of the light source, curing time, the distance between the light source and the resin surface, and the temperature of the composite resin [9, 10].

Daronch, et al., in their research, stated that the degree of conversion of the hybrid composite resin under heated conditions (60°C) was higher when compared to the condition of the composite resin at room temperature (22°C) and cold temperatures (3°C) [11]. Cold temperatures ranged from 3 - 5°C (the average temperature in the refrigerator), room temperature, and hot temperatures between 40-60°C are chosen to maintain the effectiveness of heat because when removing the composite from the syringe, filling it into the cavity, contouring, and the light-curing procedure will consume the time and simultaneously lower the temperature. Meanwhile, temperatures of more than 60°C are not recommended because of the potential to cause injury to the pulp. Thus, Kincses, et al. stated the effect of temperature on degree conversion of composite, which is the temperature would reduce the system's viscosity, increase the mobility of radicals, and produce additional polymerization [12].

The development of dental materials in recent years has produced dental composites with filler particle sizes in nano units ranging from 0.1–100 nm [13, 14]. Changes in the size of the filler result in improved mechanical properties that are better when compared to the previous type of composite, so they can also be applied to posterior teeth. Nanoparticle composites have a high level of translucency, resistance to polishing similar to microfiller composites, and wearability comparable to some hybrid composites [15]. Therefore, this research was conducted to evaluate the effect of variations in the initial temperature treatments of the nanoparticle composite resin on the conversion degree.

II. MATERIAL AND METHODS

A. Material

The material used for this study was Ceram-X™ Duo nanoparticle composite resin (Dentsply Products Germany) for posterior tooth restorations with the composite color used D3.

B. Methods

Temperature variations were conducted in the following ways: cold temperature at 5°C obtained using a refrigerator, room temperature at 25°C obtained from an air conditioner, and hot temperature at 60°C obtained using an incubator. For non-polymerized specimens, the composite paste will be directly tested using FTIR. The composite paste was put into the mold using a plastic instrument with bulk technique, then the surface of the mold was flattened. Furthermore, the surface of the composite material was coated with a mylar strip, and on top of it was placed a microscope slide and given a load of 1 kg for 20 seconds. The composite was irradiated with Litex 692 LED Curing Light with a light intensity of 700 mW/cm² and an irradiation time of 40 seconds. Each temperature group consists of 10 specimens, so the total number of specimens is 30. After one hour, the specimens were removed from the mold, washed with a mild detergent, and rinsed with water. Then the specimen was put into a plastic vial containing 3 ml of water as the immersion medium and stored in an incubator at 37 ± 1°C for 24 hours.

$$CD\% = (1 - (C_{aliphatic}/C_{aromatic})) / (U_{aliphatic}/U_{aromatic}) \times 100\% \quad (1)$$

The abbreviation "CD" refers to the conversion degree. The absorption peaks of 1638 cm⁻¹ before and after polymerization corresponds to $U_{aliphatic}$ and $C_{aliphatic}$, respectively. Similarly, the absorption peaks of 1608 cm⁻¹ before and after polymerization correspond to $U_{aromatic}$ and $C_{aromatic}$, respectively.

The results are expressed as means ± S.D which were analyzed by one-way ANOVA, followed by a Tukey multiple comparison test, the significant levels were indicated as *p < 0.05, **p < 0.01, and ***p < 0.001.

III. RESULTS

The initial temperature treatment of the composite resin was 25°C, resulting in a conversion degree of 7.24%. The degree of conversion increased to 21.38% at a temperature of 60°C and then decreased to 14.94% at a temperature of 5°C. Based on the results of statistical tests using ANOVA followed by the Tukey test, it can be concluded that the initial temperature of the composite resin affects the degree of conversion, with the highest peak degree of conversion obtained at a temperature of 60°C.

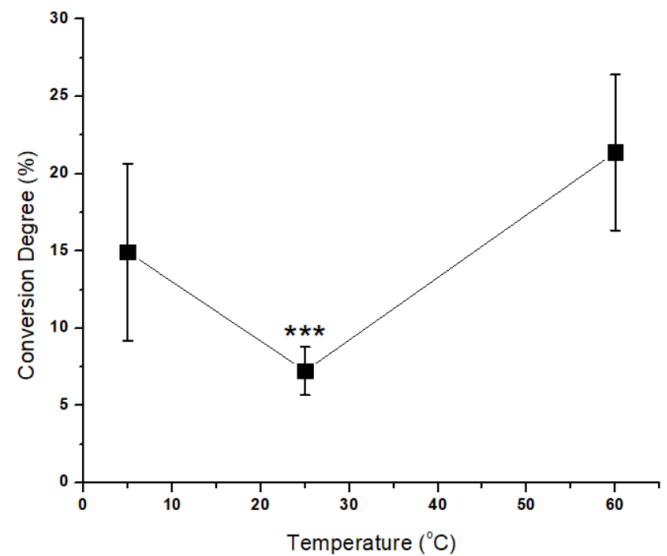


Fig 1. The Degree of Conversion in an average of Nanoparticle Composite Resin at different temperature, significance levels were indicated as *** (p < 0.001)

IV. DISCUSSION

The finding informs that the maximum degree of conversion was obtained at the highest temperature of 60°C, while the lowest degree of conversion was obtained at 25°C. Room temperature shows a lower conversion degree value when compared to cold temperatures of 5°C. Our findings were slightly different from the statement of Daronch et al. that the higher the temperature will produce a higher degree of conversion [11]. The degree of conversion in heated composite resin has a higher value when compared to room temperature and cold temperatures where high temperatures can increase molecular mobility, and reduce system viscosity; thus, more monomers will be converted [16].

Increasing the temperature (60°C) will increase the mobility of molecules due to decreased viscosity and delay the control of diffusion propagation and termination so that the system will achieve high conversion before vitrification. Thus, when the temperature of the composite is increased, more crosslinks will be formed, and at the same time, will improve the mechanical and physical properties of the composite. The high temperature will increase the degree of conversion on the upper and lower surfaces of the composite resin restoration [17, 18]. Mechanical properties such as composite hardness is correlated with the degree of conversion. The higher the hardness value of a material, the higher the degree of conversion achieved.

Composite resin at cold temperatures (5°C) showed higher conversion than at room temperature (25°C). Osterack et al., in their research on the effect of temperature on the hardness of composite resin, stated that the hardness value of composite resin at cold temperatures was higher than at room temperature. It could occur because the composite at cold temperatures is only slightly affected by the heat generated by the light source, thereby reducing the stress during polymerization. It is different for composite resins at room temperature, where polymerization occurs more quickly due

to the considerable influence of heat generated by the light source, which traps monomer molecules between polymer chains and hinders the formation of polymer networks.

According to Lovell, et al., cooled composite resin will increase the viscosity of the material and will decrease the mobility of the monomer [8]. Dall'Magro, et al., in their research, also stated that although the mobility of the monomer decreased at cold temperatures, the hardness value of the material did not change, which is a degree of conversion obtained would not decrease either [19].

The degree of conversion obtained in this study is not so high compared to the average degree of conversion achieved in general. The composite material component in the form of a combination of monomers is believed to influence the degree of conversion. The combined monomer matrices in the Ceram-X™ Duo composite resin consist of Bis-GMA, UDMA, and methacrylate modified polysiloxane. The structure of each matrix monomer is shown in Figure 2.

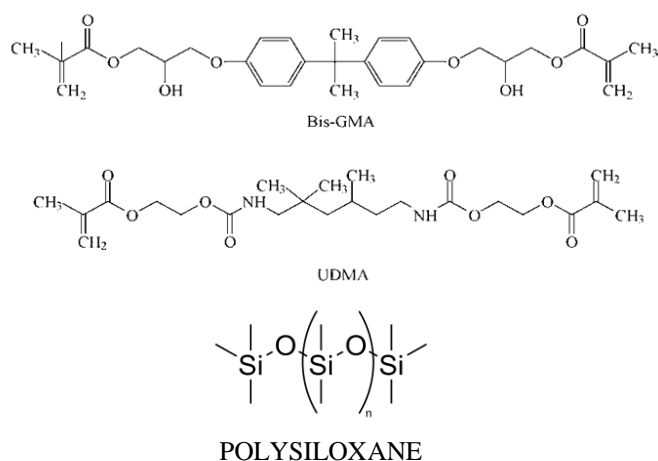


Fig 2. Structure of Bis-GMA, UDMA, and Polysiloxane monomers

A mixture of Bis-GMA and UDMA in the Ceram-X™ Duo composite resin was used as the base monomer. To increase the degree of conversion, the mixture of the two monomers still requires an additional diluent monomer, such as TEGDMA as a viscosity controller [20]. However, this TEGDMA monomer is not contained in the Ceram-X™ Duo composite resin. The absence of the TEGDMA matrix monomer is thought to be one of the reasons for the low degree of conversion achieved. TEGDMA with a low molecular weight is added to the polymer matrix to reduce the viscosity, and thus will increase the degree of conversion of the composite resin. Floyd et al. found that composite resin containing high concentrations of Bis-GMA, UDMA, and TEGDMA would produce an optimum degree of conversion. At reduced TEGDMA concentrations (increased base monomer), the degree of conversion decreased drastically due to an increase in viscosity.

Bis-GMA has a higher molecular weight, indicated by two aromatic rings in the central part of the molecule, which causes the viscosity of this monomer to increase, and low mobility due to its rigid nature [21]. UDMA is an aliphatic molecule with a high molecular weight characterized by the

presence of the (-NH-) group, which also increases the viscosity. However, this aliphatic molecule has a higher polymer chain mobility than Bis-GMA [22].

Another matrix monomer contained in Ceram-X™ Duo composite resin is methacrylate-modified polysiloxane. This matrix is here to replace the use of TEGDMA, which is considered to have drawbacks, one of which is minimizing the polymerization shrinkage that occurs. When combined with glass filler or other reactive monomers, this matrix will also make a composite resin restoration with excellent physical and mechanical properties. Polysiloxane forms a covalent block bonded by silicon atoms during photo-polymerization, and an inorganic-organic network (polymer mixture) will be developed. Polysiloxane has the same structure as silicate glass or ceramics, so the composite resin also becomes more translucent and has excellent optical properties [23, 24].

V. CONCLUSION

There is an influence on the conversion degree of the initial temperature treatment of dental nanoparticle composite resin before polymerization. Thus, to get the optimum degree of conversion, dentists could pre-warming of the composite resin before polymerization at 60°C.

REFERENCES

- [1]. K.A. Unsal, E. Karaman, Effect of additional light curing on colour stability of composite resins, *International dental journal* 72(3) (2022) 346-352.
- [2]. S. Ardjanggi, A.A. Mardiyah, D.A. Wahjuningrum, Endocrown restoration on postendodontics treatment on lower first molar, *Journal of International Society of Preventive & Community Dentistry* 9(3) (2019) 303.
- [3]. D. Bompolaki, E.B. Lubisich, A.P. Fugolin, Resin-Based Composites for Direct and Indirect Restorations: Clinical Applications, Recent Advances, and Future Trends, *Dental Clinics* (2022).
- [4]. F. Elfakhri, R. Alkahtani, C. Li, J. Khaliq, Influence of filler characteristics on the performance of dental composites: A comprehensive review, *Ceramics International* (2022).
- [5]. L. Fanfoni, M. De Biasi, G. Antolovich, R. Di Lenarda, D. Angerame, Evaluation of degree of conversion, rate of cure, microhardness, depth of cure, and contraction stress of new nanohybrid composites containing pre-polymerized spherical filler, *Journal of Materials Science: Materials in Medicine* 31 (2020) 1-11.
- [6]. J. Hayashi, J. Tagami, D. Chan, A. Sadr, New bulk-fill composite system with high irradiance light polymerization: Integrity and degree of conversion, *Dental Materials* 36(12) (2020) 1615-1623.
- [7]. A.A. Al-Ali, A.J. Mohammed, O.A.M. Sheet, D. College, Degree of conversion of modified heat cured acrylic resin.
- [8]. L.G. Lovell, An investigation into the kinetic behavior and polymer relaxation of dental resins and other dimethacrylate networks, University of Colorado at Boulder 2001.

- [9]. J.S. Siagian, D. Dennis, T. Ikhsan, T. Abidin, Effect of different LED light-curing units on degree of conversion and microhardness of bulk-fill composite resin, *J. Contemp. Dent. Pract* 21 (2020) 615-620.
- [10]. E. Lempel, Z. Óri, D. Kincses, B.V. Lovász, S. Kunsági-Máté, J. Szalma, Degree of conversion and in vitro temperature rise of pulp chamber during polymerization of flowable and sculptable conventional, bulk-fill and short-fibre reinforced resin composites, *Dental Materials* 37(6) (2021) 983-997.
- [11]. M. Daronch, F.A. Rueggeberg, M. De Goes, R. Giudici, Polymerization kinetics of pre-heated composite, *Journal of dental research* 85(1) (2006) 38-43.
- [12]. D. Kincses, K. Böddi, Z. Óri, B.V. Lovász, S. Jeges, J. Szalma, S. Kunsági-Máté, E. Lempel, Pre-heating effect on monomer elution and degree of conversion of contemporary and thermoviscous bulk-Fill resin-based dental composites, *Polymers* 13(20) (2021) 3599.
- [13]. M.N. Hegde, P. Hegde, S. Bhandary, K. Deepika, An evaluation of compressive strength of newer nanocomposite: An in vitro study, *Journal of conservative dentistry: JCD* 14(1) (2011) 36.
- [14]. J. Gupta, Nanotechnology applications in medicine and dentistry, *Journal of investigative and clinical dentistry* 2(2) (2011) 81-88.
- [15]. F.N.M. Faudzi, A.A. Hamzah, 5 - Nanoparticle in composite material, in: S.C.B. Gopinath, F. Gang (Eds.), *Nanoparticles in Analytical and Medical Devices*, Elsevier2021, pp. 71-82.
- [16]. T.T. Tauböck, Z. Tarle, D. Marovic, T. Attin, Pre-heating of high-viscosity bulk-fill resin composites: effects on shrinkage force and monomer conversion, *Journal of dentistry* 43(11) (2015) 1358-1364.
- [17]. M.R. Galvão, S.G.F.R. Caldas, V.S. Bagnato, A.N. de Souza Rastelli, M.F. de Andrade, Evaluation of degree of conversion and hardness of dental composites photo-activated with different light guide tips, *Eur J Dent* 7(1) (2013) 86.
- [18]. N.R. Fróes-Salgado, L.M. Silva, Y. Kawano, C. Francci, A. Reis, A.D. Loguercio, Composite pre-heating: effects on marginal adaptation, degree of conversion and mechanical properties, *Dental materials* 26(9) (2010) 908-914.
- [19]. E. Dall'Magro, M.A. Sinhoreti, A.B. Correr, L. Correr-Sobrinho, S. Consani, R.M. Puppini-Rontani, Effect of different initial light intensity by the soft-start photoactivation on the bond strength and Knoop hardness of a dental composite, *Brazilian dental journal* 18(2) (2007) 107-12.
- [20]. R. Yadav, H. Lee, J.-H. Lee, R.K. Singh, H.-H. Lee, A comprehensive review: Physical, mechanical, and tribological characterization of dental resin composite materials, *Tribology International* (2022) 108102.
- [21]. A. Alrahlah, R. Khan, A.-B. Al-Odayni, W.S. Saeed, L.S. Bautista, S. Haider, M.A.T. De Vera, A. Alshabib, Fabrication of Novel Pre-Polymerized BisGMA/Silica Nanocomposites: Physio-Mechanical Considerations, *Journal of Functional Biomaterials* 14(6) (2023) 323.
- [22]. Y. Sun, Z. Zhou, H. Jiang, Y. Duan, J. Li, X. Liu, L. Hong, C. Zhao, Preparation and evaluation of novel bio-based Bis-GMA-free dental composites with low estrogenic activity, *Dental Materials* 38(2) (2022) 281-293.
- [23]. A. Ershad-Langroudi, H. Fadaei, K. Ahmadi, Application of polymer coatings and nanoparticles in consolidation and hydrophobic treatment of stone monuments, *Iranian Polymer Journal* 28 (2019) 1-19.
- [24]. J.W. Suen, N.K. Elumalai, S. Debnath, N.M. Mubarak, C.I. Lim, M.M. Reddy, The Role of Interfaces in Ionic Liquid-Based Hybrid Materials (Ionogels) for Sensing and Energy Applications, *Advanced Materials Interfaces* 9(34) (2022) 2201405.