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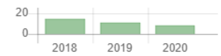

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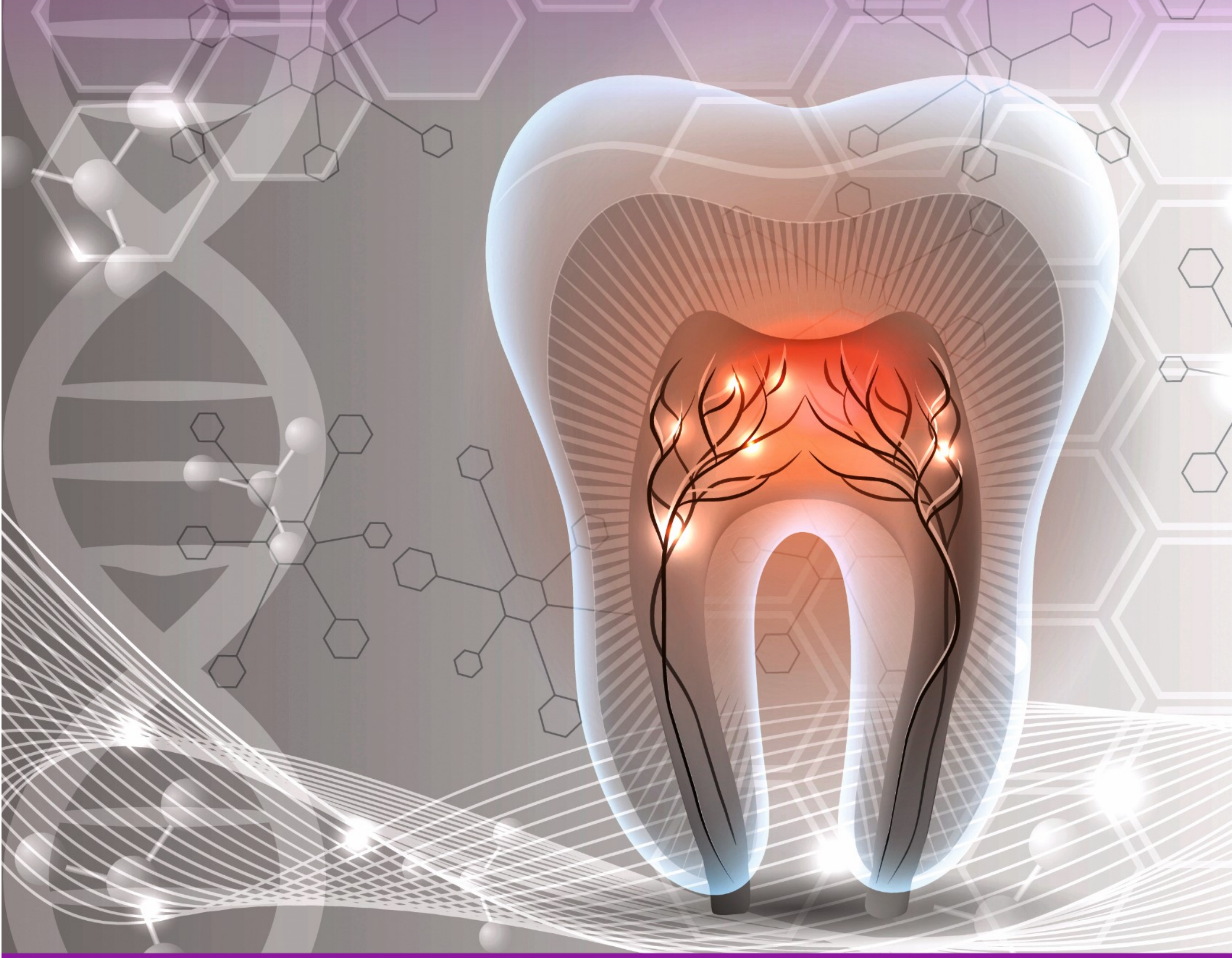

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The Effect of Repeated Preheating on Diametral Tensile Strength of Composite Resin with Different Fillers

Ellen Winarta, Tien Suwartini[1], Anastasia Elsa Prahasti[1], Rosalina Tjandrawinata[2]

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ABSTRACT

Background: The development of adhesive systems has made the removal of carious lesion a minimally invasive procedure. Composite resin is the material of choice today, but the filler composition of the resin varies. Packable composite resin has good mechanical properties, but its high viscosity makes it hard to manipulate. Several methods, such as preheating, are used to decrease this viscosity. A syringe of composite resin might be preheated several times, but the effect of repeated preheating is unknown. **Objectives:** The purpose of this research was to analyze the effect of repeated preheating on the mechanical properties of a composite resin with different fillers. **Method:** Microhybrid, nanohybrid, and nanofill composite resins were preheated (ten times, twenty times, and control), molded into cylinder molds 6 mm in diameter and 3 mm in height, flattened with a celluloid strip, and polymerized with an light-emitting diode light-curing unit for 40 s. A total of 180 specimens were tested. The specimens were divided into two groups: Group 1 was immediately tested using a universal testing machine. Group 2 was soaked in 37°C artificial saliva for 24 h before testing. Each specimen was tested using the universal testing machine with the pressure side with a 1 mm/s crosshead speed. **Result:** Nanohybrid composite resin had the most stable diametral tensile strength after repeated preheating, whereas nanofill composite had the weakest strength. The increase and decrease in the diametral tensile strength in each group were not statistically significant. **Conclusion:** Repeated preheating does not significantly affect the diametral tensile strength of composite resin.

Keywords: *Composite resin, diametral tensile strength, repeated preheating*

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Background

The development of adhesive systems has made composite resin the material of choice today.[1,2] Cavity preparation has been minimized,[3] but a small cavity is difficult to restore with condensable composites.[4-6] During mastication, the restoration is placed under pressure;[7] therefore, composite restorations require good mechanical properties.[8] A significant correlation is found between the surface of the composite restoration and its diametral tensile strength.[9] Composite resin fillers have been studied for the recommended use in the posterior teeth.[10,11]

Recently, a preheating device has been marketed.[12] Soliman concluded that heating a composite resin increased its micro strength.[13] Uctasli revealed that heated composite resin had a better adaptation to the cavity wall.[14] Nada and El-Mowafy indicated that heating composite resins increased their compression strength.[15] One syringe of composite resin can be used several times, which means that the heating process may also be repeated many times.[16,17] The aim of this study was to analyze whether reheating of composite resins has an impact on the diametral tensile strength of composite resins.

Materials and Methods

The samples in this study were 180 composite resin specimens with cylindrical shape 6 mm in diameter

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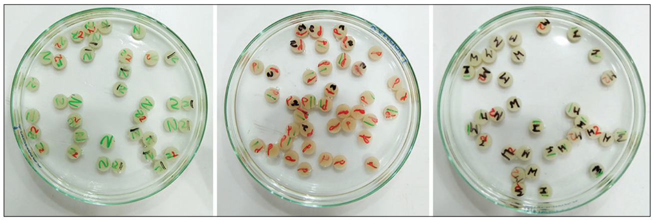

Figure 1: Specimens were soaked in artificial saliva

and 3 mm in height. The samples were fabricated from microhybrid (Z250, 3M, USA), nanofill (Palfique LX 5, Tokuyama, Japan), and nanohybrid (Ena Hri, Micerium, Italy) composite resins. Each resin was heated ten times or twenty times or not heated as a control, and the diametral tensile strength of the specimens (in groups of ten) was analyzed either immediately or after 24 h.

The composite resin heating process was carried out by inserting the composite resin syringe into a Micerium heater for 10 min at 39°C, then the material was removed with plastic filling (Hu Friedy, USA) from the syringe, and put into a 6 mm diameter and 3 mm high mold. The top surface of the composite resin was flattened using a celluloid strip (Mylar, Dentamerica), and then, the resin was polymerized using a light-curing unit (Ledex, Taiwan) at a wavelength of 470 nm for 40 s. The tip of light-curing unit was set to touch the celluloid strip.[18,19] Specimens in the Group 1 were immediately tested for their diametral tensile strength using a universal testing machine[20] (Shimadzu, Japan), whereas Group 2 [Figure 1] was immersed in artificial saliva at 37°C for 24 h before diametral tensile strength testing.[9] Diametral tensile strength was tested with a universal testing machine at PT INTEC, Karawang.

Statistical analysis

The normality of the data was tested using the Shapiro–Wilk test, which confirmed normally distributed data ($P > 0.05$). Data analyses were performed using the two-way ANOVA test using SPPS version 20 (IBM, N.Y., USA).

Results

The result of the diametral tensile strength of the three materials tested is varied [Table 1]. The statistical analysis result is shown in Table 2 which confirmed a significant difference in the diametral tensile strength among the three resin materials ($P = 0.000$).

Discussion

Research on the mechanical properties of heated composite resin is important for understanding the effects of heat on the ability of these materials to withstand mastication loads.[13,15] Increasing the temperature of the composite resin escalates the mobility of free radicals and monomers, thereby increasing the monomer conversion. This, in turn, improves the degree of polymerization, as well as the polymer crosslinking, mechanical properties, and physical properties.[14,15] High surface hardness and increased depth of polymerization are other advantages gained by heating composite resins.

The diametral tensile strength is an important factor to examine because it relates to the resistance to lateral forces that occur during mastication.[21] In this study, composite resins were heated according to the recommendations of the heating device, which is 39°C. The composite resin was repeatedly heated up to twenty times because D'Amario *et al.*'s research has indicated that a single composite resin syringe can be used to fill up to twenty cavities, especially when using the multishade layering technique.[17]

Table 1: Descriptive data of the mean and standard deviations of the diametral tensile strength of different composite resins based on time and treatment

Material	Time	Preheated	Mean	SD	*n*
Nanohybrid	24 h	Control	44.50	11.20	10
		10×	42.00	11.47	10
		20×	44.90	8.81	10
	Immediate	Control	30.70	5.63	10
		10×	35.50	5.31	10
		20×	41.10	9.84	10
Nanofill	24 h	Control	34.60	7.48	10
		10×	29.30	3.05	10
		20×	27.20	4.23	10
	Immediate	Control	34.80	2.82	10
		10×	32.40	3.59	10
		20×	35.60	2.27	10
Microhybrid	24 h	Control	46.80	4.54	10
		10×	40.30	5.25	10
		20×	40.40	8.78	10
	Immediate	Control	42.50	7.42	10
		10×	43.60	4.50	10
		20×	46.50	8.46	10

SD: Standard deviation

Table 2: Two-way ANOVA of effects of material, time, and preheating repetitions on diametral tensile strength of the composite resins

	P
Material	<0.01*
Time	0.436
Preheating repetitions	0.206
Material and time	<0.01*
Material and preheating repetitions	0.078
Time and preheating repetitions	0.001*
Material, time, and preheating repetitions	0.949

*Significance: $P<0.05$

The composite resins in this study are provided in syringes. The temperature of the material is maintained stable by placing heaters near the composite resin molds, with the aim of simplifying and speeding up the processing time while preventing a decrease in temperature during material manipulation. This was suggested by Daronch *et al*., as clinicians must work fast to ensure that only a slight decrease in temperature occurs.[22] The results of previous studies show that the temperature of the composite resin drops rapidly when the syringe is removed from the heater, and the composite resin is taken to the tooth surface.[13]

The microhybrid composite resin in this study showed an increase in diametral tensile strength in the immediately tested group. Nada and El-Mowafy study of microhybrid composite resins showed an increase in the surface hardness of the heated composite resin.[15] The degree of conversion is the percentage of carbon–carbon double bonds that have been converted into a single bond to form a polymeric resin. The higher the degree of conversion, the better the strength, wear resistance, and other important properties related to resin performance.[23] Meanwhile the shrinkage on polymerization related to the cavity configuration.[24]

The nanofill composite resin used in this study had the lowest diametral tensile strength when compared to the nanohybrid and microhybrid composite resins. This is due to the differences in the morphology of the composite resin filler. The nanofill composite resin tested in this study is a composite resin with a filler morphology in the form of prepolymerized fillers. Research by Kim *et al*. found that the amount of filler in composite resins was influenced by the filler morphology. Composite resins that contain prepolymerized filler particles have the lowest amount of filler. This type of composite resin also has the lowest flexural strength compared to composite resin with an irregular filler type or a mixture of prepolymerized and irregular forms.[25]

The microhybrid and nanohybrid composite resins tested in this study have higher diametral tensile strength than nanofill composite resins because hybrid composite resins have smaller filler particles that can enter between large fillers to filling the empty spaces between them, thereby providing better strength. By contrast, the nanofill composite resin has a filler with a rounded shape, which leaves a space among fillers, therefore decreased the strength when compared with the hybrid composite resins.

In this study, an increase and decrease were observed in the tensile strength of diametral nanohybrid, nanofill, and microhybrid composite resin composites after heating ten and twenty times when compared to controls, but the changes were not statistically significant. Research by D'Amario on nanohybrid composite resins also revealed that composite resins retain their same mechanical characteristics after 1, 10, 20, 30, and 40 times heating cycles at 39°C. The mechanical characteristics of the composite resin were not significantly different from those of the unheated composite resin.

The results in this study indicate that the significant difference observed in the diametral tensile strength between the three heated composite resins is likely due to the different filler and monomer contents. Therefore, different materials are likely to have different reactions when heated. In addition, the ability of each material to be heated also plays an important role in the compression strength of the material. Only the nanohybrid composite resins used in this study can be heated, according to their product descriptions.

This study conducted an immediate and 24 h diametral tensile strength tests to determine whether time has an influence on the diametral tensile strength. The results indicated that there are no effects of time on the diametral tensile strength. The choice of treatment time "immediately" after polymerization is important because the operator expects that the restoration will be sufficiently polymerized to endure mastication forces immediately after polymerization. If a time interval is needed for the restoration to accept this force, additional information should be listed in the manufacturer's instructions. However, manual instructions on this subject are not usually provided, but a diametral tensile strength test can immediately be carried out after polymerization.[27]

The 24 h time was chosen because a postcure polymerization occurs due to the photoactivation properties of the composite resin. After polymerization, free radicals trapped in the matrix can continue to react to slowly make bonds over time. Postcure reactions can continue as long as free radicals and reactants (for example, pendant methacrylate groups and free monomers) are still present. In general, postcure polymerization occurs during the first 24 h after polymerization. After 24 h, the amount of free radicals will decrease, and any subsequent polymerization will proceed very slowly.[28-30]

A literature study reveals that no adverse effects occur regarding the mechanical properties of composite resins due to heating procedures.[31] Research by Osternack *et al*. on microhybrid resins concluded that composite resin hardness was not affected by heating or cooling.[32] However, the majority of previous studies did not carry out repeated heating cycles. Daronch *et al*. reported that prolonged heating or ten0 repetitions of heating did not affect the degree of conversion when compared to composite resins maintained at room temperature.[18] A study by D'Amario *et al*. on nanohybrid composite resins revealed that repeated cycles of heating to 39°C did not affect the mechanical properties of composite resins. Heating to 39°C is considered sufficient to increase flowability and better adaptation to composite resins.[17]

Other ways to increase the viscosity of composite resins have been developed, including reducing the viscosity of monomers and using sonic vibrations. The viscosity of monomers can be reduced by combining bisphenol A-glycidyl methacrylate with triethylene glycol dimethacrylate. Sonic vibrations are thought to reduce the viscosity of the resin by increasing the flowability of composite resins.[4]

Besides the temperature of 39°C used in this study, other temperatures can be used for heating composite resin. The Ena Heat heater (Micerium S.p.A, Avegno, GT, Italy) has a heating temperature of 55°C that, according to the manufacturer's instructions, will produce composite resin with high flowability for use in cementation. In addition to the Ena Heat model, another composite resin heater on the market is the Calset (AdDent Inc., Danbury, CT, USA). This tool can heat the composite resin at 54°C and 68°C.

The marginal adaptation of composite resin is significantly better in axial walls when the composite resin is preheated.[6] El-Deeb *et al*. examined the effect of heating composite resin at 54°C and 68°C on the increase in intrapulp temperature and found that heating of composite resin increased intrapulp temperature without endangering the vitality of the pulp.[33]

Apart from the effects of heating on the mechanical properties of composite resins, a debate still exists over the shrinkage that occurs in heated composite resins. Deb *et al*. and Didron *et al*. indicated shrinkage in heated composite resin, but Lohbauer said that any shrinkage that occurred was not significant.[11,12,26]

Conclusion

Repeated heating has different effects on the diametral tensile strength of composite resins with different filler types. The nanohybrid composite resin in this study had the most stable diametral tensile strength after heating compared to nanofill and microhybrid types. The nanofill composite resin in this study had the lowest diametral tensile test compared to the other composite resins.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Rosalina Tjandrawinata

The Effect of Repeated Preheating on Diametral Tensile Strength of Composite Resin with Different Fillers

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The Effect of Repeated Preheating on Diametral Tensile Strength of Composite Resin with Different Fillers

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ABSTRACT

Background: The development of adhesive systems has made the removal of carious lesion a minimally invasive procedure. Composite resin is the material of choice today, but the filler composition of the resin varies. Packable composite resin has good mechanical properties, but its high viscosity makes it hard to manipulate. Several methods, such as preheating, are used to decrease this viscosity. A syringe of composite resin might be preheated several times, but the effect of repeated preheating is unknown. 8 **Objectives:** The purpose of this research was to analyze the effect of repeated preheating on the mechanical properties of a composite resin with different fillers. **Method:** Microhybrid, nanohybrid, and nanofill composite resins were preheated (ten times, twenty times, and control), molded into cylinder molds 6 mm in diameter and 3 mm in height, flattened with a celluloid strip, and polymerized with an light-emitting diode light-curing unit for 40 s. A total of 180 specimens were tested. The specimens were divided into two groups: Group 1 was immediately tested using a universal testing machine. Group 2 was soaked in 37°C artificial saliva for 24 h before testing. Each specimen was tested using the universal testing machine with the pressure side with a 1 mm/s crosshead speed. **Result:** Nanohybrid composite resin had the most stable diametral tensile strength after repeated preheating, whereas nanofill composite had the weakest strength. The increase and decrease in the diametral tensile strength in each group were not statistically significant. **Conclusion:** Repeated preheating does not significantly affect the diametral tensile strength of composite resin.

KEYWORDS: *Composite resin, diametral tensile strength, repeated preheating*

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BACKGROUND

The development of adhesive systems has made composite resin the material of choice today.[1,2] Cavity preparation has been minimized,[3] but a small cavity is difficult to restore with condensable composites.[4-6] During mastication, the restoration is placed under pressure;[7] therefore, composite restorations require good mechanical properties.[8] A significant correlation is found between the surface of the composite restoration and its diametral tensile strength.[9] Composite resin fillers have been studied for the recommended use in the posterior teeth.[10,11]

Recently, a preheating device has been marketed.[12] Soliman concluded that heating a composite resin
1 increased its micro strength.[13] Uctasli revealed that heated composite resin had a better adaptation to the cavity wall.[14] Nada and El-Mowafy indicated that heating composite resins increased their compression strength.[15] One syringe of composite resin can be used several times, which means that the heating process may also be repeated many times.[16,17] The aim of this study was to analyze whether reheating of composite resins has an impact on the diametral tensile strength of composite resins.

MATERIALS AND METHODS

The samples in this study were 180 composite resin specimens with cylindrical shape 6 mm in diameter

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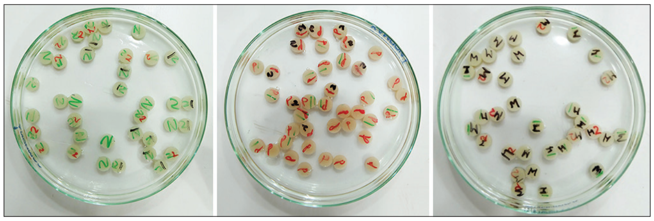

Figure 1: Specimens were soaked in artificial saliva

and 3 mm in height. The samples were fabricated from microhybrid (Z250, 3M, USA), nanofill (Palfique LX 5, Tokuyama, Japan), and nanohybrid (Ena Hri, Micerium, Italy) composite resins. Each resin was heated ten times or twenty times or not heated as a control, and the diametral tensile strength of the specimens (in groups of ten) was analyzed either immediately or after 24 h.

The composite resin heating process was carried out by inserting the composite resin syringe into a Micerium heater for 10 min at 39°C, then the material was removed with plastic filling (Hu Friedy, USA) from the syringe, and put into a 6 mm diameter and 3 mm high mold. The top surface of the composite resin was flattened using a celluloid strip (Mylar, Dentamerica), and then, the resin was polymerized using a light-curing unit (Ledex, Taiwan) at a wavelength of 470 nm for 40 s. The tip of light-curing unit was set to touch the celluloid strip.[18,19] Specimens in the Group 1 were immediately tested for their diametral tensile strength using a universal testing machine[20] (Shimadzu, Japan), whereas Group 2 [Figure 1] was immersed in artificial saliva at 37°C for 24 h before diametral tensile strength testing.[9] Diametral tensile strength was tested with a universal testing machine at PT INTEC, Karawang.

Statistical analysis

The normality of the data was tested using the Shapiro–Wilk test, which confirmed normally distributed data ($P > 0.05$). Data analyses were performed using the two-way ANOVA test using SPPS version 20 (IBM, N.Y., USA).

Results

The result of the diametral tensile strength of the three materials tested is varied [Table 1]. The statistical analysis result is shown in Table 2 which confirmed a significant difference in the diametral tensile strength among the three resin materials ($P = 0.000$).

Discussion

Research on the mechanical properties of heated composite resin is important for understanding the effects of heat on the ability of these materials to withstand mastication loads.[13,15] Increasing the temperature of the composite resin escalates the mobility of free radicals and monomers, thereby increasing the monomer conversion. This, in turn, improves the degree of polymerization, as well as the polymer crosslinking, mechanical properties, and physical properties.[14,15] High surface hardness and increased depth of polymerization are other advantages gained by heating composite resins.

The diametral tensile strength is an important factor to examine because it relates to the resistance to lateral forces that occur during mastication.[21] In this study, composite resins were heated according to the recommendations of the heating device, which is 39°C. The composite resin was repeatedly heated up to twenty times because D'Amario *et al.*'s research has indicated that a single composite resin syringe can be used to fill up to twenty cavities, especially when using the multishade layering technique.[17]

Table 1: Descriptive data of the mean and standard deviations of the diametral tensile strength of different composite resins based on time and treatment

Material	Time	Preheated	Mean	SD	*n*
Nanohybrid	24 h	Control	44.50	11.20	10
		10×	42.00	11.47	10
		20×	44.90	8.81	10
	Immediate	Control	30.70	5.63	10
		10×	35.50	5.31	10
		20×	41.10	9.84	10
Nanofill	24 h	Control	34.60	7.48	10
		10×	29.30	3.05	10
		20×	27.20	4.23	10
	Immediate	Control	34.80	2.82	10
		10×	32.40	3.59	10
		20×	35.60	2.27	10
Microhybrid	24 h	Control	46.80	4.54	10
		10×	40.30	5.25	10
		20×	40.40	8.78	10
	Immediate	Control	42.50	7.42	10
		10×	43.60	4.50	10
		20×	46.50	8.46	10

SD: Standard deviation

Table 2: Two-way ANOVA of effects of material, time, and preheating repetitions on diametral tensile strength of the composite resins

	P
Material	<0.01*
Time	0.436
Preheating repetitions	0.206
Material and time	<0.01*
Material and preheating repetitions	0.078
Time and preheating repetitions	0.001*
Material, time, and preheating repetitions	0.949

*Significance: $P<0.05$

The composite resins in this study are provided in syringes. The temperature of the material is maintained stable by placing heaters near the composite resin molds, with the aim of simplifying and speeding up the processing time while preventing a decrease in temperature during material manipulation. This was suggested by Daronch *et al*., as clinicians must work fast to ensure that only a slight decrease in temperature occurs.[22] The results of previous studies show that the temperature of the composite resin drops rapidly when the syringe is removed from the heater, and the composite resin is taken to the tooth surface.[13]

The microhybrid composite resin in this study showed an increase in diametral tensile strength in the immediately tested group. Nada and El-Mowafy study of microhybrid composite resins showed an increase in the surface hardness of the heated composite resin.[15] The degree of conversion is the percentage of carbon–carbon double bonds that have been converted into a single bond to form a polymeric resin. The higher the degree of conversion, the better the strength, wear resistance, and other important properties related to resin performance.[23] Meanwhile the shrinkage on polymerization related to the cavity configuration.[24]

The nanofill composite resin used in this study had the lowest diametral tensile strength when compared to the nanohybrid and microhybrid composite resins. This is due to the differences in the morphology of the composite resin filler. The nanofill composite resin tested in this study is a composite resin with a filler morphology in the form of prepolymerized fillers. Research by Kim *et al*. found that the amount of filler in composite resins was influenced by the filler morphology. Composite resins that contain prepolymerized filler particles have the lowest amount of filler. This type of composite resin also has the lowest flexural strength compared to composite resin with an irregular filler type or a mixture of prepolymerized and irregular forms.[25]

The microhybrid and nanohybrid composite resins tested in this study have higher diametral tensile strength than nanofill composite resins because hybrid composite resins have smaller filler particles that can enter between large fillers to filling the empty spaces between them, thereby providing better strength. By contrast, the nanofill composite resin has a filler with a rounded shape, which leaves a space among fillers, therefore decreased the strength when compared with the hybrid composite resins.

In this study, an increase and decrease were observed in the tensile strength of diametral nanohybrid, nanofill, and microhybrid composite resin composites after heating ten and twenty times when compared to controls, but the changes were not statistically significant. Research by D'Amario on nanohybrid composite resins also revealed that composite resins retain their same mechanical characteristics after 1, 10, 20, 30, and 40 times heating cycles at 39°C. The mechanical characteristics of the composite resin were not significantly different from those of the unheated composite resin.

The results in this study indicate that the significant difference observed in the diametral tensile strength between the three heated composite resins is likely due to the different filler and monomer contents. Therefore, different materials are likely to have different reactions when heated. In addition, the ability of each material to be heated also plays an important role in the compression strength of the material. Only the nanohybrid composite resins used in this study can be heated, according to their product descriptions.

This study conducted an immediate and 24 h diametral tensile strength tests to determine whether time has an influence on the diametral tensile strength. The results indicated that there are no effects of time on the diametral tensile strength. The choice of treatment time "immediately" after polymerization is important because the operator expects that the restoration will be sufficiently polymerized to endure mastication forces immediately after polymerization. If a time interval is needed for the restoration to accept this force, additional information should be listed in the manufacturer's instructions. However, manual instructions on this subject are not usually provided, but a diametral tensile strength test can immediately be carried out after polymerization.[27]

The 24 h time was chosen because a postcure polymerization occurs due to the photoactivation properties of the composite resin. After polymerization, free radicals trapped in the matrix can continue to react to slowly make bonds over time. Postcure reactions can continue as long as free radicals and reactants (for example, pendant methacrylate groups and free monomers) are still present. In general, postcure polymerization occurs during the first 24 h after polymerization. After 24 h, the amount of free radicals will decrease, and any subsequent polymerization will proceed very slowly.[28-30]

A literature study reveals that no adverse effects occur regarding the mechanical properties of composite resins due to heating procedures.[31] Research by Osternack *et al*. on microhybrid resins concluded that composite resin hardness was not affected by heating or cooling.[32] However, the majority of previous studies did not carry out repeated heating cycles. Daronch *et al*. reported that prolonged heating or ten0 repetitions of heating did not affect the degree of conversion when compared to composite resins maintained at room temperature.[18] A study by D'Amario *et al*. on nanohybrid composite resins revealed that repeated cycles of heating to 39°C did not affect the mechanical properties of composite resins. Heating to 39°C is considered sufficient to increase flowability and better adaptation to composite resins.[17]

Other ways to increase the viscosity of composite resins have been developed, including reducing the viscosity of monomers and using sonic vibrations. The viscosity of monomers can be reduced by combining bisphenol A-glycidyl methacrylate with triethylene glycol dimethacrylate. Sonic vibrations are thought to reduce the viscosity of the resin by increasing the flowability of composite resins.[4]

Besides the temperature of 39°C used in this study, other temperatures can be used for heating composite resin. The Ena Heat heater (Micerium S.p.A, Avegno, GT, Italy) has a heating temperature of 55°C that, according to the manufacturer's instructions, will produce composite resin with high flowability for use in cementation. In addition to the Ena Heat model, another composite resin heater on the market is the Calset (AdDent Inc., Danbury, CT, USA). This tool can heat the composite resin at 54°C and 68°C.

The marginal adaptation of composite resin is significantly better in axial walls when the composite resin is preheated.[6] El-Deeb *et al*. examined the effect of heating composite resin at 54°C and 68°C on the increase in intrapulp temperature and found that heating of composite resin increased intrapulp temperature without endangering the vitality of the pulp.[33]

Apart from the effects of heating on the mechanical properties of composite resins, a debate still exists over the shrinkage that occurs in heated composite resins. Deb *et al*. and Didron *et al*. indicated shrinkage in heated composite resin, but Lohbauer said that any shrinkage that occurred was not significant.[11,12,26]

Conclusion

Repeated heating has different effects on the diametral tensile strength of composite resins with different filler types. The nanohybrid composite resin in this study had the most stable diametral tensile strength after heating compared to nanofill and microhybrid types. The nanofill composite resin in this study had the lowest diametral tensile test compared to the other composite resins.

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Conflicts of interest

There are no conflicts of interest.

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