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Evaluation of the Effects of Soda on Flowable Bulk-Fill Composite Resin Compressive Strength

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ABSTRACT

Background: Flowable bulk-fill composite resin is a direct restoration material and has gained popularity in restorative dentistry for class II restoration. Soda is one of the most consumed drinks by the public and is known to be acidic. **Objective:** To determine the effect of soda on the compressive strength of flowable bulk-fill composite resin. **Methods:** This study used 54 cylindrical (diameter: 2 mm; height: 4 mm) flowable bulk-fill composite resin samples of different brands (*Beautifil Bulk Flowable, SDR Flow+, Tetric N-Flow Bulk Fill*). The samples were divided into 3 control groups and 3 experimental groups. After all groups had been incubated for 24 hours, the control groups were soaked in artificial saliva for 6 days. The experimental groups were soaked in soda for 6 hours, and then for 18 hours in artificial saliva. The solutions were replaced every day, and the pH was measured. The study is performed at a controlled temperature in an incubator at 37°C. After the samples were dried, the compressive strengths of the samples were tested using the Universal Testing Machine. **Results:** Based on the Two-Way ANOVA test, the compressive strength values between groups of flowable bulk-fill composite resins are not significantly different ($p > 0.05$). **Conclusion :** The immersion in soda does not significantly affect the compressive strength of flowable bulk-fill composite resin. Flowable bulk-fill composite resin exhibits relatively high resistance to acidic solutions.

Keywords : Compressive Strength, Dental Materials, Flowable Bulk-Fill Composite Resin, pH, Soda.

Evaluasi Pengaruh Soda terhadap Kekuatan Kompresi Resin Komposit Flowable Bulk-Fill

ABSTRAK

Latar Belakang: Resin komposit *flowable bulk-fill* adalah bahan restorasi langsung yang semakin populer dalam kedokteran gigi restoratif, terutama untuk restorasi kelas II. Soda adalah salah satu minuman yang paling sering dikonsumsi oleh masyarakat dan dikenal memiliki sifat asam. **Tujuan:** Menentukan pengaruh soda terhadap kekuatan kompresi resin komposit *flowable bulk-fill*. **Metode:** Penelitian ini menggunakan 54 sampel resin komposit *flowable bulk-fill* berbentuk silinder (diameter: 2 mm; tinggi: 4 mm) dari berbagai merek (*Beautifil Bulk Flowable, SDR Flow+, Tetric N-Flow Bulk Fill*). Sampel dibagi menjadi 3 kelompok kontrol dan 3 kelompok eksperimen. Setelah semua kelompok diinkubasi selama 24 jam, kelompok kontrol direndam dalam saliva buatan selama 6 hari. Kelompok eksperimen direndam dalam soda selama 6 jam, kemudian dalam saliva buatan selama 18 jam. Larutan diganti setiap hari, dan pH diukur. Penelitian dilakukan pada suhu terkontrol dalam inkubator pada suhu 37°C. Setelah sampel dikeringkan, kekuatan kompresi sampel diuji menggunakan Universal Testing Machine. **Hasil:** Berdasarkan uji *Two-Way* ANOVA, nilai kekuatan kompresi antara kelompok resin komposit *flowable bulk-fill* tidak berbeda secara signifikan ($p > 0,05$). **Kesimpulan:** Perendaman dalam soda tidak secara signifikan mempengaruhi kekuatan kompresi resin komposit *flowable bulk-fill*. Resin komposit *flowable bulk-fill* menunjukkan ketahanan yang relatif tinggi terhadap larutan asam.

Kata Kunci: Kekuatan Kompresi, Dental Material, Resin Komposit *Flowable Bulk-Fill*, pH, Soda.

BACKGROUND

Composite resin has become more popular due to its excellent aesthetic with tooth-colored restoration, and its adhesion to teeth, which needs far less invasive cavity preparation.[1] Composite resin mainly contains organic resin matrix such as bisphenol A-glycidyl methacrylate (Bis-GMA) or urethane dimethacrylate (UDMA), and inorganic fillers such as zirconia, silica, or glass ceramics.[2] When restoring teeth with composite resin, this material suffers a volumetric shrinkage when light-activated. Hence, applying conventional composite resins in 2 mm increments has been recommended to minimize the polymerization stress. However, this incremental technique is considered intricate and time-consuming because restoration has to be done layer by layer.[1] The incremental technique may also negatively affect the restoration, for example, due to contamination between the layers of composite resin and a weaker bond between the layers.[3] These risks affect the final result of the restoration. Thus, the development of bulk-fill composite resins is aimed at reducing shrinkage stress, simplifying material manipulation, and shortening the clinical time needed for restoration.[1]

Bulk-fill composite resin is a restoration material that can be applied in a shorter amount of time compared to conventional composite resin. Bulk-fill composite resin is known to have fewer fillers, bigger filler particles, and more photoinitiator reagents compared to conventional composite resin. This composition changes in bulk-fill composite resin can increase its photopolymerization depth so that it can be used in increments of 4-5 mm. The filler content of bulk-fill composite resins can reduce the amount of dispersion on the surface of the filler and increase the amount of light that can be absorbed to activate the photoinitiator.[4] Bulk-fill composite resins also have longer molecular bonds and shorter intermonomer distances in their matrix components compared to conventional composite resins, resulting in less shrinkage during polymerization.[5] Bulk-fill composite resin also has a lower c-factor (cavity configuration factor) so there's less microleakage in bulk-fill composite resin compared to conventional composite resin.[6]

Bulk-fill composite resin can be classified into two types, which are packable and flowable. Packable bulk-fill composite resin has a higher viscosity and higher inorganic filler content than flowable bulk-fill composite resin. Packable bulk-fill composite resin also has slumping resistance.[7] Flowable bulk-fill composite resin is a low-viscosity material with fewer filler loads and higher resin components than packable bulk-fill composite resin.[8] Flowable bulk-fill composite resin can be used clinically as preventive resin restorations (PRR), pit and fissure sealants, cavity liners, and class II restorations.[9] One of the most important characteristics of a restoration material, besides its compressive strength, is its marginal seal. An adequate marginal seal can be obtained by using a material with high adaptability to the cavity, such as flowable bulk-fill composite resin. Flowable composite resin's low elastic modulus and stress development can help to maintain its marginal seal.[9,10]

As stated in the result of Riset Kesehatan Dasar (Riskesdas) in 2018, it is known that 86.8% of Indonesians consume sodas monthly, with an average of consumption 3 times a month.[11] According to a previously conducted study, it is known that most sodas (93% out of 380 products) have a pH level below 4.0.[12] The acidity in sodas comes from acids, such as phosphoric acid and citric acid, that are added to sodas to give a distinctive taste, to balance the sweetness of sugar present in those drinks, and to improve its shelf-life.[12] Continuous consumption of sodas can reduce the strength and shorten the life of restoration materials such as glass ionomer cement, polyacid-modified resin composite, and composite resin.[13] The acidity of these drinks can also affect restoration materials by degrading the matrix and eroding the surface of fillers in the restoration materials.[14] Such erosion can result in weakening the mechanical properties of a composite resin, which can damage the restoration cavities and cause secondary caries.[15]

Compressive strength constitutes one of the most crucial characteristics of composite resins.[16] Composite resin materials with weak compressive strength cannot withstand and support stress, thus increasing the risk of restoration failure. If the material has an inadequate compressive strength, it is at risk of fracture due to masticatory stress and pressure.[17] The compressive strength of composite resin materials can be tested using a Universal Testing Machine.[11] Considering the description above, this study aims to determine the effect of soda on the compressive strength of flowable bulk-fill composite resin.

MATERIALS AND METHODS

Sample Preparation

Before the study was conducted, the equipment and materials were prepared and each of its expiration dates were checked. The equipment used in this study were beaker glass (Pyrex, China), containers, digital caliper (Krisbow, Indonesia), digital pH meter (Noyafa Multifunction EZ-9901, China), glass plates, incubator (Daihan Labtech LIB-080M General Incubator, South Korea), LED light cure unit (Fuchuang Curing Light LY-B200, China), object glass, stainless steel mold with a diameter of 2 mm and height of 4 mm, and Universal Testing Machine (Shimadzu AGS-X 5 KN, Japan). The materials used in this study were artificial saliva, celluloid strips, Coca-Cola Classic (The Coca-Cola Company, USA), distilled water (PUMA distilled water pH 7, CV Megatama Mandiri, Indonesia), flowable bulk-fill composite resin *Beautifil-Bulk Flowable* (LOT 012359, Shofu, Japan), flowable bulk-fill composite resin *SDR flow+* (LOT 00070511, Dentsply Sirona, Germany), flowable bulk-fill composite resin *Tetric N-Flow Bulk-Fill* (LOT Z03CHR, Ivoclar, Switzerland), sandpaper, and tissue paper.

The samples were prepared using a stainless-steel cylindrical mold measuring 4 mm in height and 2 mm in diameter. The flowable bulk-fill composite resins that were used in this study were *Beautifil-Bulk Flowable*, *SDR flow+*, and *Tetric N-Flow Bulk-Fill*. Each flowable bulk-fill composite resin is placed into a stainless-steel mold. Then the surface is leveled using a celluloid strip and covered with an object glass. The flowable bulk-fill composite resin was then light-cured using an LED light-curing unit for 20 seconds. The flowable bulk-fill composite resin was then removed from the stainless-steel mold, and if there was an uneven surface, the surface was leveled using sandpaper. Each sample was measured with a digital caliper. The samples were then divided into 3 control groups and 3 experimental groups based on their brand. The study is performed at a controlled temperature in an incubator at 37°C.

After the samples were made and incubated in 10 mL of artificial saliva with an incubator at 37°C for 24 hours, the control groups were then continued to be immersed in 10 mL of artificial saliva for another 6 days. Every 24 hours, the artificial saliva solution was replaced by a new artificial saliva solution and the pH was measured with a pH meter. Meanwhile, the experimental groups were immersed in 10 mL of soda for 6 hours and then in 10 mL of artificial saliva for 18 hours for 6 days (6 cycles). Each time the solutions were changed, the experimental groups' samples were rinsed with saline water and then dried with tissue paper. The new solutions' pH level was also measured. The average measured pH level for soda is 2.44 and for artificial saliva is 7.43.

Compressive Strength Testing

Samples that have been immersed are tested for compressive strength using a Universal Testing Machine (UTM). After the samples were dried using tissue paper and measured using a digital caliper, the samples were placed on the machine plate. The machine was then activated to compress the sample between two plates. Compression was carried out until the sample fractured, then the machine was stopped, and the amount of force shown on the screen was recorded. The test was conducted on 54 flowable bulk-fill composite resin samples.

Statistical Data Analysis

Compressive strength data obtained from the study was statistically analyzed using Statistical Package for The Social Sciences (IBM SPSS Statistics for Macintosh, Version 23.0, USA). Data from the compressive strength test were then tested using the Kolmogorov-Smirnov test for normality and the Levene test for homogeneity. Normally distributed and homogeneous data were then further analyzed with the Two-Way ANOVA test.

RESULTS

After conducting the study, the result data were then gathered. The results of the average compressive strength of each group, their standard deviation, and their compressive strength loss percentage can be seen in Table 1. All data were then tested with the Kolmogorov-Smirnov test, the Levene test, and the Two-Way ANOVA test.

Table 1. Compression strength test results

Composite Resin	Testing Group	Compressive Strength Control Group (MPa)	Compressive Strength Loss (%)
Beautifil-Bulk Flowable	Control Group	224.31±29.56	8.332
	Experimental Group	209.84±36.94	
SDR flow+	Control Group	224.31±29.56	2.495
	Experimental Group	218.71±26.77	
Tetric N-Flow Bulk-Fill	Control Group	203.86±23.24	3.228
	Experimental Group	197.208±25.14	

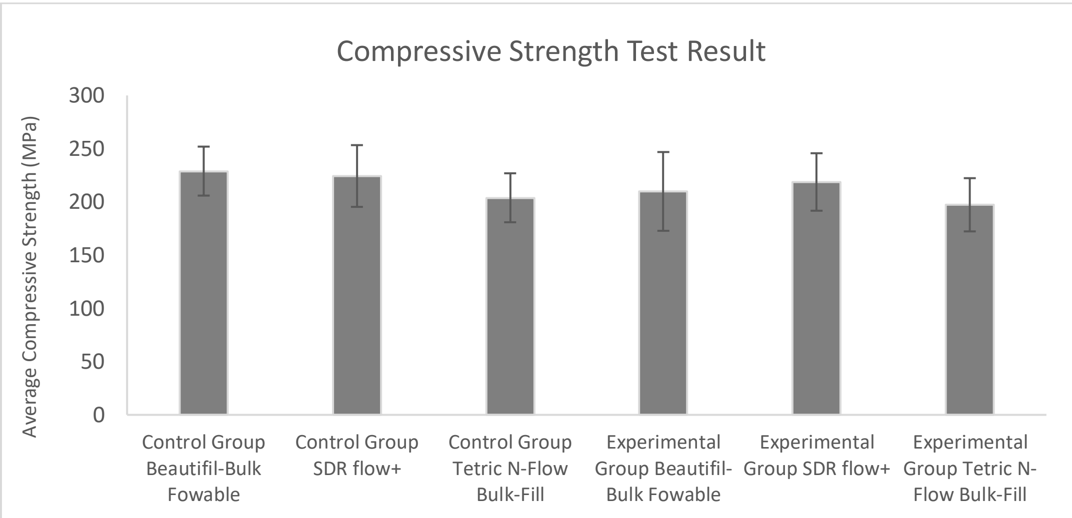

Figure 1. Compressive Strength Testing

Based on Two-Way ANOVA, it is known that there is no significant difference in compressive strength values between the flowable bulk-fill composite resin brands used ($p > 0.05$). Based on the type of treatment performed on the control group and the experimental group of flowable bulk-fill composite resins, it was found that there was no significant difference in compressive strength values ($p > 0.05$). It was also found that there was no significant interaction between the type of flowable bulk-fill composite resin used and the type of treatment performed in affecting the compressive strength of flowable bulk-fill composite resin ($p > 0.05$).

Table 2. Two-Way ANOVA test result

Variables	*p*-Value
Composite Resin	0.055
Testing	0.175
Composite Resin*Testing	0.724

DISCUSSION

The results of the conducted investigation indicate that flowable bulk-fill composite resins exhibit a little, but discernible, loss in compressive strength after being submerged in soda for 6 hours and in artificial saliva for 18 hours over the course of 6 days. The duration of the samples in soda is considered equivalent to Indonesians consuming soda 3 times a week for 1 year.[11] This compressive strength loss may be due to the presence of phosphoric acid content in sodas that have a low pH, so this acidic solution can reduce the mechanical properties of composite resins.[15] The absorbed soda has the potential to break down the chemical bonds in the composite resin and cause the dimethacrylate monomers' ester bonds (TEGDMA, Bis-GMA, and UDMA) in the organic matrix to hydrolyze.[18] The hydrolysis of ester bonds in composite resin is mainly caused by water. Hydrolysis is normally a slow process in the oral cavity, but different environments can accelerate the process. Acids, bases, enzymes, food, and oral physiology can catalyze hydrolysis. This hydrolysis will cause the material to deteriorate the material and cause the resin to release degradation products. These degradation products vary between the types of the matrix. Bis-GMA and TEGDMA can result in the formation of bishydroxy-propoxy-phenyl-propane (BisHPPP) and triethylene glycol methacrylate (TEGMA). TEGMA then breaks down to triethylene glycol (TEG). Further degradation may increase water sorption, thus increasing the diffusion of unreacted monomers and degradation products.[19] The degradation of the matrix resin can also affect the fillers and cause the loss of filler particles from the surface of the composite resin. Additionally, the high concentration of protonated protons from phosphoric acid accelerates the sorption process.[18]

Based on the decrease in compressive strength data, whilst still being inconsequential, SDR flow+ has the least amount of compressive strength loss when compared to Beautifil-Bulk Flowable and Tetric N-Flow Bulk-Fill. The difference in the compressive strength loss in these three flowable bulk-fill composite resins can be caused by differences in composition.

The high content of *SDR flow+* filler (70.5% of total weight, 47.4% of total volume) can improve the resistance of this composite resin to damage caused by acidic solutions, such as sodas. Fillers can enhance the mechanical properties of the composite resin.[18] *SDR flow+* also contains modified urethane di-methacrylate (UDMA), which contains a polymerization modulator that can lower its polymerization shrinkage, thus minimizing the polymerization stress and the material can be more stable.[20] According to these results, while being inconsequential, the *SDR flow+* composition has a higher resistance to acidic solutions compared to the other two flowable bulk-fill composite resins.

It can also be concluded that *Beautifil-Bulk Flowable* and *Tetric N-Flow Bulk-Fill* have a higher amount of compressive strength loss when compared to *SDR flow+* according to the results of the study while being irrelevant. This can be caused by the monomers (Bis-GMA and TEGDMA) that are more hydrophilic which can increase the hydrolysis activity. This can damage the chemical bonding of the composite resin. In addition, fillers such as barium can be damaged in an acidic environment. The barium filler contained in composite resins is an electropositive element that can react with water and this reaction can reduce the mechanical properties of the composite resin.[18]

Although *Beautifil-Bulk Flowable* composite resin has the highest filler content (73% by weight, 60% by volume) compared to the other two flowable bulk-fill resins, the component of hydrophilic monomers and metallic fillers may insignificantly reduce its resistance to acidic solutions. *Beautifil-Bulk Flowable* composite resin is a giomer flowable bulk-fill composite resin containing surface pre-reacted glass (S-PRG) filler. This filler is coated with an ionomer lining, incorporated in the resin matrix.[21] According to a previously conducted study, composite resins with S-PRG filler content are known to experience higher erosion and loss of mechanical strength compared to conventional composite resins when immersed in acidic solutions.[22] These may result in *Beautifil-Bulk Flowable* having a higher amount of compressive strength loss compared to the other two flowable bulk-fill composite resins while being insignificant.

Tetric N-Flow Bulk-Fill, besides its more hydrophilic monomer and barium filler component, has a lower amount of filler than the other two flowable bulk-fill composite resins (64.9% by weight). This lower filler content may result in the loss of mechanical strength of the composite resin and may result in *Beautifil-Bulk Flowable* having higher compressive strength loss.[23] This also affects its average compressive strength data, which can be concluded from the conducted study, whilst still being irrelevant, that *Tetric N-Flow Bulk-Fill* has the lowest amount of average compressive strength when compared to the other flowable bulk-fill two composite resins.

Based on the average compressive strength test results of the control group and experimental group of flowable bulk-fill composite resins based on the brand, it was found that *SDR flow+* has a higher average compressive strength value than the other two flowable bulk-fill composite resins whilst being inconsequential. The difference in compressive strength test results of flowable bulk-fill composite resins can be influenced by the filler content. The higher the filler content, the higher the compressive strength of the composite resin.[24] SDR flow+ is known to have a high filler content and a modified UDMA matrix. The modified UDMA matrix can increase the mechanical strength due to less volume shrinkage due to polymerization so that the material becomes more stable.[20] These compositions in *SDR flow+* can affect its average compressive strength.

In addition to *SDR flow+*, *Beautifil-Bulk Flowable* is known to have a higher compressive strength than *Tetric N-Flow Bulk-Fill*. *Beautifil-Bulk Flowable* contains Bis-GMA and UDMA matrix whilst still being irrelevant. These ingredients have high molecular weight and high mechanical strength.[25] The high filler content and inter-filler bonding of S-PRG (cross-linked polymer matrices) contained in this giomer composite resin are also known to have high compressive strength at normal oral pH levels.[21] This matrix and filler content may increase the resistance of the *Beautifil-Bulk Flowable* composite resin to fracture.

The compressive strength loss caused by soaking in soda in this study was not significant, thus showing that flowable bulk-fill composite resin has a resistance to acidic solution. This could be due to several factors and ways that companies use to reduce flowable bulk-fill composite resin hydrolysis from acidic solutions. The matrix content contained in the flowable bulk-fill composite resin can have stability and resistance to hydrolysis that can be caused by acidic solutions, such as soda.[26] Some types of matrix, such as UDMA, are also known to be more hydrophobic than others by adding a hydrophobic substituent to the monomer, which prevents the absorption of acidic solutions and prevents damage to the chemical bonds of the composite resin. The addition of more hydrophobic materials in the monomer can also reduce the water sorption and the solubility of the material.[27] Other ways to reduce hydrolysis is by using fluorinated monomers. The hydrophobicity in fluorinated monomers can reduce ester bonds' sensitivity to hydrolysis. Furthermore, the modified monomer's internal fluorocarbon chain is longer than hydrocarbons', providing steric hindrance to further protect ester linkages. Though using fluorinated monomers can reduce the materials' mechanical properties.[26]

According to a previous study, it is known that flowable bulk-fill composite resins can be used as materials for class II dental restorations because flowable bulk-fill composite resins are known to have low volume shrinkage, minimal polymerization stress, and good marginal seal.[9,10] The results of this study also prove that flowable bulk-fill composite resin has a relatively high resistance to acid solutions, so flowable bulk-fill composite resin can be used as a reconstructed restoration material, especially for filling deep cavities in posterior teeth as a class II restoration.

This study was accomplished *in vitro*. Although this study was done in a similar environment to an oral cavity, there were some limitations in simulating a true oral cavity environment. In this study, research has been conducted on the effect of soda on the overall strength of flowable bulk-fill composite resins, namely through their compressive strength. Further research can be done by examining the effect of soda on the surface of flowable bulk-fill composite resins, such as hardness and roughness. Further research can also be done by increasing the duration of soda immersion of flowable bulk-fill composite resins.

CONCLUSION

Based on the results of this research, it can be concluded that the immersion of flowable bulk-fill composite resin in soda does not significantly affect its compressive strength. Flowable bulk-fill composite resin exhibits relatively high resistance to acidic solutions.

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