Effect of White Portland Cement Addition on Type III Dental Gypsum Compressive Strength

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Abstract

Type IV gypsum products are used to fabricate final dental casts due to their superior mechanical properties, however, when compared to type III gypsum, type IV gypsum products are significantly more expensive. Type 3 gypsum must be adjusted to achieve compressive strength equivalent to or greater than type IV gypsum.

The aim of this study is to evaluate the effect of White Portland Cement (WPC) addition in different concentration to dental gypsum type III's compressive strength and compare them the strength of dental gypsum type IV. A total of 24 samples were divided into 4 main groups: 100% type IV gypsum (control group), 60 wt% type III gypsum + 40 wt% WPC, 50 wt% type III gypsum + 50 wt% WPC, and 40 wt% type III gypsum + 60 wt% WPC. Stone samples were constructed with 40 mm height and 20 mm diameter. The compressive strength test was carried out on all samples using a universal testing machine.

The results showed that the highest compressive strength was a mixture of gypsum type III 40% and WPC 60%, and the lowest compressive strength was 40 wt% type III gypsum + 60 wt% WPC group. There was a significant difference in compressive strength between the gypsum type IV group compared to all mixed gypsum type III and WPC groups, except for 40 wt% type III gypsum + 60 wt% WPC. The addition of WPC to type III gypsum can increase the compressive strength of gypsum and can achieve similar compressive strength as type IV gypsum.

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Introduction

The duplicate of the oral structures that used construct a prosthesis or restoration is called a working model (cast). In the dental laboratory and in clinical practice, stone castings are essential components that must properly replicate the structures acquired through impressions. Accuracy procedures and the proper materials are needed to complete this.[1] To withstand the force when applied for clinical purposes, these materials must be strong enough and resistant to abrasion.[2] For safe laboratory operations, dental models must be able to withstand repeated handling without breaking.[3]

Gypsum and its byproducts have been employed for ages in a variety of industries. It is mostly used in dentistry to create casts and to support various dental laboratory procedures involved in the creation of oral and maxillofacial prosthesis.[4] Gypsum products are chemically based on calcium sulfate hemihydrate ($CaSO4.2H2O$) and are distinctive in nature. To enhance the physical and mechanical qualities, these materials can be altered utilizing chemicals and other materials.[5]

According to American Dental Association (ADA) specifications No. 25, dental gypsum consists of five types: type I – type V. Due to its strength of fracture and abrasive, Type III Gypsum, also known as dental stone, is one type of gypsum that is frequently used to manufacture

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dental models (cast models or dies). It also has enough strength to be utilized in the creation of acrylic denture bases. Gypsum of type IV, often known as die stone, is a form of modified hemihydrate that offers a hard surface and resistance to abrasives. This advantage is very beneficial because it can protect the working model from sharp instruments when engraving wax model.[5] Type IV is usually used to fabricate the final dental casts, owing to their premium mechanical properties such as great resistance to abrasion and high compressive strength, in addition to high accuracy due to little setting expansion when compared with other gypsum product types.[6] Compared to type III gypsum, type IV gypsum products are significantly more expensive, therefore type III gypsum is preferrable.[7] To attain compressive strength equal to or greater than type IV gypsum, type 3 gypsum must be modified.

There have been several attempts made to increase the compressive strength of gypsum products by adding various inorganic additives and fillers. The addition of chemicals such as glass fiber, cured resin, and pulverized stone can increase the compressive strength. The interaction between chemical additives and gypsum will strengthen the bonds between the dihydrate crystals that will be formed, so that the material can produce a higher compressive strength than pure gypsum. Previous research has found that the compressive strength of type III gypsum combined with a 1.5% potassium sulfate (K2SO4) solution nearly equaled type IV gypsum's compressive strength.[8]

The most widely used cement is White Portland cement (WPC), which is primarily made of calcium, silicon, and aluminum oxides. Portland cement is a key component of concrete, stucco, plaster, mortar, and grout.[9] Portland cement was first used in dentistry more than a century ago, and its potential clinical uses were discovered later.[10] WPC can generate concrete that is long-lasting and appropriate for harsh settings, protecting building structures against chloride and sulfate assault.[11]

The aim of this study is to evaluate the effect of WPC addition in different concentration to dental gypsum type III's compressive strength and compare them the strength of dental gypsum type IV.

Materials and methods

Materials and Sample Groups

Three kinds of materials were utilized in this study (Table 1). A total of 24 samples were divided into 4 main groups: 100% type IV gypsum (control group), 60 wt% type III gypsum + 40 wt% WPC, 50 wt% type III gypsum + 50 wt% WPC, and 40 wt% type III gypsum + 60 wt% WPC. The control group were used to compare the compressive strength of die stone and experimental groups.

Product	Manufacturer
Dental Gypsum Type III	Probase, USA
Dental Gypsum Type IV	Probase, USA
White Portland Cement (WPC)	Semen Tiga Roda, Indonesia

Table 1. Material and Manufacturer.

Sample Preparation

An aluminum split mold was designed and constructed for the purpose of the preparation of a stone sample with 40 mm height and 20 mm diameter in accordance to ADA Specification No 25 for dental gypsum products (ADA Spec, 2000). The inside surface of the mold was painted with thin layer of Vaseline separating material to permit easy separation after setting.

The control group sample preparation started by mixing the powder with water according to the manufacturer instruction (50 gr/12 ml) and slowly poured into the mold under vibrator for 30 seconds. Same procedure was applied to the experimental samples after combining the type III dental gypsum and WPC with provided weight ratio. All the samples were air dried at room temperature for 24 hours before testing.

Compressive Strength Test

The compressive strength test was carried out on all samples using a universal testing machine (Instron, Germany). The load was applied on each sample with a constant speed of 1 mm/min until fracture. The resultant values (MPa) represented the compressive strength by the following formula: Load (gr) / Surface area (mm^2).

Statistical Analysis

Bivariate analysis is used to determine the effect of compressive strength between the independent variables (type IV gypsum, type III gypsum mixture with WPC of various concentrations and the dependent variable (compressive strength). The normality of strength for each group was tested by the Shapiro-Wilk test. The Bartlett test was used to examine whether the homogeneity assumption was violated. The one-way ANOVA was performed to examine if there was a difference among four types. Subsequently, we performed the Dunnett Test to find out which type had a significant difference with the control group. The Dunnett test is used by researchers interested in testing two or more experimental groups against a single control group. The level of significance in this test is α = 0.05. The hypothesis (H0) will be rejected if p <0.05 and H0 is accepted if p >0.05. The null hypotheses were that the compressive strength of type III gypsum was not affected by the addition of WPC.

In addition, the multiple regression analysis was performed to examine the effect of weight addition of the WPC on the gypsum compressive strength. Furthermore, a Lack of fit test was performed to examine whether the model was fit despite multiple compressive strengths with the same concentration.

Results

Table 2 showed the means of compressive strength Compressive Strength of Type III Gypsum Mixture + WPC of Various Concentrations and Type IV Gypsum. The highest mean value among all groups is Type IV Gypsum which equals to 35.68 MPa. Figure 1 depicted the increase of compressive strength of Type III Gypsum as the increase of WPC addition concentration.

Groups	Mean ± SD	Min (MPa)	Max (MPa)
100% type IV gypsum	35,68 ± 1,81	33,83	38,61
60 wt% type III gypsum + 40 wt% WPC	29,70 ± 1,54	27,91	31,91
50 wt% type III gypsum + 50 wt% WPC	32,11 ± 2,18	29,55	34,75
40 wt% type III gypsum + 60 wt% WPC	37,58 ± 1,51	35,75	39,95

Table 2. Compressive Strength of Type III Gypsum Mixture + WPC of Various Concentrations and Type IV Gypsum.

The results of the One Way Anova test based on Table 3, 4 obtained a value of p = 0.000, there was a significant difference of compressive strength among four groups (F(3, 20) = 23.57, p < 0.05). Furthermore, the Dunnett Test concluded that the strength of the first and second group was significantly lower than the control group, (Diff 2-1 = -5.98, p < 0.001; Diff 3-1 = -3.57, p < 0.05). In contrast, there was no significant strength difference between control group and fourth group (40 wt% type III gypsum + 60 wt% WPC), Diff 4-1 = 1.89, p = 0.189).

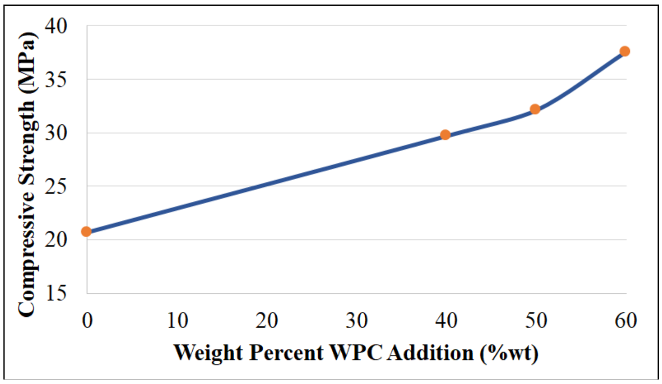

Figure 1. Plots of Compressive Strength Versus Weight Percent WPC.

Groups	Mean ± SD	P
100% type IV gypsum	35,68 ± 1,81	
60 wt% type III gypsum + 40 wt% WPC	29,70 ± 1,54	0,000
50 wt% type III gypsum + 50 wt% WPC	32,11 ± 2,18	
40 wt% type III gypsum + 60 wt% WPC	37,58 ± 1,51	

Table 3. ANOVA Test Results of Compressive Strength of Type III Gypsum Mixture and WPC of Various Concentrations with Type IV Gypsum.

Group	Group	Difference	Lower CI	Upper CI	*p*
60 wt% type III gypsum + 40 wt% WPC	100% type IV gypsum	-5.98	-8.60	-3.36	<0.05
50 wt% type III gypsum + 50 wt% WPC	100% type IV gypsum	-3.58	-6.19	-0.96	<0.05
40 wt% type III gypsum + 60 wt% WPC	100% type IV gypsum	1.89	-0.72	4.51	0.189

Table 4. Dunnet Test for Multiple Comparison of Compressive Strength of Type III Gypsum Mixture and WPC of Various Concentrations with Type IV Gypsum.

Based on regression analysis, there was a positive significant effect of weight addition of WPC to the compressive strength (b = 39.39, p < 0.001). An increase of 10% concentration of type III gypsum increased the strength by 3.9 MPa. The lack of fit test concluded that the use of linear regression was as good as using separate means at the three weight addition, F(1,15) = 2.99, p = 0.104. Therefore, we could predict even for the percentage between those measured.

Discussion

Many researches have shown that enhancing mechanical properties of dental materials using inorganic materials is effective.[12-14] Gypsum materials must have great compressive strength, as well as fracture and abrasion resistance, to be clinically beneficial. The compressive strength of gypsum products is typically associated to the water/powder ratio, mixing time, free water content in the set product, volume of mixture, chemical composition, relative humidity, room temperature at which the material is stored, and time passed after the cast is poured.[15] Several investigations on gypsum materials have been undertaken in order to improve their mechanical properties.

According to the findings of this investigation, the different concentrations of WPC in this study impacted the increase in compressive strength of type III gypsum mixture with WPC. When compared to pure type III gypsum compressive strength, the higher the WPC concentration, the stronger the compressive strength of type III gypsum. The difference in compressive strength between all groups of type III gypsum and WPC mixtures was influenced by the additives contained in the WPC such as trass and fly ash which contain silicate oxide (SiO2). SiO2 contained in fly ash and trass can affect and increase compressive strength. WPC also has limestone which contains calcium carbonate ($CaCO_3$) which can increase the compressive strength of cement.[11] Therefore, the higher concentration of WPC in the gypsum type III and WPC mixture will cause he higher the percentage of fly ash and limestone, which generated the higher the compressive strength of the cement mixture in the production of the resulting gypsum.[16-17]

Based on the regression test, an increase of 10% concentration of WPC in type III gypsum would increase the strength by 3.9 MPa. The additives in the WPC concentration that can increase the compressive strength of the type III gypsum. The higher the WPC concentration, the more additives such as SiO2 which can increase the higher compressive strength in a mixture of cement.[18-20] The group of type III gypsum and WPC mixtures compared to type IV gypsum also had a significant increase in compressive strength, except for the 40%wt type III gypsum + 60%wt WPC mixture group. Therefore, the addition of 60%wt WPC concentration is the proper concentration as a mixture for type III gypsum to achieve similar compressive strength as type IV gypsum.

Conclusions

The addition of WPC to type III gypsum can increase the compressive strength of gypsum and can achieve similar compressive strength as type IV gypsum. The higher the WPC concentration will result in a higher compressive strength in a mixture of type III gypsum cement.

Declaration of Interest

The authors report no conflict of interest.

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