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Effect of Adding some Additives and Drying Method on Compressive Strength of Gypsum Products

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Key words
Compressive strength, gypsum products.

Abstract

Gypsum products (dental plaster and stone) are widely used in dentistry. However, the main problem with any gypsum products is reproduction of fine details and dimensional stability. The current study was conducted to assess the effect of incorporating various additives (i.e. cured resin, pulverised stone, pulverised plaster, and glass fibers) and drying method on compressive strength of gypsum products. A total of 160 specimens were divided into 2 groups according to the method of drying (air and microwave). For each drying method, each group was subdivided depending on the type of material used into 2 groups; dental plaster and dental stone. Variuos additives were used for reinforcement; cured resin, pulverised plaster, pulverised stone, and glass fibers. The unmodified group was considered as control. The specimens were dried and the compressive strength test was applied on all specimens. All specimens' data were statistically analysed via ANOVA, Tukey and independent T tests.The compressive strength of gypsum products was significantly influenced by the type of additive used. The specimens reinforced with glass fibers, cured resin, pulverised plaster, and stone had a greater value of mean compressive strength compared with unmodified groups. Statistically, highly significant differences were observed among all dried groups ($P \leq 0.001$). As well, the microwave specimens were more resistant to compressive loadings than air dried specimens. No significant differences, however, were recorded between the two drying methods ($P > 0.05$).The glass fibers have a significant effect on compressive strength of gypsum products. The pulverised particles and cured resin can be added at 1 % by weight to enhance the mechanical properties of plaster and stone. Microwave drying for 5 minutes can fasten the drying time and permit early manipulation of plaster and stone models.

Introduction:

Gypsum products are used in several areas in the field of dentistry.
These materials must possess high mechanical properties (i.e. high compressive strength) in order to withstand the force when used to be clinically useful. For example, die stones are mainly used for crown and bridge restoration. Gypsum products are also used in casting gold alloys and soldering. Gypsum products can be used as mould materials for fabrication of removable appliance (i.e. orthodontic appliance)[1-3]. Gypsum products are based chemically on calcium sulfate hemihydrate $CaSo_4\ 2H_2O$

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and be unique in nature[4]. For this reason, these materials can be modified by using chemicals to improve the physical and mechanical properties. The addition of chemicals reduces the amount of water required when mixing leading to enhance the mechanical properties[5]. The strength of gypsum products can be affected by several factors including the water / powder ratio, additives, mixing time, etc[6-8] . For example, a large amount of water relative to the powder leads to poor compressive strength. In addition, the additives such as gum arabic, ferric oxide, calcium oxide, and calcium carbonate have significantly enhanced the compressive strength of gypsum products [9-16]. Moreover, the pulverised stone and cured resin, which were considered as waste materials, can be used again to enhance the mechanical properties of improved dental stone[17]. Dental models must be completely dry before using by the dental technician. This process often takes a longer time. As a result, several techniques have been used to speed up the drying time. It was found that the microwave drying method has a significant influence on the compressive strength of Iraqi plaster and improved dental stone [17,18]. The aims of the current study were to evaluate the incorporation of some additives (i.e. cured resin , pulverised stone, pulverised plaster, and glass fibers) and drying method on compressive strength of plaster and stone. The null hypothesis imposed that there are no significant differences among all groups.

Materials and method:

Materials and Specimen groups

A total of 160 specimens were divided into 2 main groups depending on drying method; air and microwave techniques. Each group was subdivided into two main groups according to material utilized; dental plaster (Saffa, Jordan) and dental stone (Zhermack,Italy). For each material, we have 3 experimental groups and control with each group had 10 specimens. The control groups (unmodified) were used to compare the compressive strengths of both plaster and dental stone to experimental groups.

Additives for reinforcement

In this study, four different additives; cured resin particles (Spofadental,Czech Republic), pulverised stone (Zhermack,Italy), pulverised plaster (Saffa, Jordan) and glass fiber (fiber strength, SYNCA, Canada). These additives were weighed in an electronic balance and added at 1 % by weight to the dry powder before mixing with water[17].

Specimen preparation

A plastic cylinder (40 mm length and 20 mm diameter) was used to fabricate the specimens according to ANSI/ADA NO 25[19]. This pattern was duplicated via a silicone putty (Zhermack,Italy). Once the putty has completely set, the silicone mould was then split up into 2 pieces and the pattern was carefully removed as shown in Figure 1. The control specimen preparation started by mixing the powder with water according to the manufacturer instructions (100g/25 ml) and slowly poured under vibrator into the mould. Similar methodology was carried out for the preparation of experimental specimens with exception that the cured resin, glass fibers, pulverised plaster and pulverised stone were separately added at 1% by weight to the dry powder which mixed with water, and slowly poured into the mould[17].

Drying method

For air drying technique, eighty specimens were left in air at 20 + 2 °C for 24 hours before testing. For microwave drying, the other 80 specimens were placed after two hours from mixing and kept inside a glass beaker (with 400 ml of water) to protect the electon tube of microwave. The beaker was positioned within microwave (Kenstar, Malaysia). In the present study, a low power of 400 Watts for 5 minutes was carried out as high power might generate more heat causing water loss, and subsequently shrinkage of specimens [17]. Following that, all specimens were ready for testing.

Compressive strength test

The compressive strength test was carried out on all specimens using a universal testing machine (Instron, Germany). The

load was applied on each specimen with a constant speed of 0.5 mm/min until fracture as shown in Figure 2. By the following formula: compressive strength = load (g) / surface area (3.14 cm^2), the resultant values represented the compressive strength ($gram/cm^2$ =MPa) [20].

Results:

In the current study, the data were analysed using the SPSS 16.1 software. Among all groups, the comparisons were recorded using ANOVA (Analysis of variance), Tukey HSD (Honestly ignificant Difference), and independent T tests with making into consideration the siginficant findings (*P=0.05*). The results of the study indicated that the compressive strength was significantly affected by the kind of additive utilised as demonstrated in Table 1 and Figure 3, there was a siginificant increase in the values of mean compressive strength for cured resin, pulverised plaster, pulverised stone and glass fiber specimens compared with control in all groups (dental plaster and dental stone). The multiple comparison test (Tukey) revealed the ability of additives to increase the compressive strength of plaster and stone as significant differences among all tested groups were observed ($P \leq 0.001$) as illustrated in Tables 2 and 3. For drying method, the independent T test confirmed statistically no significant differences were observed between the two drying methods *(P*>0.05*)* as illustrated the Figure 4.

Discussion

Various studies have been conducted on gypsum products to enhance their mechanical properties. The incorporation of various additives (i.e. gum arabic, calcium oxide, etc) could decrease the amount of water when mixing leading to improved the mechanical properties of gypsdum products [21,22]. In the current study, glass fibers, cured resin, pulverised plaster and stone have been used to indicate whether there is an improvement in the mechanical properties of gypsum products or not. According to the literature, the use of glass fibers has a great influence on mechanical properties of gypsum products[23]. In the current study, It was found that the use of glass fibers has a significant effect on compressive strength of gypsum products (Table 1). In addition, the use of cured resin and pulverised plaster or stone in this study showed that the plaster and stone specimens were more resistant to force compared with control group. These results agrees with a study conducted by Vijayaraghavan *et al,*[17] which confirmed that there is a significant improvement in the compressive strength of all specimens after using cured resin and pulverised plaster or stone. The cured resin has the ability to reduce the brittleness and improve the scratches during the sculpting process. The use of cured resin at 1% by weight in this study as a greater concentration would reduce the setting time of hemihydrates [24]. On the other hand, that the use of pulverised plaster and stone gives a more dense arrangement of crystals leading to increased hardness and compressive strength [25]. Regardless of the type of additive used, the current results are consistent with the study carried out by Hatem *et al*. [9], which revealed that the use of calcium oxide and gum arabic enhanced reasonably the compressive strength of dental stone. Besides, the results of the study showed no significant difference between the two drying methods. The microwave specimens, however, had the highest values. These findings are in accordance with Vijayaraghavan *et al.*[17] which indicated no significant differences were observed between the methods of drying. The current results, on the other hand, opposes the results conducted by Hassan and Mohammed[26] study, which found significant differences between the two drying methods with higher values for air dried specimens. The differences between the current study and Hassan and Mohammed[26] study could be related either to use different methodology, different materials or to the elapsed time following samples casting. The null hypothesis was refused since significant differences were observed among all groups. Further studies will be required to investigate other properties (i.e accuracy

of details and dimensional stability) of gypsum products.

Conclusion:

The present study concluded the following points-:

1.The glass fibers have a significant effect on compressive strength of gypsum products.

2. The cured resin and pulverised particles can be added at 1 % by weight to enhance the mechanical properties of dental plaster and dental stone.

3.Drying the plaster and stone specimens in the microwave for 5 minutes can fasten the drying time and permit early manipulation of models.

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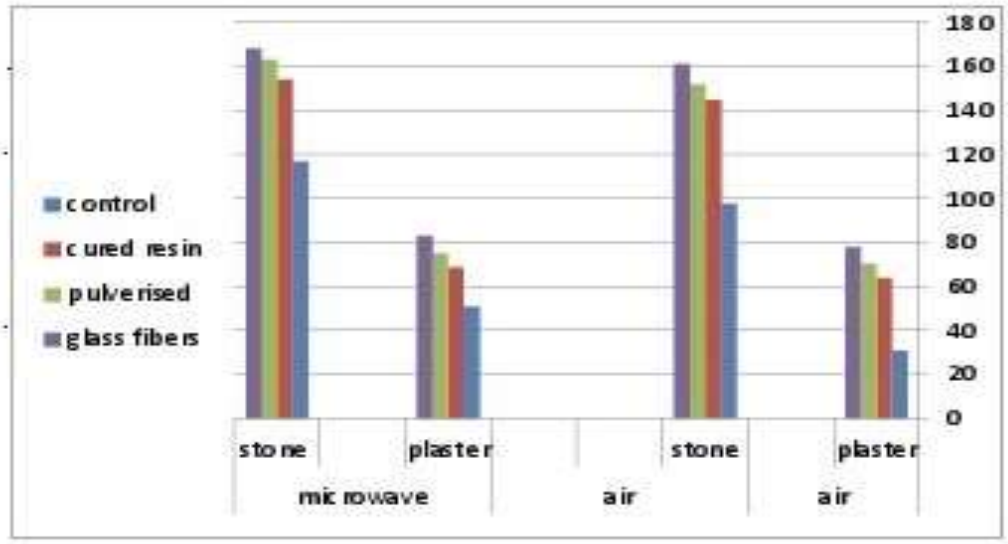
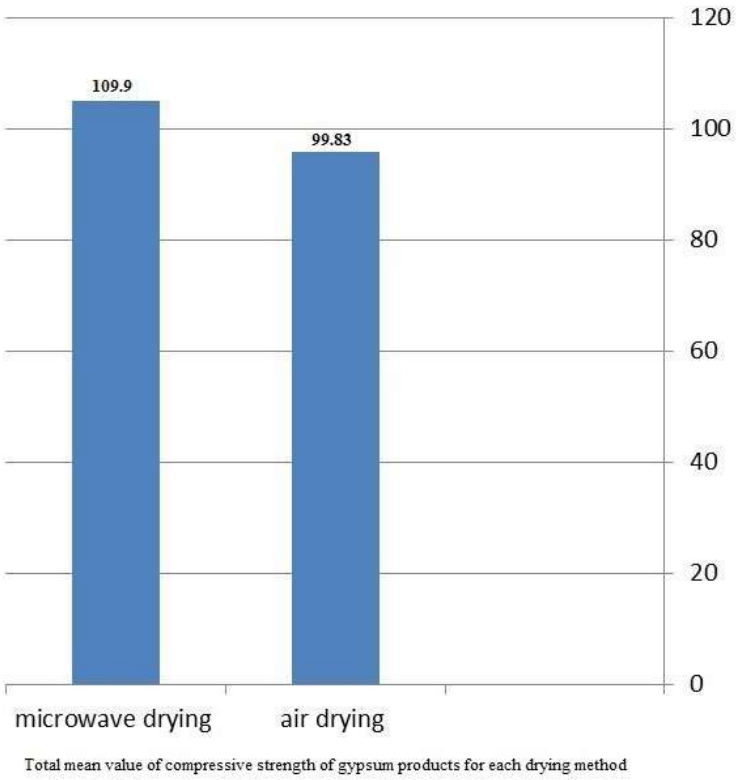
Fig. (1):Plastic pattern, plaster sample and silicone putty mould

Fig. (2): Specimen under test



mean values of compressive strength for all groups

Fig. (3): Mean values of compressive strength for all groups



Total mean value of compressive strength of gypsum products for each drying method

Fig.(4): Mean values of compressive strength of gypsum products for each drying method

Table (1): Mean and standard deviation of all studied groups

Drying method	Material	Groups	Mean	Standard deviation
Air	Plaster	Control	30.76	2.83
		Cured resin	63.87	3.06
		Pulverised plaster	70.44	3.53
		Fibers	77.91	2.82
	Stone	Control	97.82	3.10
		Cured resin	144.84	2.94
		Pulverised stone	151.96	3.15
		Fibers	161.07	2.93
Microwave	plaster	Control	50.87	3.04
		Cured resin	68.64	2.70
		Pulverised plaster	75.00	3.15
		Fibers	82.94	2.89
	stone	Control	116.95	2.98
		Cured resin	153.90	3.11
		Pulverised stone	163.30	3.04
		Fibers	167.98	3.07

Table (2): Comparison between two groups of additives for microwave drying

Mirowave drying						
Plaster	Control Cured resin	0.000*	Control Pulverised plaster	0.000*	Control Fibers	0.000*
	Cured resin Fibers	0.000*	Pulverised plaster Fibers	0.000*	Cured resin Pulverised plaster	0.000*
Stone	Control Cured resin	0.000*	Control Pulverised stone	0.000*	Control Fibers	0.000*
	Cured resin Fibers	0.000*	Pulverised stone Fibers	0.000*	Cured resin Pulverised stone	0.000*

H.S*: highly significant ($P \leq 0.001$)

Table 3. Comparison between two groups of additives for air drying

Air drying						
Plaster	Control Cured resin	0.000*	Control Pulverised plaster	0.000*	Control Fibers	0.000*
	Cured resin Fibers	0.000*	Pulverised plaster Fibers	0.003	Cured resin Pulverised plaster	0.001
Stone	Control Cured resin	0.000*	Control pulverised stone	0.000*	Control Fibers	0.000*
	Cured resin Fibers	0.000*	Pulverised stone Fibers	0.001*	Cured resin Pulverised stone	0.000*

H.S*: highly significant ($P \leq 0.001$)

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