The Surface Hardness Measurement of Stone and Improved Die Stone After the Addition of a Mixture of Chemical Additives with Different Proportion

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ABSTRACT

Background: Incorporation of chemical additives has long been a technique used to improve properties of the gypsum products. The purpose of this work was to study the effects of adding a combination of gum Arabic and calcium hydroxide to a type III dental stone and type IV improved die stone with different proportion. The effect on water/powder ratio, and surface hardness was determined.

Material and method: Both material stone and die stone were blended with two proportion of additives so that each material was mixed twice but with different proportion of gum Arabic (0.1% and 0.2%) and calcium hydroxide (0.5 % and 0.3%). Data for hardness were subjected to two-way analysis of variance.

Results: The results revealed that the chemical additives were reduced the water requirements of gypsum products so that the reduction of water lead to increase the density of mixture that sets harder. For type III dental stone the additives significantly improved the surface hardness, while for type IV improved die stone the surface hardness was not enhanced except it was designed to be mixed at low water/powder ratio, and in some instances a reduction in hardness was observed, especially at the most reduced water / powder ratio (0.18).

Keyword: Surface hardness, die stone **(J Bagh Coll Dentistry 2018; 30(1):1-4)**

INTRODUCTION

Dental gypsum products are the most widely used among cast and die materials because of ease of manipulation, reproduction of details, acceptable compressive strength and hardness, compatibility with different impression materials, and lower cost [1,2]. It is important that cast and die materials have adequate surface hardness to resist abrasion when a wax pattern is being carved [3]. Improved die stone is harder and stronger than type III stone materials because they can be mixed at a typical water/powder ratio of 0.21 compared with a water/powder ratio of 0.30. Lower water/powder ratio give rise to denser gypsum that sets harder.

The incorporation of chemical additives to produce gypsum product with superior mechanical properties has been a development of great commercial and technical importance for many years. One method of improving impression surface properties is to use gypsum hardening solution that are applied to the set material [4,5]. Gypsum can also be hardened by epoxy resin impregnation [6]. An alternative method of hardening is to soak the impression in an aqueous solution of a potassium salt before preparation of a gypsum cast [7]. Studies to reduce the water requirement of dental gypsum products have been conducted to produce set materials with less porosity, greater density, and improved mechanical properties. Lignosulfonates were found to achieve these results [8]. Zakaria et al. [9] reported some benefit from using two agents, a "liquid dispersing agent" and a "microcrystalline additive,". The addition of a mixture of gum Arabic and calcium oxide or hydroxide to type II and III gypsum have also demonstrated the same effect [10]. More recent Khalid et al. [11] evaluated a casts poured in gypsum with gum Arabic and calcium hydroxide additives. Others [12,13] used both gum Arabic and calcium hydroxide additives to modify the hemihydrate powder before mixing with chemical disinfectant. Strength and hardness of gypsum products is directly related to the density of the set mass, because it is mixed with the least amount of water [14]. Shen et al. proved that by adding K_2SO_4, in a proportion of 1.0 % the strength of plaster increased, because it created spherical crystals [15]. Also Khalid et al. concluded that, modifying dental stone powder with gum Arabic and calcium hydroxide additives (before mixing at the manufacturers recommended liquid/powder ratio), improved the wetting behavior of the mixed materials in some cases, but results were not consistent, and other study investigates some new commercial, resin reinforce gypsum products [16,17]. Many authors recommended the addition of some chemical to improve the mechanical properties [18], or by using various proportion of plaster to stone [19], and soaking the powder with water for 1 minute before mixing [20].

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In this study two different proportion of chemical additives were added to stone and die stone to improve the surface hardness and reduce the water requirement of gypsum products.

MATERIALS AND METHODS

One batch of a type III dental stone (Zhermack-elite model, Type 3 model dental stone-thixotropic) and one batch of type IV improved die stone (Silky-Rock, type IV Die Material-Violet-Whip Mix, Louisville, Kentucky) were used. Both materials, stone and die stone were blended with two proportion of additives, so that each material was mixed twice but with different proportion and as follows:

1- Calcium sulfate (stone and die stone) mixed with 0.1 % gum Arabic and 0.5% calcium hydroxide.
2- Calcium sulfate (stone and die stone) mixed with 0.2% gum Arabic and 0.3% calcium hydroxide.

The mixing procedures were conducted by using a vacuum mixture according to ADA specification. The gypsum material was mixed with distilled water at the manufacturers recommended water/powder ratio for unmodified materials (control group). For the modified materials the water/powder ratio were determined according to the consistency test which was carried out by placed the gypsum material in a cylinder with a 10 mm inside diameter. A 20 mm length of material was extruded into a glass plate on vibrator, the material was vibrated at high speed for 5 seconds, during which, and time the material flowed to form circular mass of material. For type III dental stone at the manufacturers water/powder ratio of 0.30 the mean diameter was 20mm and for the improved die stone at a water/powder ratio of 0.21 the mean diameter was the same. Six group of stone and die stone specimens (designated ST1 to ST3 and IDS1 to IDS3*) were formulated (Table1). For the preparation of hardness specimens, the mix was gently vibrated into the mold and glass plates were placed at each end of the mold to insure flat parallel faces. Four samples were prepared under each condition and four readings were taken. Hardness was measured on Vickers scale by applying a 2000 gf for 10 seconds on a diamond indenter by use of a microhardness tester. The data were evaluated with two-way analysis of variance (ANOVA) to determine any significance.

*ST= Stone.
IDS=Improved die stone.

RESULTS

The results were compared with the unmodified specimens (control group). Some mixture of gum Arabic and calcium hydroxide were found to reduce the water requirement of dental stone and improved die stone. Table 1 shows the type III dental stone and type IV improved die stone formulations by using chemical additives as shown in table 1.

For the consistency testing it was found that with additives the type III dental stone at water/powder ratios of 0.26 and 0.24 had similar consistencies to unmodified material at a water/powder ratio of 0.30ml. Likewise with similar amounts of additives to the improved die stone, reduction in the water/powder ratio from 0.21 to 0.19 and 0.18 were obtained.

The hardness data are recorded in table 2, the benefit of using the additives was observed with the ratio of 0.2% gum Arabic and 0.3% calcium hydroxide for type III dental stone and not for the type IV improved die stone, in which w/p ratio were reduced to 0.18. For type III dental stone the result revealed that for all cases the data were significantly different from one another for each pair, except for the comparison between the water/powder ratio of 0.24 without additives and the water/powder ratio of 0.26 with additives. While for the improved die stone the Vickers hardness values was not enhanced by the additives at the most reduced water/powder ratio of 0.18 (62.37 without additives and 60.25 with additives).

DISCUSSION

In relation to the type III dental Stone, it was shown that an increase in hardness value was obtained when the water/powder ratio was reduced gradually. However, this improvement was achieved even without the inclusion of the additives, but the mixture was thick that made the manipulation difficult. With additives a considerable reduction in water requirement were achieved regardless of the type of gypsum material. This result is much closer to the findings of Sanad et al. [8] who also found that the reduction in water/powder ratio produces a much denser mass of set material with less excess water content. The benefit of such a reduction in water requirement is that the production of denser gypsum casts leads to significant improvements in mechanical properties (Table 2). However, in the presence of powder modifying additives, a marked improvement in hardness was evident, possibly due to the adhesive action of gum Arabic additives among surface dehydrate crystals. This

improvement was also observed in the results of Sanad et al [10] and Alsadi et al [18]. It was probably enhanced by the regularity and condensation of surface crystals. The hardness values for the modified dental stone was significantly better than unmodified materials, while for the improved die stone were not greatly enhanced by the additives, this result agree in certain aspect with the result of adding some additives that Alsadi and Combe [11] presented in a previous study. When they concluded that dental cast materials with superior surface properties can be produced by a simple change of formulation. The results show that the hardness of improved die stone has a non-significant difference at ($p > 0.05$) between state of with and without additives. While significant difference at ($p < 0.05$) with type III dental stone material.

The difference in behavior between the two types of gypsum products may be explained by the fact that the improved die stone is designed to be mixed at water/powder ratio of 0.21, which is close to the theoretic limit. A water/powder ratio of 0.18, if this could be achieved to give a smooth mix, would only have enough water to completely hydrate the calcium sulfate hemihydrate.

Conclusion

By the use of a combination of gum Arabic and calcium hydroxide additives a considerable reduction in water requirement were achieved regardless of the type of gypsum material. The type III dental stones improved in term of surface hardness, while the improved die stone's hardness was not greatly enhanced by the additives, and in some instances a reduction in hardness was observed, especially at the most reduced water/powder ratio.

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Table 1: Type III dental stone and Type IV improved die stone formulation.

Material	Calcium Sulfate (g)	Gum Arabic (g)	Calcium Hydroxide(g)	W/p ratio
ST1	100	-	-	0.30
ST2	100	0.1 %	0.5%	0.26
ST3	100	0.2%	0.3%	0.24
IDSl	100	-	-	0.21
IDS2	100	0.1%	0.5%	0.19
IDS3	100	0.2%	0.3 %	0.18

Table 2: Vickers hardness data (mean ± SD, n=4).

Material	W/P	Average of hardness without additives Mean ± SD	Average of hardness with additives Mean ± SD	C.S By + test
ST1	0.30	17.58 ± 1.4	23.78 ± 1.2	S
ST2	0.26	16.29 ± 0.44	24.69 ± 0.38	S
ST3	0.24	26.32 ± 0.32	33.56 ± 0.61	S
IDS1	0.21	57.82 ± 0.82	61.17 ± 1.1	S
IDS2	0.19	53.09 ± 0.9	57.84 ± 0.53	S
IDS3	0.18	62.73 ± 0.4	60.25 ± 0.87	NS

NS : Non – Sigificant at p > 0.05
S: Significant at p < 0.05

Table 3: ANOVA values for type III dental stone – hardness.

S.O.V	D.F	Sum of squares	Mean square	*F* value	*P* value
Between groups	2	4226	2113	5.28	0.05
Within groups	33	13215	400.45		
Total	35	17441	498.3		

Table 4: ANOVA values for improved die stone – hardness.

S.O.V	D.F	Sum of squares	Mean square	*F* value	*P* value
Between groups	2	6314	3157	8.4	0.05
Within groups	33	12405	375.9		
Total	35	18719	534.8		