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Comparison of Some Properties between Commercially Available Gypsum Products

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gypsum products, dimensional stability, surface hardness, reproduction of details, surface porosity.

Abstract

Gypsum models are often used in dental healthcare, and there is an increased need for manipulation of master casts in extensive reconstructions requiring a material that is not easily abraded or damaged with dimensional accuracy, accurate reproduction of details, and the use of a voids free surface master model. This study was conducted to compare between commercially available type III and type IV dental stones in some of their properties.

Four groups were compared: Zhermack and Geastone of Type III dental stone, and Zhermack and Bluejey of Type IV improved dental stone. Ten specimens were fabricated for each material from a rubber ring with dimensions of 20mm height and 30mm diameter. Dimensional stability, reproduction of details, surface porosity, and surface hardness were evaluated for the different gypsum products.

Results of this study show that for the dimensional stability there was an increase in dimension more than that of the test block and was only highly significant for groups Z3 and Z4. The surface hardness for groups Z3 and Z4 was significant higher than groups G3 and B4 in all of time intervals except after 24h for groups Z4 and B4 this was insignificant. Surface porosity test and reproduction of details test, both revealed no significant difference between the test groups.

As conclusion the Zhermack dental stone products, type III & IV, showed higher surface hardness than Zeus dental stone products, type III & IV (Geastone and Bluejey). On the other hand we found that Zeus dental stone products showed good dimensional stability than the Zhermack dental stone products. All stone products provided similar scores for details reproduction, and were similar in relation to surface porosity.

Introduction

Gypsum products probably serve the dental profession as one of the main materials used in dentistry. Replica models of patient's teeth and oral soft tissue are often used in dentistry to enable documentation, treatment planning, and fabrication of prosthetic constructions or dental appliances[1,2].Dental gypsum is available in five forms (ADA types I-V), defined as "impression plaster", "model plaster", "dental stone", "high-strength dental stone", and "high-strength and high expansion dental stone"[3,4,5].During the setting reaction of model plaster, dental stone, and high-strength dental stone, water is driven out of the dihydrate gypsum to form the hemihydrates. All forms of calcium sulfate hemihydrates

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react with water to form the dihydrate (Gypsum) as shown in the following reaction:

$$(CaSo_4.\ ½\ H_2O+1½H_2O \longrightarrow CaSo_4.2\ H_2O)^{(1,4)}.$$

Dimensional stability of cast and die materials has been the subject of several in vitro investigations over the past decades with some conflicting findings[6]. Dimensionally accurate die materials are critical to the fit of the fixed prosthesis. The benefits of an accurate die material become even more important as the span and complexity of the prosthesis increases[7].One of the main requirements of gypsum products is accurate reproduction of details, and in order to construct accurate casts or models, it is extremely important to know the details reproduction of impression materials. Inaccuracies in the replication process will ultimately have an adverse effect on the adaptation of the final restoration[1,8].Voids on the surface of a cast or die affect the accuracy of a cast restoration. This is due to the formation of air bubbles in the mixed dental stone, and the technique of pouring the impression[9,10].The nature of porosity can be divided into: Air bubble porosity and micro porosity. Air bubble porosity is caused by the incorporation of air while the gypsum and water are being mixed. The extent of this form of porosity depends on the mixing method, on water/powder ratio, and on whether there was any evacuation of air during or immediately after mixing. On the other hand, microporosity is due the reaction product of setting reaction. The degree of microporosity increases with water/powder ratio and with the setting expansion of the gypsum product[11].Other major desirable characteristics of die materials include surface hardness. For many dental applications, it would be useful to develop gypsum products having improved mechanical properties. Strength, surface hardness, and good resistance to abrasion are all important considerations[12]. Dies used to fabricate dental prostheses are often made from gypsum materials to produce a hard, accurate surface on which to make the wax pattern for the prosthesis. These materials are often thought to differ significantly in their hardness[13].It has been found possible to produce gypsum products with superior mechanical properties by reducing the water requirement of the water/powder ratio[14].The purpose of this investigation was to compare the dimensional stability, surface details, surface porosity, and surface hardness after (1h, 2h, 24h and 1week) of 4 commercially available types of dental gypsum products.

Material and Methods

Included in this study were the following commercially available gypsum products as follows:

1. Zhermack (group Z3) Type III dental stone [Zhermack, 45021 Badia Polesine (Rovigo), Italy].
2. Geastone (group G3) Type III dental stone [Geastone, Zeus sri Loc. Tamburino 58036 Roccastrada (GR), Italy].
3. Zhermack (group Z4) Type IV improved dental stone [Zhermack, 45021 Badia Polesine (Rovigo), Italy].
4. Bluejey (group B4) Type IV improved dental stone [Bluejey, Zeus sri Loc. Tamburino 58036 Roccastrada (GR), Italy].

Preparation of the Gypsum Specimens

A rubber ring with dimensions of 20mm height and 30mm diameter was used for making the stone samples. An Electronic balance and a measuring cylinder were both used for measuring the dental stone and distilled water. Hand mixing with constant manual vibration was carried out according to the manufacturer’s instructions. All the stone samples were removed from the rubber ring after one hour of mixing.Ten specimens for each test were prepared and used for dimensional stability, details reproduction, surface porosity, and surface hardness after at one hour, two hours, 24 hours, and one week.

Evaluation of Dimensional Accuracy and Surface Detail Reproduction

A test block certified according to ADA specification No. 19[15]. was used to make specimens for evaluation of reproduction of details and dimensional accuracy. The test block had one horizontal line scribed at depth of 0.05mm and 60°angle, for the evaluation of surface details, and two vertically parallel crossing lines with a fixed predetermined length, for the determination of dimensional stability.
Before the fabrication of each specimen, the surface of the test block was cleaned with cotton gauze soaked in alcohol, rinsed with distilled water, and dried. The test block was fixed under the ring and the gypsum product was poured with constant vibration into the ring and then covered with a glass slab.The ten samples made for each gypsum product were examined after one hour by one examiner under low angle light at x20 magnification with a stereozoom microscope (Biovision NTX-3C) for the entirety of 0.05mm wide line. The examination was repeated after two weeks by the same examiner to confirm the values.The ANSI/ADA specification No.25 requires that gypsum products reproduce a line of 0.05mm in width[3]. The reproduction of a 0.05mm wide line on the test samples was used for the surface detail evaluation, scored as follows:

Score1:Well-defined,sharp,and ontinuous.
Score2:Continuous and clear for more than half the length.
Score3:The continuity and clearness was less than half the length.
Score4:The ridge failed to be reproduced along the length of the sample.

Evaluation of the Surface Porosity

The ten samples were poured with constant vibration in the rubber ring, previously mentioned, with a glass slab under it and then the poured gypsum product in the ring was covered with a glass slab. Testing of the surface porosity was performed by evaluating a circular area of 4mm diameter in the center of each sample. Within this circular area visual examination was done under low angle light at x20 magnification with a stereozoom microscope (Biovision NTX-3C), and the total number of pores was counted. The examination was repeated after two weeks by the same examiner to confirm the values.

Evaluation of the Surface Hardness

The stone samples for each material were prepared in the same manner as that of the samples of the surface porosity test. For the surface hardness test there were four groups arranged according to the different time intervals of testing; one hour, two hours, 24 hours and one week after mixing and each group consisted of ten samples for each material. All specimens were tested in Brinell Hardness Tester, with a tungsten carbide ball of (4mm) in diameter with 40 Kg load that was maintained for 30 seconds on the surface of the samples. The resulted hardness value represented by the Brinell Hardness Number (BHN) was calculated from the following formula:

$$BHN = \frac{L}{\frac{\pi D}{2\left(D - \sqrt{D^2 + d^2}\right)}} = \frac{Kg}{mm^2}$$

L: Load in Kg, D: Diameter of ball = 4mm, d: diameter of indentation in mm.
Statistical analysis included descriptive statistics, Independent T-test, and Chi-square test to determine the significance of the relationship between the numbers and scores.

Results

The dimensional stability values for all the test groups showed an increase in dimensions from that of the test block, but this increase was highly significant only for the samples of groups Z3 and Z4, as seen in table (1), and figure (1). On the other hand, groups G3 and B4 showed a slight increase that was insignificant. Thus, the increase in dimensions for group Z3 was by 0.624%, group Z4 by 0.466%, group G3 by 0.162%, and group B4 by0.046%.Comparison of the reproduction of details between group G3 and Z3, and between group B4 and Z4 revealed no significant difference, in which the percentage were 40% score 1 and 60% score 2 for G3, 60% score 1 and 40% score 2 for B4. While Z3 and Z4 showed the same percentage; 90% score 1 and 10% score 2, as seen in table(2) and figure (2). No samples registered a score of 3 or 4. The means for surface porosity count for all the test groups showed no significant difference statistically although some had a slightly greater count, as seen in table (3), and figure (3). The surface hardness after one hour, two hours, 24 hours, and one week for group Z3 was greater statistically than for group G3, for all time intervals and this was highly significant, as seen in table(4), and figure (4). The comparison of surface hardness between groups Z4 and B4 after one hour, two hours, and one week showed a highly significant difference in which the values for Z4 were greater than those for B4. After 24h, both groups showed no significant difference, as seen in table (5), and figure (5).

Discussion

The dimensional stability test revealed that groups Z3 and Z4 showed a setting expansion which was highly significant. Unlike the samples of group G3 and group B4 which were statistically insignificant from that of the test block. This may be due to the difference of gypsum setting expansion which can produce differences in die size[16,17,18].The setting expansion was represented by an increase in dimensions by percent for Z3 (0.624%), Z4 (0.466%), G3 (0.162%), and B4 (0.046%). All these values were greater than the requirements for setting expansion of gypsum products of ADA specification No.25[19].except for group B4 which had a lower setting expansion, as shown in table (1). The increase in dimensions of the set gypsum product samples was in agreement with the results of Duke et al[20]. & Shereen et al[21]. who concluded that gypsum materials exhibited a setting expansion and this was true for Z3 and Z4 but disagreed with the results of group G3 and B4.All the gypsum products used in this research had the same capacity for surface details reproduction. As the surface of the gypsum products was slightly porous, minute surface details which were less than 20μm were not readily reproduced. However, macroscopic surface details were very accurately reproduced, although air bubbles entrapment could contribute to the less of surface details[19] .This could come in agreement with the results of this research as the surface porosity for all the test groups showed no significant difference. This was also in disagreement with the results of Derrien and Menn[22].who both demonstrated that dental stone was porous and did not reproduce details smaller than 20μm.Voids formation on the surface of the dental cast may be due to air bubbles entrapped during mixing and pouring of the gypsum product[9,10].The conventional pouring technique consists of introducing the vacuum mixed stone from the periphery of the impression, and vibrating it downward along the walls of the impression[23]. The results of the studies conducted by Mazzetto et al[23].And Schelb[10].Both showed that the two different techniques of spatulation, manual spatulation and vacuum mechanical spatulation, did not influence the superficial smoothness of the models significantly. Also, to the knowledge of the researchers most of the Iraqi dentists mix the gypsum products manually so manual spatulation was employed in this research.It was noticed from the outcome of this research that the surface porosity of all the test groups was insignificantly different (table 3) and this could be due to the fact that all the samples were obtained from the same manual mixing and pouring of the gypsum mixture.The surface hardness for type III dental stone for group Z3 was higher significantly than group G3 after one hour, two hours, 24 hours, and one week. The same findings were true for surface hardness after one hour, two hours, and one week between type IV dental stone groups B4 and Z4 in which the later had significantly higher surface hardness. This could be due to mixing time, water temperature, as well as storage conditions, which are factors that might influence the hardness of final gypsum body[24]. It could also be discussed whether or not the water composition affected the hardness[25]. In this study the mixing time, water temperature, and storage conditions were all standardized and the same for all the test groups, and the water used was also the same for all test groups. The surface hardness increased for both groups Z3 and Z4 as shown by the increase in percentage of setting expansion more than groups G3 and B4 and this could be due to formation of more crystals in relation to increased setting expansion giving a harder surface, as stated by Lautenschlager & Corbin[26].who proposed that the expansion of dental stone was caused by the impingement of growing crystals producing an outward thrust.In a summary, the comparision between Zhermack dental stone, and Zeus dental stone type III and IV revealed an increase in the surface hardness for Zhermack than Zeus products. While Zeus products where more dimensionally stable than Zhermack products. All of the test groups showed no deffernce in reproduction of details and surface porosity.

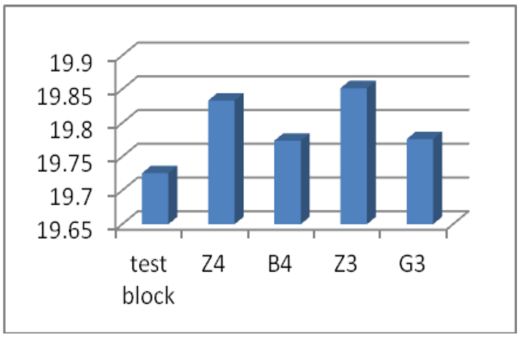

Fig.(1):- dimensional stability of the different gypsum products.

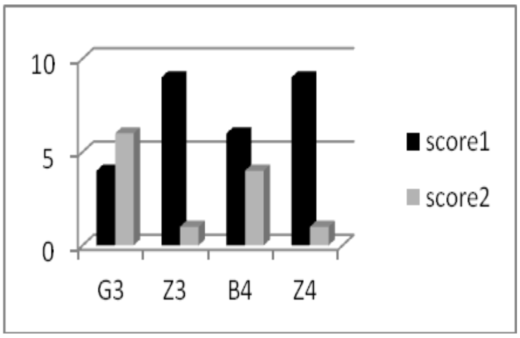

Fig.(2):- Reproduction of details scores.

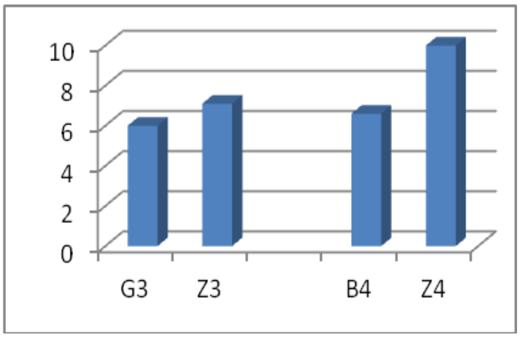

Fig.(3):- Surface Porosity count for the different gypsum products.

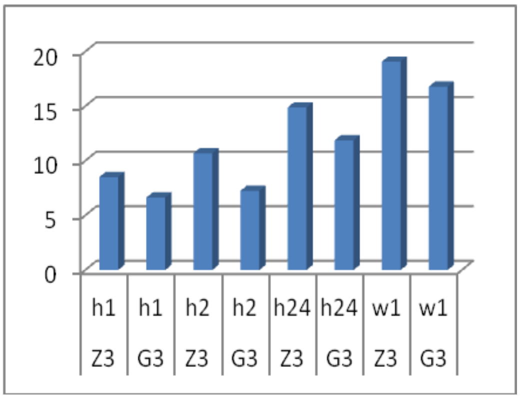

Fig.(4):- Surface hardness for G3-Z3.

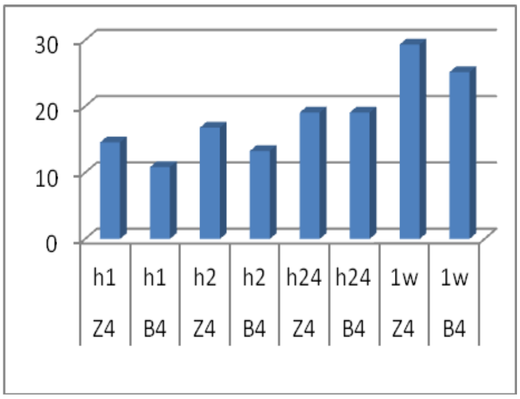

Fig.(5):- Surface hardness for B4-Z4.

Table (1):- t-test for dimensional stability of the different gypsum products.

	Mean diff.	Std. Dev.	t	df	Sig.
G 3- Test block	-.03185	.0724	-1.391	9	.198
Z 3- Test block	-.12295	.0675	-5.758	9	.000(**)
B 4- Test block	-0.0096	.0186	-.518	9	.617
Z 4- Test block	-.09238	.0649	-4.501	9	.001(**)

* Significant p<. 05, ** Highly significant p< .01

Table (2):- Chi-square test for Reproduction of details.

	Chi-square	df	Asymp. Sig.
G3-Z3	1.667	1	0.19
B4-Z4	0.476	1	0.490

* Significant p<. 05, ** Highly significant p< .01

Table(3):- t-test for Surface Porosity count for the different gypsum products.

	Mean	Std. Dev.	t	df	Sig.
G3	6.0000	3.55903	-.751	18	.462
Z3	7.1000	2.96086			
B4	6.6	2.83627	-1.454	12.013	.172
Z4	10	6.83130			

* Significant p<. 05, ** Highly significant p< .01

Table (4):- t-test for Surface hardness G3-Z3.

	Mean Diff.	t	df	Sig.
1h	-1.93217	-4.303	18	.000(**)
2h	-3.02623	-6.333	14.591	.000(**)
24h	-3.26968	-4.949	18	.000(**)
1week	-3.23154	-3.280	18	.004(**)

* Significant p<. 05, ** Highly significant p< .01

Table(5):- t-test for Surface hardness B4-Z4.

	Mean Diff.	t	df	Sig.
1h	-3.92795	-4.614	11.436	.001(**)
2h	-3.91371	-4.312	11.376	.001(**)
24h	-1.03323	-1.114	18	.280
1week	-4.55705	-3.724	18	.002(**)

* Significant p<. 05, ** Highly significant p< .01

Table (6):- ADA specification No.25. for setting expansion of gypsum materials.

Gypsum products	Type	Setting expansions (%)
Plaster	II	0.20-0.30
Stone	III	0.08-0.10
High-strength stone	IV	0.05-0.07

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