Dentistry
ISSN: 2161-1122

Denizoglu et al., Dentistry 2015, 5:6
DOI: 10.4172/2161-1122.1000308

Research Article Open Access

The Linear Setting Expansions of the Dental Stone and Whose Initial Setting Times

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Abstract

Objectives: The aim of this study is to compare the setting time, which is shortened by using various different slurry water concentrations with the changes of setting expansions of plaster and stones.

Materials and Methods: In this study, two improved dental stones were used to fabricate master casts and dies. The tested fabrications were BegoStone, Moldano and plaster of paris.

Three specimens per stone were fabricated to be 100 mm in length and triangular in cross-section (33×50×33 mm).

Mixing was performed with distilled water, tap water and 2% and 16% slurry water. The mixtures were poured into an electronic expansion-measuring device, and setting expansion values were continuously measured and recorded for 24 hours.

Results: The mixtures were poured into an electronic expansion-measuring device, and setting expansion values were continuously measured and recorded for 24 hours. In the first five hour period not only did the initial setting time shorten, the amount of the expansion also increased to a considerable level.

Conclusions: Within the context of this study, it was observed that not only did the initial setting time shorten but the amount of the expansion also increased to a pronounce level in the first 24 hours when slurry water was used. Unexpected results may be faced when indirect dental restorations are done within this period of time.

Clinical Relevance: Dental gypsum products must have specific setting times and setting expansion. The setting rate for gypsum materials can be accelerated by various methods.

Keywords: Linear setting expansions; Model stone; Slurry water

Introduction

Dental stone and plaster are referred to as the interval materials used in the fabrication of prosthesis as a last product such as, complete denture, fixed partial denture or removable orthodontic appliance in practical dentistry. A dental cast or die is plaster or stone which is poured into an impression made for a negative reproduction. With this procedure, exact copies of hard and soft tissues are obtained. These products must be constant and have resistant to dimensional changes, correctness and dimension [1,2].

The main difference between the basic powders lies with the variations in the sizes, shapes and the porosity of particles produced by the manufacture, with different methods [3].

According to their types, plaster and stones show different dimensional changes during and after their setting [2,4]. Plaster or dental stones, which sometime show high rate of setting expansion, are preferred for the purpose of compensating the expected polymerization shrinkage states of the materials used as resultant production [5,6].

The setting rate for gypsum materials can be accelerated by various methods, such as typical additions of NaCl or KCl, K_2SO_4, or slurry water [7].

According to its use, dental gypsum products, plaster, stone and die stone must have specific setting times, expansion and characteristics [8]. The final setting procedure must be completed before the die obtained by using gypsum products and models are taken out of the impression, otherwise physically insufficient die and models may be obtained [9].

The purpose of this study is to compare the setting time, which is shortened by using various different slurry water concentrations with the changes of setting expansions of the plaster of paris and two other brands of dental stones with normal time duration by using distilled and tap water. The null hypothesis tested was that there is shortened setting time of dental stones by using various different slurry water concentrations.

Methodology

In this study, two improved dental stones were used to fabricate master casts and dies. The tested fabrications were BegoStone (Bego Bremer, Goldschlägerei Wilh. Herbst GmbH and Co. Wilhelm Herbst-Strabe 1 D 28359 Bremen Germany), Moldano (Heraeus Kulzer GmbH and Co. KG Gruner Weg 11 D-63450 Hanau Germany) and plaster of paris (BMT, PK 121 Sivas, Turkey). Together with the manufacturer's values, the setting time and setting expansion amounts of the dental stone and plaster used in this study are shown in Table 1.

Distilled water (Hinckley and Schmidt, Chicago, Ill. USA), tap water and slurry water prepared with the volume ratio of 16% and 2% were used as liquid for mixing the dental stone and plaster. In order

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Received April 14, 2015; **Accepted** May 14, 2015; **Published** May 19, 2015

Citation: Denizoglu S, Yanıkoglu N, Baydas B (2015) The Linear Setting Expansions of the Dental Stone and Whose Initial Setting Times. Dentistry 5: 308. doi:10.4172/2161-1122.1000308

Stone/Plaster	Type	Setting time (Minute)	Setting expansion (%)
BegoStone (die stone)	IV	15	0,09
Moldano (model stone)	IV	15	0,2
Plaster of paris	II	30	0,2

Table 1: Setting period and expansion amounts for dental stone and plaster.

to prepare the slurry water, the slurry cast, taken from the model trimming device during the model correction, was accumulated inside the scaled container (Simax Kavalier stable). In order to decompose into its fractions, the addition of water was performed in terms of the height of the cast particles, within the whole volume in which 2% of it precipitated on the base of the container and the obtained suspension was kept on the stable plate for about a week, parallel to the ground.

Samples which were prepared with distilled water were conformed to ADA Specification 25 [4] and International Standards Organization (ISO) 6873M [10] for measurement of the expansion of dental gypsum products. Three specimens per stone were fabricated to be 100 mm in length and triangular in cross-section (33×50×33 mm). A standardized technique that conformed to the manufacturers' instructions and recommendations was used during the fabrication of each specimen except the use of slurry water and tap water. The temperature of the liquids was held at the temperature of 22°C, and the room temperature was maintained at 22°C ± 2°C. No other standardized conditions (such as humidity) were established during specimen preparation and testing. Every attempt was made to evaluate stone expansion in a realistic clinical and laboratory setting.

Mixing procedures were performed in accordance with the manufacturers' specific recommendations. Water was placed in a bowl, and the gypsum powder was added to the water. The powder and water mixture process to be controlled by increased setting time control was performed by hand and was immediately poured into a V-shaped expansion device (EMI 300, SAM Präzisiontechnik GmbH, Munich, Germany) with hand vibration as shown in Figure 1.

The V-shaped expansion tray was isolated with Vaseline in order to prevent the adhesion of the gypsum. The expansion device was connected to a computer (hp-Compaq, desktop) through a serial interface (S-box 9 MUX, SAM Präzisiontechnik GmbH, Munich, Germany). The setting expansion of each specimen was measured continuously for 24 hours and was automatically recorded. The raw expansion data was expressed in millimeters. However, the recorded data was evaluated as a direct percentage because the length of the prepared sample was 100 mm.

The first starting time duration of the expansion was taken to be as the moment of the beginning of the setting of the powder and water mixture. It was also observed in all the tests performed that the first thermal variation occurred coincided with time in which the expansion had started.

Statistical analysis

The descriptive analysis of the data, mean and standard deviations together with the other kind of statistical analysis were performed with the help of the SPSS software program (SPSS Inc., Chicago USA). The effects of the dental stone, plaster and liquids used on the setting expansion and initial setting time and the interactions among them were evaluated with the multivariate analysis of variance (ANOVA). The differences among the groups were compared with each other by using the post hoc test (Bonferroni) (Table 2).

Results

The data of the mean and standard deviations of the expansion amounts for the time durations of 2 hours and 24 hours together with the initial setting time of the three different cast types used in the study, mixed with four different type of water are given in Figures 2 and 3.

The multiple comparison test (Bonferroni) between the used three types of gypsum products is given in Table 3 and the results of the multiple comparison tests for which the effect of the liquids on the initial setting time are given in Table 4.

The multiple comparison tests of the gypsum products which were mixed with different liquids after 0.5, 1, 2, 5 and 24 hours are shown in Table 5.

According to the multivariate (ANOVA) test results the initial setting time of a gypsum type and the expansion amounts for the times of 0.5, 1, 2, 5 and 24 hours are found to be statistically significant ($p<0.001$). In terms of the used liquid type, the initial setting time of a

Figure 1: V-shaped expansion device and serial interface.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Stone/ Plaster	IS	2383200,000	2	1191600,000	700,941	***
	1/2H	4,685E-02	2	2,343E-02	496,059	***
	1H	3,867E-02	2	1,934E-02	348,050	***
	2H	2,967E-02	2	1,484E-02	333,812	***
	5H	2,734E-02	2	1,367E-02	378,538	***
	24H	2,181E-02	2	1,090E-02	261,667	***
Liquid	IS	7378400,000	3	2459466,667	1446,745	***
	1/2H	2,867E-02	3	9,558E-03	202,412	***
	1H	1,019E-02	3	3,396E-03	61,133	***
	2H	9,189E-03	3	3,063E-03	68,917	***
	5H	9,564E-03	3	3,188E-03	88,282	***
	24H	5,386E-03	3	1,795E-03	43,089	***
Stone/ Plaster * Liquid	IS	2192800,000	6	365466,667	214,980	***
	1/2H	2,262E-02	6	3,769E-03	79,824	***
	1H	6,261E-03	6	1,044E-03	18,783	***
	2H	6,661E-03	6	1,110E-03	24,979	***
	5H	6,994E-03	6	1,166E-03	32,282	***
	24H	1,039E-03	6	1,731E-04	4,156	*
***p<0.001, *p<0.05						

Table 2: Multivariate test.

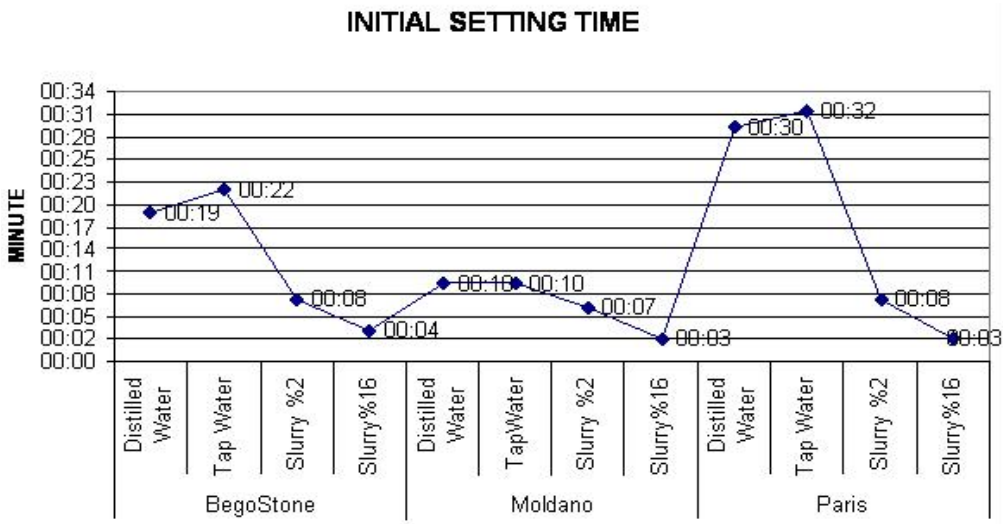

Figure 2: Average expansion amounts and standard deviations of 120 minute and 24 hour and initial setting time of plasters mixed with various liquids.

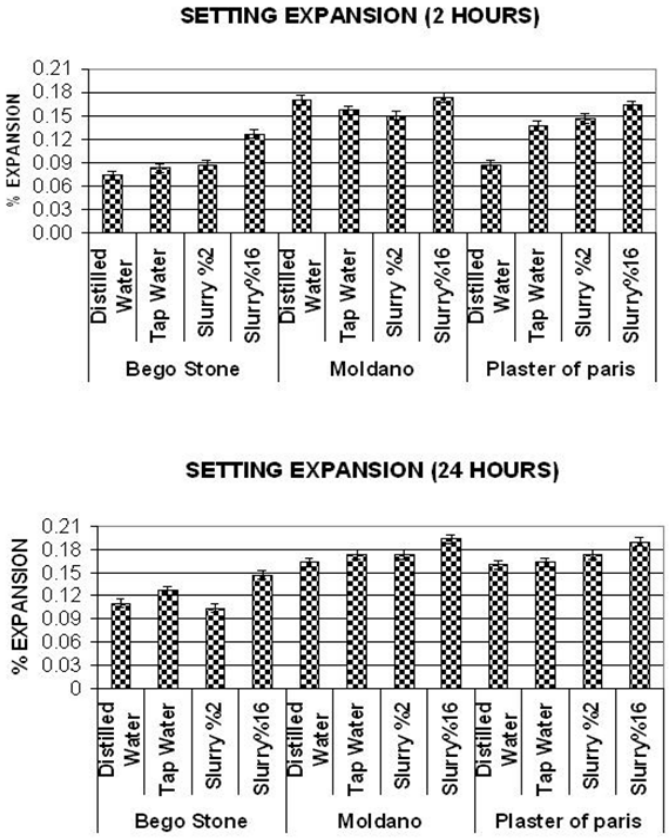

Figure 3: Mean expansion amounts and standard deviations of 2 and 24 hours.

cast type and the expansion amounts for the times of 0.5, 1, 2, 5 and 24 hours are also found to be statistically significant ($p<0.001$). In the gypsum type of liquid interactions in between the expansion amounts after the time of 1.5, 1,2 and 5 hours a significance was found in the level of $p<0.001$, whereas after 24 hours among the expansion amounts the significance found to be about in the level of $p<0.05$.

According to the Bonferroni test results, when the expansion amounts were compared within the first hour, there was no significant difference between the 2% slurry and distilled water, on the other hand, there was a statistically significant difference in the level of $p<0.05$ between the tap water and the distilled water and this significance for the other liquids was of about in the level of $p<0.001$. In the second

Dependent Variable	(I) Stone/plaster	(J) Stone/plaster	Mean Difference (I-J)	Sig.
Initial Setting	BegoStone	Moldano	0,05	***
	Plaster	BegoStone	0,05	***
	Plaster	Moldano	0,10	***
1/2 hour expansion	Moldano	BegoStone	8,000E-02	***
	Moldano	Plaster	7,250E-02	***
	Plaster	BegoStone	7,500E-03	*
1 hour expansion	Moldano	BegoStone	8,000E-02	***
	Moldano	Plaster	3,417E-02	***
	Plaster	BegoStone	4,583E-02	***
2 hours expansion	Moldano	BegoStone	7,000E-02	***
	Moldano	Plaster	2,917E-02	***
	Plaster	BegoStone	4,083E-02	***
5hours expansion	Moldano	BegoStone	6,667E-02	***
	Moldano	Plaster	2,417E-02	***
	Plaster	BegoStone	4,250E-02	***
24 hours expansion	Moldano	BegoStone	5,417E-02	***
	Moldano	Plaster	4,167E-03	
	Plaster	BegoStone	5,000E-02	***

***p<0.001, *p<0.05

Table 3: Multiple comparisons (Bonferroni) test for model stones and plaster of paris.

Dependent Variable	(I) LIKIT	(J) LIKIT	Mean Difference (I-J)	Sig.
Initial setting	Distilled Water	Slurry% 2	0:11	***
	Distilled Water	Slurry% 16	0:15	***
	Tap Water	Distilled Water	0:01	***
	Tap Water	Slurry% 2	0:13	***
	Tap Water	Slurry% 16	0:17	***
	Slurry %2	Slurry% 16	0:03	***

***p<0.001

Table 4: Multiple comparison (Bonferroni) test results of effects to the setting time of liquids used in cast mixtures.

hour, while there was no pronounced difference between the expansion amounts of the 2% slurry together with tap water, the differences between the other liquids is significantly high (p<0.001). In the fifth hour, where the difference between the values of the 2% slurry and the tap water is not significant, the differences among the other liquids are found to be highly significant (p<0.001). For the values at the end of the 24 hours, while the difference between the 2% slurry-tap water and the 2% slurry-distilled water are statistically not significant, the difference between the tap and distilled water are found to be statistically significant in the level of p<0.05, and the difference between the 16% slurry and the other liquids are found to be statistically significant in the level of p<0.001.

When considering the initial setting time, the results were obtained such that the effect of all the liquids on the initial setting times were of very significant level (p<0.001). In same way, the BegoStone and the plaster of paris, which were mixed with distilled water hardened in a shorter initial setting time compared to that of mixed with the tap water. For the Moldano, there was no observed difference from the point of initial setting time for distilled and tap water. The initial setting process starts after eight minutes when the 2% slurry water is mixed with the BegoStone, while on the other hand the time duration was reduced to four minutes for the 16% slurry water. For the Moldano, while 2% slurry water shortened the setting time about three minutes compared to the distilled water and tap water, the 16% slurry water shortened the beginning of the setting time about three minutes.

According to the multiple comparison tests for the gypsum products, in 0.5 hour, while more setting expansion was observed in the level of p<0.05 in the plaster of paris significantly compared to the BegoStone, the difference in between the expansion amounts of the Moldano and the plaster of paris at the end of 24 hours was found to be in the level of no importance.

When considering the importance levels of the general mean values, the initial setting of the BegoStone is short in the significance level compared to the Moldano and the initial setting time for plaster of paris is found to be shorter compared to both of the BegoStone and Moldano. For the other time periods, (1, 2 and 5) the differences in between the expansion amounts of the gypsum types used in the study are statistically in the significant level (p<0.001).

Discussion

For the fabrication of restoration, which is used comfortably by the patient and without causing difficulties for the dentists, casts and dies must include some specific requirements such as dimensional accuracy and long-term stability. The results of this study show that when the die, model stone or plaster of paris are mixed with slurry water, the mixture changes the initial setting time and also increases the amount of expansion in a pronounced ratio within the first 5 hours, however, at the end of 24 hours these values converge to the same values. In addition, this procedure of shortening the initial setting time actually means that the accuracy of the model or die is changed within the first

Time/Expansion	(I) Liquid	(J) Liquid	Mean Difference (I-J)	Sig.
1/2 hour	Distilled Water	Tap Water	4,444E-03	
	Slurry% 2	Distilled Water	4,000E-02	***
	Slurry% 2	Tap Water	4,444E-02	***
	Slurry% 16	distilled water	6,333E-02	***
	Slurry% 16	Tap Water	6,778E-02	***
	Slurry% 16	Slurry% 2	2,333E-02	***
1 hour	Tap Water	Distilled Water	1,111E-02	*
	Slurry% 2	Distilled Water	1,667E-02	***
	Slurry% 2	Tap Water	5,556E-03	
	Slurry% 16	Distilled Water	4,556E-02	***
	Slurry% 16	Tap Water	3,444E-02	***
	Slurry% 16	Slurry% 2	2,889E-02	***
2 hours	Tap Water	Distilled Water	1,556E-02	***
	Slurry% 2	Distilled Water	1,778E-02	***
	Slurry% 2	Tap Water	2,222E-03	
	Slurry% 16	Distilled Water	4,444E-02	***
	Slurry% 16	Tap Water	2,889E-02	***
	Slurry% 16	Slurry% 2	2,667E-02	***
5 hours	Tap Water	Distilled Water	2,111E-02	***
	Slurry% 2	Distilled Water	2,778E-02	***
	Slurry% 2	Tap Water	6,667E-03	
	Slurry% 16	Distilled Water	4,556E-02	***
	Slurry% 16	Tap Water	2,444E-02	***
	Slurry% 16	Slurry% 2	1,778E-02	***
24 hours	Tap Water	Distilled Water	1,000E-02	*
	Tap Water	Slurry% 2	4,444E-03	
	Slurry% 2	Distilled Water	5,556E-03	
	Slurry% 16	Distilled Water	3,222E-02	***
	Slurry% 16	Tap Water	2,222E-02	***
	Slurry% 16	Slurry% 2	2,667E-02	***

***p<0.001, *p<0.05

Table 5: Multiple Comparisons (Bonferroni) test results of expansions after setting time of 0.5, 1, 2, 5 and 24 hours.

24 hours. It is likely that prosthetic restorations fabricated during this time may cause unfitting or poor adaptations.

In this study, the water and powder ratio for every group are prepared according to the recommendations of the manufacturing company. For the process of spatulation, when the slurry water of 16% volume concentration is used, the hand and vacuum mixing procedure is not applied and the dental stones and plaster are mixed only by hand because the initial setting time is shortened too much.

In this study the initial setting time was taken into account as the setting time. In order to determine the initial setting time the beginning time of the first expansion was taken as reference and during this time the increase of the temperature together with the beginning of the exothermic reaction was controlled. This value was recorded as the initial setting time.

Winkler et al. [9] reported that if the setting gypsum is disturbed while developing microscopic structure may cause adverse affects and result in problems such as weakening, easily abraded or distorted casts. The SEM evaluation, setting expansion and X-ray diffraction can indicate changes which can occur at times after a clinically relevant set is obtained in the gypsum setting reaction.

Fraunhofer and Spiers [8] report that, as a convenient method for accelerating the setting rate of dental stone, addition of KCl and dry powder will accelerate the setting reaction but will have no effect on the strength of the final cast. DeCounter et al. [7] described the preparation of the slurry water and they stressed that this preparation was reliable at known concentrations.

The conflicted situation in between the true volumetric concentration, which occurs during the setting of the gypsum products and the typical final volumetric expansion that occurs after the setting time of the gypsums is explained with the pore formation inside the stone. Due to the disorder of the particle structure of the plaster of paris, the pore formation is high and for this reason the occurring expansion is too much. In other words, the irregular shapes of the particles prevent them from fitting firmly. Because of their particle characteristics, the alpha hemihydrate required less gauging water and was about two and half times stronger than that of the plaster [6].

When observing the parameters of this study, the expansion amount in the initial settings of the dental stone and plaster of paris increases when added to slurry water, however, once the 2 hours noted as final setting was completed there appeared a certain expansion but it was observed as more than 75% - 80% of the maximum expansion appeared during the first 2 hours. As Heshimati et al. [3] reported 22% and 71% of the total expansion formed in the first 2 hours for all the stones tested. Results showed that fundamentally all the test samples at the end of 96 hours completed their expansions, it was also reported that in regards to the final setting expansion term, discussion topic and the existing studies show parallelism.

Salloum [11] stated that the use of high expansion dental stone can be recommended as investing material to reduce the increase in occlusal vertical dimension that occurs after processing complete dentures.

De Cesero et al. [12] suggested that Surface roughness, compressive strength, and diametric tensile strength of of dental stone were assessed at 1 hour, 24 hours, and 7 days after pouring. Surface roughness, diametric tensile strength and compressive strength increased significantly with time after pouring.

Conclusions

The results within the limits of this study can be reported as:

- The plaster type and mixing liquid used has effects over the initial setting time and maximum expansion amount.
- BegoStone die material showed the lowest expansion compared to the others.
- Although the use of 16% of slurry water in plaster mixture decreased the initial setting time by a significant level, it increased the expansion amount at a great measure in the first 2 and 5 hours and with the expansion levels being close to one another at the end of the 24 hours, there was significant expansion level of the 16% slurry.
- At the end of 24 hours, 2% for BegoStone and the expansion amount between the slurry and distilled water did not change, however the initial setting time was reduced at a significant level.
- It was concluded that slurry water usage for Moldano cast stone material did not have much of an effect on expansion.

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