Original Article

Comparison of Physical Properties of an Iranian and a German Dental Stone Type IV According to ADA Specifications

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Abstract

Background and Aim: Dental stone type IV and V are predominantly used for construction of cast and die in fixed prosthodontics and must have some special properties. The aim of this study was to compare the three physical properties of an Iranian a German dental stone type IV.

Materials and Methods: In this experimental study, setting time, setting expansion and compressive strength properties were evaluated according to ADA specification No.25for Iranian Tara and German Gildand type IV dental stone. For setting time, setting expansion and compressive strength tests, Vicat apparatus, extensometer and universal testing machine were used, respectively. Data were compared to ADA specification No.25 for dental stone type IV and statistically analyzed using t-test with a 0.05 level of significance.

Results: Mean of setting expansion for Iranian and German dental stone were 0.024±0.011 and 0.0245±0.009, respectively and were within the limits of ADA specification and there was no statistically significant difference between them (p=0.966). Mean of setting time for Iranian and German dental stone were 44.5±0.70 and 17.29±0.41 and mean of compressive strength for Iranian and German dental stone were 16.17±0.97 and 20.15±1.96 and both specifications were not within the limits of ADA specification, but statistically significant differences were found between groups (p<0.001).

Conclusion: Iranian dental stone type IV could not fulfill 2 out of 3 tested ADA specification and modification of this stone is necessary for use in fixed prosthodontics laboratory processes.

Key Words: Calsium sulfate, Compressive strength, Physical properties

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Introduction

Gypsum products are widely used in dentistry and especially in prosthodontics [1]. Gypsum used in dentistry are a form of calcium sulfate hemihydrate ($CaSO_4.½H_2O$), which is classified into five types according to the American Dental Association (ADA) specification #25. Although these types have identical chemical formula, they pose different physical properties making each of them desirable for different purposes [2]. There are various properties that could be evaluated for dental stones, but according to ADA specification #25 five main properties are considered to assess dental stones which are as follow: setting time, fineness, setting expansion, compressive strength and consistency (Table 1).

Table 1. Properties of five types dental stones according to ADA

Type	Setting time (min)	Setting expansion at 2hours		Compressive strength (MPa)	Fineness		Testing consistency (mm)	Powder/water ratio
		Min %	Max %		passes 150µm %	sieves 75 µm %		
Type I(plaster, impression)	4±1	0/00	0/15	4	98	85	--	0/40-0/75
Type II(plaster, model)	12±4	0/00	0/30	9	98	90	30±3	0/45-0/50
Type III(dental stone)	12±4	0/00	0/20	21	98	90	30±3	0/28-0/30
Type IV(dental stone, high strength)	12±4	0/00	0/10	35	98	90	30±3	0/22-0/24
Type V(dental stone, high strength, high expansion)	12±4	0/01	0/30	49	98	90	30±3	0/18-0/22

Cast and die used for indirect casting technique must have specific properties in order to construct a favorable restoration which is especially more important for implant-supported restorations. Type IV and V dental stones are the most frequently used materials for fabrication of casts and dies, due to their perceived dimensional accuracy, low cost and ease of use [1,3-4]. There are some studies evaluating the physical properties of Iranian dental stones [5-7], but there is no study evaluating the physical properties of type IV Iranian dental stone. Therefore, the aim of this study was to compare three physical properties of one Iranian and one German type IV dental stone.

Materials and Methods

An Iranian dental stone type IV (Tara 250, Kheyzaran, Isfahan, Iran) and a German dental stone type IV (Gildand, Germany) were used in this experimental study. There was no analytical procedure for evaluating the sample size. Sample size, the way for preparing the samples and the condition of study were in accordance with ADA specification #25 and similar studies [5-11]. The environment with a temperature of 23±2ºC and a humidity of 50±10% was considered for all devices at least 15 hours before study.

Setting time was determined through already established methodology [8], using Vicat apparatus (Isfahan, Iran). This apparatus allowed the analysis of the setting time through the insertion of a metallic needle (1 mm diameter and 50 mm length) connected to a vertically mobile aluminum rod, under a total weight of 300g. A PVC cylinder with an internal diameter of 70 mm in top and 60 mm in bottom and height of 40mm was attached to a 100×100 mm glass plate. The plaster mass was mixed according to manufacturer's recommendations and shed into the cylinder with the aid of a vibrator (Whip mix Corp., Louisville, KY) and then placed under the Vicat apparatus. The needle was placed at a distance of 0.5 mm from the gypsum surface and abruptly set free 2 minutes before the mass lost its superficial luster, then sequential insertions were carried out every 15 seconds in different areas (standardized in quadrants), until the needle could not fully penetrate the mass any longer [12]. The time spent between the beginning of the mixing up to the point where the needle could not fully penetrate the mass any longer was measured with chronometer and setting time was

obtained [5,8]. This procedure was done twice for each dental stone.

Setting expansion was determined with expansion meter device constructed with impervious stainless steel. This device consisted of a V-shaped gutter fixed on a base and a mobile steel cube of 30±1 mm height and 200±10 g weight. The gutter shell thickness was 4 mm with an internal diameter of 30±1 mm and the angle of two opposite sides was 90 degrees. The gutter was open at one side and closed on the other side. A micrometer (Ericsson, Hudiksvall, Sweden) with 0.005 mm accuracy, fixed in place using aluminum bearing, was used to measure the expansion of plaster models. At the start of the test, the length between the moving part of steel cube and fixed part of V-shaped gutter was adjusted to 100±1 mm using a digital caliper (CCCP, Russia) with an accuracy of 0.05 mm. Then, the bottom of the V-shaped gutter was covered with a 0.1 mm thickness latex rubber dam (Dentorama, Stockholm, Sweden) to prevent limiting the expansion of gypsum [13]. Water and powder was mixed according to the manufacturer's instructions and shed into the V-Shaped gutter using the vibrator. The top of the gutter was covered with a sheet of latex rubber dam to prevent evaporation of water. The measurement was done one minute before setting and two hours after mixing and then the percentage of expansion was calculated according to following formula: $\frac{L_F - L_o}{L_o} \times 100$ where L_F was the final length and L_o was the initial length. This procedure was done twice for each dental stone.

To test compressive strength, 5 split stainless and impervious teflon cylinders with diameter of 20±0.2 mm and height of 40±0.4 mm were used. Initially, each teflon mold was placed on a glass plate and then water and powder was mixed according to the manufacturer's instructions and poured into the molds to be slightly overfilled using the vibrator. Before the surface of the mixture lost its luster, the second glass had been placed on it, so that the plaster surface was in contact with the glass. The molds was separated 45±1 minutes after mixing and samples were maintained in environment with 23±2 ºC temperature and 95±5% humidity. Any sample with porosity or fracture was excluded and new sample was prepared. Compressive strength test was done for all samples using universal testing machine (Instron Corp., Canton, Mass) with the force of 5±2 KN/min.

The data were statistically analyzed by SPSS software (Version 16) using t-test with 0.05 level of significance.

Results

The results were summarized in table 2. The mean of compressive strength of Iranian and German dental stones were 16.17±0.97 and 20.15±1.96 MPa, respectively which both were below the ADA standards. The mean compressive strength of two dental stone had statistically significant differences with each other and also with standard value (35MPa) using t-test ($p<0.001$). The mean of setting expansion of Iranian and German dental stones were 0.024±0.011% and 0.0245±0.009%, respectively which both were within the standard range (0-0.1%) and did not have any significant difference ($p=0.966$).

The mean of setting time of Iranian and German dental stones were 44.5±0.70 and 17.29±0.41 minutes, respectively. Although both values were more than the standard range (12±4 min), they had a statistically significant difference with each other ($p=0.001$).

Discussion

This study evaluated and compared setting time, setting expansion and compressive strength of two type IV dental stones.

Setting time

The time between start of mixing water and gypsum and completion of setting is called setting time [14]. This time should not be too short to get the appropriate time from technician, and not too long to waste the time of the laboratory personnel. This time is usually determined by one kind of penetration test and based on the ADA specification #25, this was determined with standard Vicat apparatus

Table 2. Statistical parameters of compressive strength, setting time and setting expansion of two studied dental stones

Plaster type	Property	Mean	Standard deviation	Minimum	Maximum
Compressive strength	Iranian plaster	16/17	0/97	14/97	18/15
	German plaster	20/15	1/96	17/83	24/84
Setting time	Iranian plaster	44/50	0/70	44/00	45/00
	German plaster	17/29	0/41	17/00	17/58
Setting expansion	Iranian plaster	0/024	0/011	0/016	0/032
	German plaster	0/0245	0/009	0/018	0/031

[2]. Setting time of different dental stones depend on factors such as water-powder ratio, time and speed of spatulation, temperature of water and environment, composition of water and powder, humidity of environment and the colloidal system (blood and saliva)[1,15]. Factors that reduce setting time are reduced water-powder ratio, increase time and speed of spatulation, adding Terra Alba, increase salt such as sodium chloride or 0.4 potassium sulfate and increase the temperature of water and environment from 23 ºC to 30 ºC. The opposite factors increase the setting time [15]. The results of this study showed that the mean of setting time of Iranian and German dental stones were 44.5±0.70 and 17.29±0.41 minutes, respectively, which were more than the ADA standard setting time (12±4 min) but the difference between Iranian dental stone and standard value was more than that of German dental stone. In the study of Lucas et al. the setting time of evaluated type IV dental stone was 10 minutes, which was within the normal range [11].

Von Fraunhafer and Spiers [16] and Brukl et al. [17] showed that increasing of 5% potassium chloride and potassium bicarbonate could lead to decreased setting time. Distilled water was used in this study because the minerals in the water of different regions could affect the setting time of gypsum.

Setting expansion

Expansion of gypsum during calcium sulfate hydration has been discussed [18-19] and the linear expansion of 0.06 to 0.5 is expected based on the gypsum composition and calcination process [1,20]. Based on ADA standards, setting expansion of type IV dental stones range from 0 to 0.1%. In this study setting expansion of Iranian and German dental stones were 0.024±0.011% and 0.0245 ± 0.009%, respectively which were within the acceptable range of ADA. In a study by Abdollah, setting expansion of a type IV dental stone was 0.013±0.012%, which was lower than the present data [10]. Dimensional stability of gypsum is of upmost importance in dental casts, because changes in cast surface lead to poor quality prostheses [21-28]. Success and adaptation of casting restorations depend on the dimensional accuracy, strength and ability to construct the details of materials used for die. The margin of restoration will be in more contact with tooth finish line, if the die has above qualities and the problems resulting from marginal discrepancies of restoration such as cement solution [21], caries [22-23], pulpal involvement [24]. Increase microbial plaque [25], change in subgingival flora [26] and gingival inflammation [27-28] will be reduced to a minimal level.

The accuracy and stability of master cast are the primary essentials in the manufacture of implant-supported prostheses. Marginal discrepancies and lack of seal in implant-supported prostheses increase the solution of cement in margin and can lead to eccentric forces applied to the implant [13].

Moreover, marginal discrepancies can lead to plastic deformation of the metal framework, porcelain detachment, fracture of implant system components and plaque accumulation, and thus plays an important role in the survival rate of prostheses [29-30].

If the gypsum used for making master cast had small expansion rate and was stable, the adaptation of restoration made through indirect technique could improve. Based on Anusavice [1] and O'Brien [20], chemicals that regulate the setting time of gypsum products, result in reduced expansion rate during calcium sulfate hydration. Hence, manufacturers can simultaneously control the setting time and decrease expansion rate by controlling the accelerators and inhibitors.

Factors which increase the setting expansion are reduced water-powder ratio, increase time and speed of spatulation, increase environment and water temperature from 23 ºC to 30 ºC and adding materials like sodium chloride. On the other hand, adding materials like potassium sulfate can lead to decrease in setting expansion of gypsum products [1,13,17,31]. Lauten Schlager and Corbin in a study about relationship between porosity and expansion of dental stones, concluded that with increasing water-powder ratio, the density and expansion of gypsum will decrease [32].

Compressive strength

Strength of type IV and V dental stones especially in complex fixed prostheses is very important. Strength is a basic requirement in fabrication of porcelain margins and where the need for fabrication of transfer coping exists. Therefore, use of type IV dental stone impregnated with resin or copper coated die will be recommended in this situation due to better dimensional stability and strengths compared with type IV and V dental stones [33-34]. However, the use of gypsum products is easier. Compressive strength of type IV dental stone must be at least 35 MPa according to ADA standards. In this study compressive strength of Iranian and German dental stones were 16.17±0.97 and 20.15±1.96 MPa, respectively, and both values showed significant differences with the standard value.

Compressive strength of one type IV dental stone in Abdullah study was 38.27±0.32 MPa which was within the ADA standard range [10]. Compressive strength of gypsum depends on water-powder ratio. Decreasing of this ratio leads to increase in compressive strength. Increase time and speed of spatulation and changes in environment and water temperature do not affect the compressive strength of gypsum [15,20].

Setting time and compressive strength of Iranian and German dental stones were not within an acceptable range and this is probably due to the high water-powder ratio. However, setting time and compressive strength values of German dental stones were closer to ADA specification #25. Consistency and ability to reconstruct details, which are two main features of ADA standards, were not evaluated in this study. Among three properties that were evaluated, Iranian dental stone failed to achieve two ADA standards.

Conclusion

1. Setting expansion of Iranian and German type IV dental stones were within the standard range of ADA.
2. Setting time and compressive strength of Iranian and German type IV dental stones were not within the standard range of ADA.
3. The differences between setting time and compressive strength values with standard values were higher for Iranian type IV dental stone when compared to German type IV dental stone.

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References

1- Anusavice KJ. Gypsum products. In: Phillips' science of dental materials. 11th ed. St. Louise: Mosby Elsevier; 2006, 255-81.

2- American National Standards/American Dental Association, Specification 25 for dental gypsum products. New York: American National Standards Institute; 2000, 244-53.

3- Winkler MM, Monaghan P, Gilbert JL, Lautenschlager EP. Comparison of four techniques for monitoring the setting kinetics of gypsum. J Prosthet Dent. 1998 May;79(5):532-6.

4- He LH, van Vuuren LJ, Planitz N, Swain MV. A micro-mechanical evaluation of the effects of die hardener on die stone. Dent Mater J. 2010 Aug; 29(4):433-7.

5- Golbidi F, Kiani M, Ebrahimi M. Evaluation of physical properties of Khodabandeloo plaster (An in vitro study). J Dent Sch Shahid Beheshti Med Sci Univ. 2006 Summer;24(2):235-42.

6- Golbidi F, Davari M. Evaluation of three phyisical properties of iranian stones. Dent J Islamic Ass of Dent. 2003 Jan;14(4):51-64.

7- Golbidi F. Davari M. Comparision of consistenscy and setting time of iranian and foreign stones. Res Med Sci. 2000 Autumn; 5(3):257-9.

8- American Dental Association: Specification No. 25 for dental gypsum products. In ADA: Guide to Dental Materials and Devices. Chicago: ADA; 1973, 253-8.

9- Duke P, Moore BK, Haug SP, Andres CJ. Study of the physical properties of type IV gypsum, resin-containing, and epoxy die materials. J Prosthet Dent. 2000 Apr;83(4):466-73.

10- Abdullah MA. Surface detail, compressive strength, and dimensional accuracy of gypsum casts after repeated immersion in hypochlorite solution. J Prosthet Dent. 2006 Jun;95(6):462-8.

11- Lucas MG, Arioli-Filho JN, Nogueira SS, Batista AU, Pereira Rde P. Effect of incorporation of disinfectant solutions on setting time, linear dimensional stability, and detail reproduction in dental stone casts. J Prosthod. 2009 Aug; 18(6):521-6.

12- Rudd KD, Morrow RM, Brown CE Jr, Powell JM, Rahe AJ. Comparison of effects of tap water and slurry water on gypsum casts. J Prosthet Dent. 1970 Nov;24(5):563-70.

13- Heshmati RH, Nagy WW, Wirth CG, Dhuru VB. Delayed linear expansion of improved dental stone. J Prosthet Dent. 2002 Jul;88(1):26-31.

14- Breault LG, Paul JR, Hondrum SO, Christensen LC. Die stone disinfection: Incorporation of sodium hypochlorite. J Prosthod. 1998 Mar; 7(1): 13-6.

15- Powers JM, Sakaguchi RL. Gypsum products and inverstment. In: Craig's restorative dental materials. 12th ed. St. Louis: Mosby Elsevier; 2006, 313-36.

16- Von Fraunhofer JA, Spiers RR. Strength testing of dental stone: A comparison of compressive, tensile, transverse, and shear strength tests. J Biomed Mater Res. 1983 Mar;17(2):293-9.

17- Brukl CE, McConnell RM, Norling BK, Collard SM. Influence of gauging water composition on dental stone expansion and setting time. J Prosthet Dent. 1984 Feb;51(2):218-23.

18- Scaranelo RM, Bombonatti PE, Rister RP, Bombonatti R, Bombonatti JF. Influência de soluções desinfetantes cloradas no tempo e na expansão de presa de dois tipos de gesso. Rev Odont de Araç. 2004 Jun-Jul;25(1):44-8.

19- Twomey JO, Abdelaziz KM, Combe EC, Anderson DL. Calcium hypochlorite as a disinfecting additive for dental stone. J Prosthet Dent. 2003 Sep; 90(3):282-8.

20-O'Brien WJ. Gypsum products. In: Dental materials and their selection. 4th ed. Chicago: Quintessence; 2008, 38-61.

21-Jacobs MS, Windeler AS. An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent. 1991 Mar; 65(3): 436-42.

22-Phillips RW, Swartz ML, Lund MS, Moore BK, Vickery J. In vivo disintegration of luting cements. J Am Dent Assoc. 1987 Apr; 114(4):489-92.

23-Preston JD. Rational approach to tooth preparation for ceramo-metal restorations. Dent Clin North Am. 1977 Oct;21(4):683-98.

24-Goldman M, Laosonthorn P, White RR. Microleakage–full crowns and the dental pulp. J Endod. 1992 Oct; 18(10):473-5.
25-Khu CH, King NM, Lee AM, Yiu CK, Wei SH. A pilot study of the marginal adaptation and surface morphology of glass-cermet cements. Quintessence Int. 1996 Jul;27(7):493-501.
26-Lang NP, Kiel RA, Anderhalden K. Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins. J Clin Periodontol. 1983 Nov; 10(6):563-78.
27-Schwartz NL, Whitsett LD, Berry TG, Stewart JL. Unserviceable crowns and fixed partial dentures: Life-span and causes for loss of serviceability. J Am Dent Assoc. 1970 Dec; 81(6):1395-401.
28-Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: Length of service and reasons for replacement. J Prosthet Dent. 1986 Oct;56(4):416-21.
29-Castillo-de-Oyagüe R, Sánchez-Turrión A, López-Lozano JF, Albaladejo A, Torres-Lagares D, Montero J, et al. Vertical misfit of laser-sintered and vacuum-cast implant-supported crown copings luted with definitive and temporary luting agents. Oral Med Oral Patol Oral Cir Bucal. 2012 Jul 1; 17 (4):e610-7.
30-Beuer F, Aggstaller H, Edelhoff D, Gernet W, Sorensen J. Marginal and internal fits of fixed dental prostheses zirconia retainers. Dent Mater. 2009 Jan; 25(1):94-102.
31-Mahler DB, Ady AB. An explanation for the hygroscopic setting expansion of dental gypsum products. J Dent Res. 1960 May-Jun;39(3):578-89.
32-Lautenschlager EP, Corbin F. Investigation on the expansion of dental stone. J Dent Res. 1969 Mar-Apr; 48(2):206-10.
33-Ragain JC, Grosko ML, Raj M, Ryan TN, Johnston WM. Detail reproduction, contact angles, and die hardness of elastomeric impression and gypsum die material combinations. Int J Prosthodont. 2000 May-Jun;13(3):214-20.
34-Aramouni P, Millstein P. A comparison of the accuracy of two removable die systems with intact working casts. Int J Prosthodont. 1993 Nov-Dec; 6 (6):533-9.