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THE EFFECT OF POSTPOURING TIME ON TENSILE STRENGTH, SURFACE ROUGHNESS AND COMPRESSIVE STRENGTH OF TYPE IV DENTAL STONE: AN IN VITRO STUDY

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ABSTRACT

A wide variety of materials are used to fabricate dental casts for fixed dental prosthesis, of which Type IV dental stones are commonly used because of its superior physical and mechanical properties. The principal requisites for Type IV dental stones commonly known as die materials are its strength, hardness, abrasion resistance and minimum setting expansion. The strength of die stone is generally expressed in terms of compressive and diametric tensile strength. Another mechanical property is surface roughness, which is influenced by the reproduction of impression material. The time between the pouring and removal of the gypsum cast from impression is termed as postpouring time, which has a major influence on physical and mechanical properties of dental cast. Moreover different commercial brands also exhibit distinct mechanical behaviour.

INTRODUCTION

Dental stone is versatile and important for the production of precise casts that represent clinical situations. [1] An ideal die material should demonstrate high strength, superior abrasion resistance, and ability to reproduce the details of the impression, high dimensional stability, and good colour contrast with impression and pattern materials. Traditionally, gypsum products obtained by wet calcinations of the gypsum are most widely used for this purpose. These materials are easily available with suitable manipulative characteristics making them attractive for use in day-to-day practice. [2] With numerous dental gypsum products available, dentists can be confused about which product will meet the clinical needs. The type IV American Dental Association (ADA)-approved die stones offer a variety of information about compressive strength as it may relate to surface hardness. A harder die stone, because it is more resistant to abrasion is theoretically a superior material. [3] The point of discussion, when using dental stone materials, relies upon the final setting time to use in clinical and laboratorial procedures, because mechanical properties alter as time passes accordingly to the literature previously described. [4]

Gypsum materials are chosen as a die material for the reason that is easy manipulation, economic disposition compatibility and their passion towards most impression materials. [5] Die materials play an important role during the fabrication of indirect dental restorations and prostheses. Indirect method of fabrication of inlays, crowns and bridges demand die materials that are of the highest quality with respect to accuracy and strength. [6] Successful die materials should have good strength and hardness to withstand normal laboratory and clinical handling. [3] Gypsum products are the most commonly used material to pour the impressions due to their versatile nature. Stone Type IV is a modified α-hemihydrate which is obtained by calcination of gypsum in calcium chloride solution and has very dense and cubic-shaped particles. They have a great strength, hardness, and resistance to abrasion, while their setting expansion is low. As a result, they are suitable for preparing die. [8] The postpouring time (the time between the pouring and removal of the dental stone cast from the impressions) affects the mechanical properties of the stone.

Type IV dental stone casts should be manipulated 24 hours after pouring to minimize the risks of fracture, cracks, and abrasion because the compressive and diametric tensile strength will be increased. [4] In this study, comparison of surface roughness, compressive strength and tensile strength according to postpouring time is done and also comparison between four different commercial brands of type IV dental stone is also done. This helps us to conclude which is a better type IV dental stone to use in our day to day practice. The purpose of this study was evaluate and compare influence of postpouring time of Type IV dental stone on its surface roughness, compressive strength and diametric tensile strength. The null hypothesis tested was that postpouring has no effect on the mechanical properties tested.

MATERIALS AND METHOD

Sample size calculation

Applied formula

$$N = \frac{(Z\alpha/2 + Z\beta)2 \times 2(\sigma)2}{d2}$$

A total of 288 specimens were prepared from four commercial brands of dental stones with 72 specimens from each brand.(Elite stone – Zhermack, Kalrock – Kalabhai, Moldastone - Heraeus Kulzer, GC Fuji rock) These 72 samples were divided into 24 samples each for compressive strength, diametric tensile strength and surface roughness. Each of these 24 samples are again subdivided into group of 8 each measured after 1 hour, 24 hours and 7 days' time intervals.(postpouring time intervals) The materials used in study are described in Table I, together with their manufacturers, classifications, and proportions.

Table I. Description of materials used

Sl no:	Product name	Manufacturers	Batch No.	Powder - Water Ratio	Mixing Time
1	GC FUJIROCK	GC EUROPE	1811224	1:5	60 Sec
2	ELITE ROCK	ZHERMACK	295649	1:5	60 Sec

3	HERA OCTASUPERROCK	KULZER	4952772	1:5	60 Sec
4	KALROCK	KALABHAI	190903	1:5	60 Sec

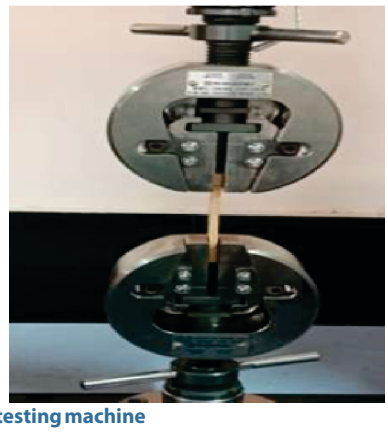
Figure 1 Type IV die stone materials used

The four brands of type IV dental stone used in this study were measured using a digital weighing machine. Distilled water was measured with a glass pipette of 10 ml. Mixing was performed with a water powder ratio of 1:5 with the help of vaccum mixing machine according to the manufactures recommendations. The mix was poured under vibration into respective molds.

For measurement of surface roughness and compressive strength the mix was poured into preformed square shaped mold of measurement 2cm. The preformed molds were made of silicone material .For measurement of diametric tensile strength a rectangular shaped mold was used, which was custom made with a dimension of 5cm length, 1cm width and 0.5cm thickness.

A total of 96 specimens from four brands of type IV dental stone with 24 specimens from each brand were used to measure surface roughness, compressive strength and tensile strength. One hour after pouring, the specimens were removed from the molds. Thereafter, the specimens were analyzed under stereoscopic microscope. Those with voids and cracks were eliminated from the study. The approved specimens were divided into 1-hour, 24-hour and 7-day groups containing 8 samples each. The 1- hour specimens were tested immediately and the 24-hour and 7-day specimens were stored at normal room temperature and tested accordingly. The surface roughness of each specimen was measured using a surface profilometre (Mitutoyo SJ 410) and was noted manually. The compressive strength of each specimen was measured using a universal testing machine with a cross head speed of 1mm/min and was noted using computer software (UTM Software,TRAPEZIUMX). The tensile strength of each specimen was measured using a universal testing machine with a cross head speed of 0.5mm/min and was noted using computer software (UTM Software, TRAPEZIUMX). After the required storage time the surface roughness, tensile strength and compressive strength of remaining specimens were also calculated.

Surface profilometre



Universal testing machine

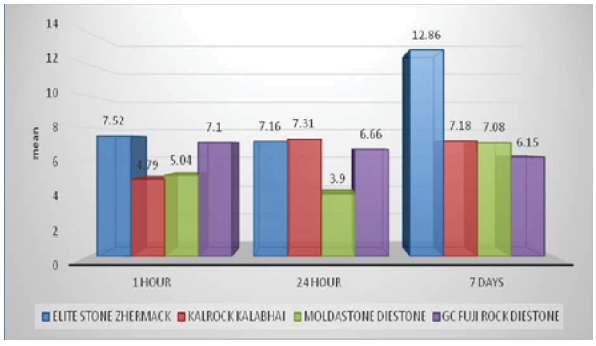
RESULTS

The measured data were tabulated and subjected to statistical analysis using SPSS Statistics Version 20 for Windows (IBM,Chicago,IL). Mean and standard deviation of each group was calculated and ANOVA followed by Tukey's post hoc analysis was done. P value was determined to identify the statistical significance and the significance level was set at P≤ 0.05.

Table 2: Comparison of COMPRESSIVE STRENGTH (MPa) means according to postpouring time and dental stone type

Duration	ELITE STONE ZHERMACK	KALROCK KALABHAI	MOLDASTONE DIESTONE	GC FUJI ROCK DIESTONE	P value
1 hour	7.52(4.82)	4.79(2.86)	5.04(1.42)	7.10(0.83)	0.16
24 hour	7.16(2.76)a	7.31(1.85)b	3.90(2.01)abc	6.66(1.19)c	0.007*
7 days	12.86(4.48)abc	7.18(1.43)a	7.08(1.38)b	6.15(0.71)c	<0.001**

* Significant, **Highly significant One way ANOVA; Tukeys post hoc test analysis; Same alphabets indicate significant difference across groups



Graph 1: Comparison of COMPRESSIVE STRENGTH means according to postpouring time and dental stone type

Comparing the compressive strength mean according to postpouring time and the brand of dental stone that was used. It was seen that according to one way ANOVA; Tukeys post hoc test analysis significant difference was seen across groups. The compressive strength was highly significant 7 days after the pouring of the mold. It is said to be highly significant because the P value was <0.001.It was seen to be statistically significant 24 hours after pouring (Pvalue 0.007).

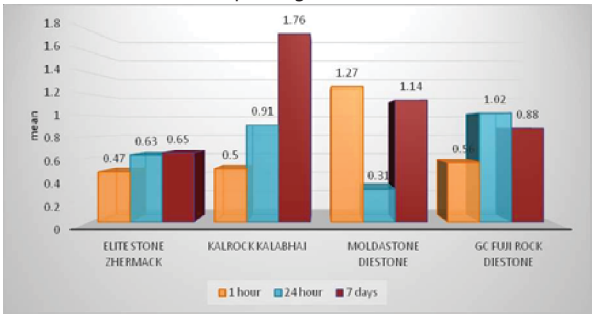
One hour after pouring the compressive strength seems not significant. From this it was also clear that maximum compressive strength was shown by Elite stone Zhermack 7 days after pouring and least compressive strength was shown by Moldastone 24 hours after pouring.

Table 3: Comparison of TENSILE STENGTH (MPa) means according to postpouring time and dental stone type

Duration	ELITE STONE ZHERMACK	KALROCK KALABHAI	MOLDASTONE DIESTONE	GC FUJI ROCK DIESTONE	P value
1 hour	0.47(0.11)a	0.50(0.08)b	1.27(0.64)abc	0.56(0.10)c	<0.001**
24 hour	0.63 (0.11)ab	0.91 (0.22)c	0.31 (0.09)acd	1.02 (0.54)bd	<0.001**
7 days	0.65 (0.16)ab	1.76 (0.39)acd	1.14 (0.59)bc	0.88 (0.18)d	<0.001**

* Significant, **Highly significant One way ANOVA; Tukeys post hoc test analysis; Same alphabets indicate significant difference across groups

Comparing the Tensile strength mean according to postpouring time and the brand of dental stone that is used. It was seen that according to one way ANOVA; Tukeys post hoc test analysis significant difference was seen across groups. The tensile strength was seen to be significant one hour, 24 hours and 7 days after pouring of the mold.It is said to be significant because the p value was<0.001. There was no much difference in significance when comparing the tensile strength of different brands of dental stone poured according to different postpouring time. From this it is also clear that maximum tensile strength was shown by Kalrock kalabhai stone 7 days after pouring and least tensile strength was shown by Moldastone 24 hours after pouring.

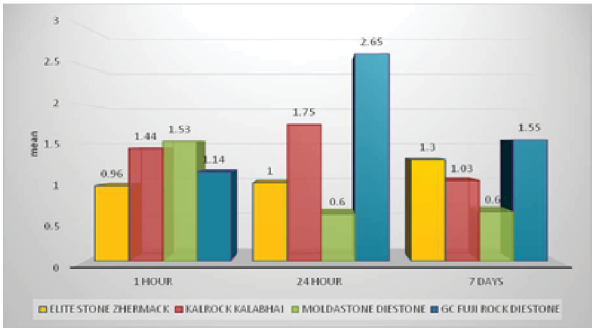


Graph 2: Comparison of TENSILE STENGTH means according to postpouring time and dental stone type

Table 4: Comparison of SURFACE ROUGHNESS (μm) means according to postpouring time and dental stone type

Duration	ELITE STONE ZHERMACK	KALROCK KALABHAI	MOLDASTONE DIESTONE	GC FUJI ROCK DIESTONE	P value
1 hour	0.96 (0.08)ab	1.44 (0.18)ac	1.53 (0.38)bd	1.14 (0.27)cd	<0.001**
24 hour	1.00 (0.27)ab	1.75 (0.38)acd	0.60 (0.23)ce	2.65 (0.97)bde	<0.001**
7 days	1.30 (0.27)ab	1.03 (0.31)ac	0.63 (0.20)bcd	1.55 (0.16)d	<0.001**

* Significant, **Highly significant One way ANOVA; Tukeys post hoc test analysis; Same alphabets indicate significant difference across groups



Graph 3: Comparison of SURFACE ROUGHNESS means according to postpouring time and dental stone type

Comparing the Surface roughness mean according to postpouring time and the brand of dental stone that was used. It was seen that according to one way ANOVA; Tukeys post hoc test analysis significant difference was seen across groups. The surface roughness was seen to be significant one hour, 24 hours and 7 days after pouring of the mold.It is said to be significant because the p value is<0.001. There was no much difference in significance when comparing the surface roughness of different brands of dental stone poured according to different postpouring time. From this it was also clear that maximum surface roughness was shown by GC Fujirock stone 24 hours after pouring and least roughness was shown by Moldastone 24 hours and 7 days after pouring.

DISCUSSION

Gypsum products ultimately serve the dental profession as one of the main materials used in dentistry. [8] Dental stone are characterized by its versatile use. This material has a relevant importance to produce precise die models that represent clinical situations extra orally. It makes easier the diagnosis, treatment plan and indirect dental work manufacture. [1] Popularity of type IV gypsum is attributed to its ease of use, relatively quick setting, and reasonable accuracy.[9] A crucial factor in the success of this process is having a model that is both accurate and possesses a smooth surface.[10] In dentistry, die is very relevant owing to its use in studying and working models.[1]

This in vitro study evaluated and compared influence of postpouring time of four different brands of Type IV dental stone on its surface roughness, compressive strength and diametric tensile strength.Progressively higher values of DTS and compressive strength were observed with increased postpouring times.[11] Differences in mechanical behavior were observed among the commercial dental stone brands tested (P<.05).A number of studies have been undertaken to evaluate the influence of postpouring time on the tensile strength, compressive strength and surface roughness of type IV dental stone

Rodrigues, Curtis and Bartlett conducted a study were lesser roughness for Fuji Rock, 0.94 μm was recorded. [12]De Cesero et al recorded a surface roughness value of 0.37μm which was lesser than the previous studies.[4] Rodriguez et al in his study found that dental stone showed statistically significant differences in roughness values (Ra, Rq, and Rt).

These differences were related to the color and transparency of the materials.He also found that the dental stone with the highest roughness values was also the darkest in color (SuperRockTM [NoritakeGypsumCo. Ltd.,Nagoya, Japan]) and MoonstoneTM (Bracon Ltd., Etchingham, England) showed the lowest roughness values.[13] Geastone and Bluejey conducted a study on the surface roughness of Zhermack and Zeus dental stone.It was seen that Zhermack showed higher surface roughness than Zeus.[8] This was explained on the basis of mixing time,water temperature and storage conditions that influenced the surface roughness of the material.[8]

In this study significant differences were observed in surface roughness among the four commercial brands and the postpouring time (P<.05). A significant difference in surface roughness was found between Fujirock specimen at one hour and 24 hours and a decrease in measurement was noted from 24 hours to 7days time interval.But no significant difference between 24 hours and 7days was noted for Moldastone. But the surface roughness decreased significantly between one hour and 24 hours.For Zhermack specimen there was no significant increase in surface roughness between one hour, 24 hours and 7 days, only a slight increase was noted. For Kalrock stone increase in surface roughness from one hour to 24 hours was noted but it decreased significantly as it reaches 7 days. The technology applied to obtain small, shaped particles, and the sources of hemihydrates (obtained naturally from gypsum or chemically) are possible explanations for the differences in the behavior observed.

The strength of dental gypsum products has always been expressed as a compressive or "crushing" strength. Almost all the reported work on this subject has involved compressive strength measurements only but in other cases tensile strength is of more importance. For example, when teeth fracture from a gypsum cast, they do so by failing in tension. Thus both tensile and compressive strength of gypsum are of practical significance. [14] Mahler et al reported an increase in compressive strength while stored in a drying atmosphere and reached their optimum condition after 2 weeks'after storage.[15] Jorgensen et al in their study found an increase in compressive strength with time. This was due to loss of excess water.[16]Cesero et al found that the compressive strength of dry specimens was approximately twice that obtained 1 hour after mixing.[17] 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. [18]

In this study, significant differences in compressive strength were noted among the 3 commercial brands at the times studied (P<.05). The greater the postpouring time, the greater the compressive strength of the dental stones measured. The compressive strength of elite stone Zhermack increased significantly from 24 hours to 7 days. There was a slight decrease in compressive strength for the Fuji rock specimen as the postpouring time increase which was not so significant. For the Moldastone specimen though there was a slight decrease in compressive strength 24 hours after the pouring of the mold, while the compressive strength significantly increased in 7 days. For Kalrock specimen there was a significant increase in compressive strength as the postpouring time increased. Casemiro, Hamida, Panzeri and Pires-de- Souza[19] have studied the compressive strength for Fuji Rook, 49.79 MPa (1 hour) and 59.59 MPa (24 hours) in comparison to 7.5 MPa and 7.15 MPa respectively.[20] The maximum compressive strength was shown by zhermack elite stone 7 days after pouring of the mold.

Azer et al observed an increase in the diametric tensile strength of Snap-Stone (Type IV) from 1 hour to 24 hours.[21] Hersek et al in their study found that the mean DTS values for different time intervals were 2.65, 2.73, and 2.89 MPa for 30, 60, and 120 minutes, respectively. The increase in values was significant (P=.04). The mean difference between the time intervals was significant when 30 and 120 minutes were compared (P=.01). [22] The mean difference between values at 30 and 60 minutes (P=.40) and between values at 60 and 120 minutes (P=.11) was nonsignificant. The mean DTS values for the dental stones were 2.42 MPa (Moldano), 2.54 MPa (Amberok), 2.82 MPa (Herastone), 2.84 MPa (Shera-Sockel), and 3.16 MPa (Fujirock).[40] Mori and Yamane found intercrystalline fracture and noted that strength depended on the amount of porosity present. They concluded that the strength of gypsum depended on establishing close contact between calcium sulfate dihydrate crystals. [23] Casemiro et al studied the diametric tensile strength of fuji rock at one hour and 24 hours and recorded 3.68 MPa after 1 hour and 3.88 MPa after 24 hours.[20] However in this study, DTS of 0.56Mpa after one hour and 1.02Mpa after 24 hours was recorded. Such differences might be explained by the methodology. The specimen sizes used were different in 3 studies The cross-head speed was different in 2 studies and the positioning of the specimens during testing was different from Hersek et al. [22] There is statistically significant difference in the diametric tensile strength between the commercial brands and in the different times studied (P<0.05). The greater the storage time after pouring, the greater was the strength but there was a slight decrease in strength for Moldastone and Fujirock specimen. The mean registered in this study for Fuji Rock at 1 hour (0.56 MPa) was less than that observed in the previous study (3.16 MPa).[22]

The mechanical properties of dental stone materials are influenced by several factors. [2] The water-to-powder ratio significantly affects compressive strength because water creates pores inside the material that weaken it because there are fewer crystals by volume. Longer mixing times have a negative influence on dental stone strength because the initial crystallization is disrupted and decreases crystal interlocking.[20] Mixing methods have no significant effects on DTS or compressive strength.[11] However, those variables were not studied because the tested materials were manipulated according to the manufacturers' specifications. Therefore, when using dental stone to produce casts, they should be manipulated at least 24 hours after pouring. At that time, the increased diametric tensile strength and compressive strength will minimize the risks of fracture, cracks, or abrasion. No clinically relevant differences in the surface roughness of the tested materials were observed among the times studied, and little variability was observed (0.96- 1.00 mm). Thus, the materials could be used at any of the times studied. Such variability can be partially explained by the different contractions and expansions of these materials.[24] Schwedhelm et al said that Type IV die stone materials can be removed at 12 hours with less risk of fracture than at ½ and 1 hour but do not benefit if removed at 24 hours.[25]

Within the limitations of this study, the use of additives to improve mechanical properties and variation in the powder-water ratios recommended by the manufacturer could have affected the results of this research. The lack of standardization of diametric tensile strength methodology in the literature makes it difficult to compare results. Studies should test other commercial brands of dental stone for their ability to reproduce detail, superficial hardness, and wear resistance. There are few studies comparing the effect of postpouring time on compressive strength diametric tensile strength and surface roughness of type IV dental stone.

CONCLUSION

- Compressive strength, tensile strength and surface roughness of Elite stone Zhermack specimen increases significantly with increase in postpouring time
- In kalrock specimen as the postporing time increases the tensile strength increases significantly but the surface roughness decreases significantly but the decrease in compressive strength of the material is negligible.
- In Moldastone specimen as the postpouring time increases the compressive and tensile strength increases but the surface roughness decreases significantly
- In Fuji rock sample the tensile strength and surface roughness increases with postpouring time but the compressive strength decreases.
- The maximum compressive strength was shown by Zhermack stone 7 days after pouring and least was shown by Moldastone 24 hours after pouring.
- The maximium tensile strength was shown by Kalrock specimen 7 days after pouring and least was shown by Moldastone 24 hours after pouring.
- The maximum surface roughness was shown by Fuji rock specimen 24 hours after pouring and least was shown by Moldastone 24 hours after pouring.
- The commercial brands used significantly effects the tensile strength, compressive strength and surface roughness of type IV dental stone used.
- This variation in tensile strength, compressive strength and surface roughness of type IV dental stone used in this study can be due to the effect of modifiers added by different manufacturers.

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