The influence of postpouring time on the roughness, compressive strength, and diametric tensile strength of dental stone

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Statement of problem. The optimum time after pouring a dental impression before removing the dental cast is unknown with regard to the strength and roughness of the stone. Setting times and the commercial products used are important variables.

Purpose. The purpose of this study was to evaluate the effect of postpouring time on the surface roughness, compressive strength, and diametric tensile strength of Type IV dental stone.

Material and methods. A total of 270 specimens were prepared from 3 commercial brands of dental stone (Durone, Fuji Rock, and Tuff Rock). Surface roughness, compressive strength, and diametric tensile strength were assessed at 1 hour, 24 hours, and 7 days after pouring. Specimens 6 mm in diameter and 3 mm in height were produced for roughness and diametric tensile strength tests. Specimens 3 mm in diameter and 6 mm in height were used to measure compressive strength. The results were analyzed with the general linear model and Tukey honestly significant difference test (α=.05).

Results. The surface roughness measured for the different types of dental stone tested varied from 0.3 μm (Durone, 1 hour) to 0.64 μm (Tuff Rock, 7 days). The diametric tensile strength ranged from 3.94 MPa (Tuff Rock, 1 hour) to 9.20 MPa (Durone, 7 days). The compressive strength varied from 26.67 MPa (Durone, 1 hour) to 65.14 MPa (Fuji Rock, 7 days).

Conclusions. Surface roughness (P=.005), diametric tensile strength (P=.001), and compressive strength (P=.001) increased significantly with time after pouring. The commercial brand used affected roughness (P=.001), diametric tensile strength (P=.004), and compressive strength (P=.001). Tuff Rock exhibited the highest surface roughness. The highest diametric tensile strength values were recorded for Durone and Fuji Rock. Fuji Rock exhibited the highest compressive strength. (J Prosthet Dent 2014;112:1573-1577)

Clinical Implications

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. The surface roughness of the tested materials exhibited no clinically relevant differences at the different times studied.

Dental stone is versatile and important for the production of precise casts that represent clinical situations. Dental stone facilitates the diagnosis, treatment planning, and fabrication of indirect dental restorations[1] and is the material most commonly used for preparing casts.[2-4] Many different types of cast materials exist and have different indications for use.[5,6] The criteria used to select the stone include its mechanical properties (such as, surface roughness),[7,8] diametric tensile strength (DTS),[2,9-11] compressive strength,[2,8,10] wear resistance,[11,12] surface hardness,[1,10,11] and ability to reproduce

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detail.[4,12] Research questions have persisted regarding the determination of the appropriate setting time in clinical and laboratory procedures because mechanical properties alter with time.[1-3,9-12] How 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 has not been established. Moreover, different commercial brands exhibit distinct mechanical behavior, manufacturing technologies, and cost. The purpose of this study was to evaluate the influence of postpouring time on the surface roughness, DTS, and compressive strength of Type IV dental stone. The null hypothesis tested was that postpouring time and commercial brand have no effect on the mechanical properties tested.

MATERIAL AND METHODS

Two hundred and seventy specimens were divided into groups based on 3 commercial brands (Durone, Fuji Rock, and Tuff Rock) (n=90). The specimens of each material then were subdivided according to test (surface roughness, DTS, and compressive strength) (n=30). The subgroups were further subdivided according to time after pouring (1 hour, 24 hours, and 7 days) (n=10). The materials used in the experiment are described in Table I, together with their manufacturers, classifications, and proportions. For surface roughness and DTS tests, cylindrical silicone (Express; 3M ESPE) molds (inner diameter 6 mm, height 3 mm) were used. The specimens used in the compressive strength tests were formed in cylindrical silicone molds (inner diameter 3 mm, height 6 mm).

The dental stone powder was weighed by using a digital scale (EC-301 SL; Gama), distilled water was measured with a 10-mL glass pipette (Satelit), and mechanical mixing was performed in a vacuum at 60 Hz (Polidental) according to the manufacturers' recommended time (Table I). The mixtures were poured under vibration in small amounts with the assistance of a no. 2 brush. Glass plates were placed under and on top of the mold to produce flat specimens. One hour after pouring, the specimens were removed from the casts. Thereafter, the specimens were analyzed with a stereoscopic microscope (×10 magnification; Caltex VZM-200; Caltex Scientific); those with voids and cracks were excluded from further analysis. The approved specimens were divided into 1-hour (n=10), 24-hour (n=10), and 7-day (n=10) groups.[10,13] The 1-hour specimens were tested immediately, and the 24-hour and 7-day specimens were stored at 25°C ±2°C. The surface roughness of each specimen was measured on a central diametric line established by using digital calipers. A reading 2.5 mm in length was made with a surface roughness tester (SJ 201; Mitutoyo). The surface roughness results were digitally recorded in micrometers.

After the reported storage times, the specimens were mounted in a universal testing machine (DL 2000; Emic) with a cross-head speed of 0.5 mm/min and a 500-N load cell. The compression test was performed according to the American National Standards Institute/American Dental Association Specification no. 25 for dental stone.[14] After the reported postpouring time, each specimen was mounted in the universal testing machine with a cross-head speed of 1 mm/min and a 2000-N load cell. The data were tabulated and analyzed with software (Statistical Package for the Social Sciences Version 13.0 for Windows; SPSS Inc). The mean (standard deviation) of surface roughness, DTS, and compressive strength were recorded for Durone, Fuji Rock, and Tuff Rock at 1 hour, 24 hours, and 7 days after pouring (Tables II-IV). The data were compared with the multivariate general linear model and the Tukey honestly significant difference (HSD) test (α=.05). The postpouring time (1 hour, 24 hours, and 7 days) and dental stone brand (Durone, Fuji

TABLE I. Description of materials used

Product	Manufacturer	Type	Batch No.	Powder-Water Ratio (g/mL)	Mixing Time (s)
Durone	Dentsply Intl	Mineral	2188178	100/19	40
Fuji Rock	GC Europe	Synthetic	B-3001	100/20	30
Tuff Rock	Talladium	Synthetic	0325111	100/21	40

TABLE II. Comparison of surface roughness means according to postpouring time and dental stone type

Material	Time	Surface Roughness (μm) (mean [SD])
Durone	1 h	0.30 ±0.08^{c}
	24 h	0.48 ±0.11^{b}
	7 d	0.4 ±0.09^{bc}
Fuji Rock	1 h	0.38 ±0.11^{bc}
	24 h	0.36 ±0.09^{bc}
	7 d	0.37 ±0.08^{bc}
Tuff Rock	1 h	0.48 ±0.07^{b}
	24 h	0.48 ±0.05^{b}
	7 d	0.64 ±0.15^{a}

SD, standard deviation.
Values with different superscript letters are significantly different ($P<.05$).

Table III. Comparison of diametric tensile strength means according to postpouring time and dental stone type

Material	Time	Diametric Tensile Strength (MPa) (mean [SD])
Durone	1 h	5.82 ±0.81^{bcd}
	24 h	8.01 ±2.31^{ab}
	7 d	9.20 ±2.71^{a}
Fuji Rock	1 h	5.13 ±0.85^{cd}
	24 h	7.60 ±2.07^{ab}
	7 d	8.59 ±1.49^{a}
Tuff Rock	1 h	3.94 ±0.99^{d}
	24 h	7.09 ±0.97^{abc}
	7 d	7.70 ±1.32^{ab}

SD, standard deviation.
Values with different superscript letters are significantly different ($P<.05$).

Table IV. Comparison of compressive strength means according to postpouring time and dental stone type

Material	Time	Compressive strength (MPa) (mean [SD])
Durone	1 h	26.67 ±7.14^{f}
	24 h	43.79 ±8.89^{cd}
	7 d	56.44 ±14.19^{ab}
Fuji Rock	1 h	43.45 ±4.44^{cd}
	24 h	61.66 ±8.22^{ab}
	7 d	65.14 ±10.35^{a}
Tuff Rock	1 h	30.84 ±3.81^{ef}
	24 h	40.12 ±5.75^{de}
	7 d	52.57 ±8.65^{bc}

SD, standard deviation.
Values with different superscript letters are significantly different ($P<.05$).

Table V. Surface roughness, diametric tensile strength, and compressive strength means according to postpouring time

Postpouring Time	Surface Roughness (μm)	Diametric Tensile Strength (MPa)	Compressive Strength (MPa)
1 h	0.39^{b}	4.96^{b}	33.65^{c}
24 h	0.44^{ab}	7.57^{a}	48.52^{b}
7 d	0.47^{a}	8.50^{a}	58.05^{a}

Values with different superscript letters are significantly different ($P<.05$).

Rock, and Tuff Rock) were established as fixed factors, and the mechanical test (surface roughness, DTS, and compressive strength) was the dependent variable.

RESULTS

Significant differences with regard to the postpouring time were found for surface roughness ($P=.005$), DTS ($P=.001$), and compressive strength ($P=.001$). In addition, the dental stone brand significantly affected roughness ($P=.001$), DTS ($P=.004$), and compression ($P=.001$). The means and results of the Tukey HSD multiple comparison analysis are presented in Tables V and VI. The mean surface roughness registered for the different dental stone brands ranged from 0.3 μm (Durone, 1 hour) to 0.64 μm (Tuff Rock, 7 days). When the data were submitted to ANOVA and the Tukey HSD test, statistically significant differences were observed among the tested materials and times ($P<.05$) (Table II). The mean DTS values measured for the various brands ranged from 3.94 MPa (Tuff Rock, 1 hour) to 9.20 MPa (Durone, 7 days). When the data were submitted to ANOVA and the Tukey HSD test, significant differences were observed among the tested materials and times ($P<.05$) (Table III). The mean compressive strengths of the various dental stone brands ranged from 26.67 MPa (Durone, 1 hour) to 65.14 MPa (Fuji Rock, 7 days). When the data were submitted to ANOVA and the Tukey HSD test, significant differences were observed among the tested materials and times ($P<.05$) (Table IV).

DISCUSSION

The null hypothesis was rejected. The postpouring time significantly affected the mechanical properties of dental stone ($P<.05$). Progressively higher values of DTS[9,10] and compressive strength were observed with increased postpouring times.[10] Differences in mechanical behavior were observed among the commercial dental stone brands tested ($P<.05$). Significant differences were observed in surface roughness among the 3 commercial brands and the postpouring times studied ($P<.05$). Rodrigues et al[7] measured a higher roughness for Fuji Rock (0.94 μm) than that measured in this study (0.37 μm). A significant difference in roughness was found between Durone specimens at 1 hour and at 24 hours; however, the

TABLE VI. Surface roughness, diametric tensile strength, and compressive strength means according to dental stone type

Product	Surface Roughness (μm)	Diametric Tensile Strength (MPa)	Compressive Strength (MPa)
Durone	0.39[b]	7.68[a]	42.30[b]
Fuji Rock	0.37[b]	7.11[ab]	56.75[a]
Tuff Rock	0.53[a]	6.24[b]	41.17[b]

Values with different superscript letters are significantly different ($P<.05$).

difference was not significant between 24 hours and 7 days. Soares and Ueti,[8] when studying Vel-Mix (Type IV dental stone), recorded a mean of 0.73 μm after 24 hours, different from the value of 0.48 μm measured in this study. For Tuff Rock, no significant difference was noted between 1 and 24 hours; however, there was a significant difference between 24 hours and 7 days. The surface roughness of Fuji Rock dental stone was not affected by time. 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.

DTS differed significantly depending on the commercial brand and the time studied ($P<.05$). The greater the storage time after pouring, the greater the strength that was measured. Azer et al[10] observed an increase in the DTS of Snap-Stone plaster (Type IV) from 1 hour to 24 hours. The mean registered in this study for Fuji Rock at 1 hour (5.13 MPa) was greater than that observed in the previous study (3.16 MPa).[9] Casemiro et al[2] studied the DTS of Fuji Rock and Tuff Rock at 1 hour and 24 hours and recorded 3.86 MPa after 1 hour and 3.88 MPa after 24 hours. The values that the authors obtained for Fuji Rock were 3.68 MPa after 1 hour and 3.88 MPa after 24 hours,[2] different from 5.13 ±0.85 MPa and 7.60 ±2.07 MPa, respectively, recorded at the same time points in this study. For Tuff Rock, Casemiro et al[2] obtained means of 3.07 MPa and 3.26 MPa after 1 and 24 hours, respectively, compared with 3.94 ±0.99 MPa and 7.09 ±0.97 MPa, respectively, as observed in this study. Such differences might be explained by the methodology. The specimen sizes used were different in 3 studies (40×20 mm,[2] 10×60 mm,[9] and 12.5×25 mm[10]), the cross-head speed was different in 2 studies (5 mm/min)[2,9] and the positioning of the specimens during testing was different from Hersek et al.[9]

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 strength of dry specimens was approximately twice that obtained 1 hour after mixing.[11] Similar behavior also was observed in this study (Durone at 1 hour exhibited a strength of 26.6 MPa compared with 56.4 MPa at 7 days). An increase in compressive strength between 1 hour and 24 hours was observed in a previous study of Snap Stone (a Type IV dental stone).[10] Abdullah[4] obtained a compressive strength of 38.27 MPa for Excalibur (Type IV) at 24 hours, and Soares and Ueti[8] obtained a compressive strength of 51.93 MPa for Vel-Mix (Type IV), similar to the strength obtained here for Durone of 43.79 ±8.89 MPa. Casemiro et al[2] studied the compressive strength of Fuji Rock and Tuff Rock, and recorded results similar to those obtained in this study: 49.79 MPa (1 hour) and 59.59 MPa (24 hours) compared with 43.45 ±4.44 MPa and 61.66 ±8.22 MPa for Fuji Rock, and 29.30 MPa (1 hour) and 39.64 MPa (24 hours) compared with 30.84 ±3.81 MPa and 40.12 ±5.75 MPa for Tuff Rock. For Durone, compressive strength increased from 1 hour to 24 hours and from 24 hours to 7 days ($P<.05$). A significant increase was observed for Fuji Rock from 1 hour to 24 hours; however, the difference between 24 hours and 7 days was not significant. Tuff Rock dental stone had no increase in compressive strength from 1 hour to 24 hours; however, compressive strength increased significantly from 24 hours to 7 days. These results were similar to those of previous studies because of the use of the standard American Dental Association methodology.[14]

The mechanical properties of dental stone materials are influenced by several factors. The water-to-powder ratio significantly affects compressive strength[5] 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.[2] Mixing methods have no significant effects on DTS or compressive strength.[10] 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 DTS 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 (0.30-0.64 μm). 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.[15]

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 DTS 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.

CONCLUSIONS

Based on the results obtained and the statistical analysis used, the following conclusions were drawn. A significant increase in surface roughness (P=.005), DTS (P=.001), and compression (P=.001) exists in relation to the postpouring time. The commercial brand used significantly affected surface roughness (P=.001), DTS (P=.004), and compression (P=.001). Tuff Rock dental stone exhibited the highest roughness, Durone and Fuji Rock exhibited the highest DTS, and Fuji Rock exhibited the highest compressive strength.

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