

# The effects of drying techniques on the compressive strength of gypsum products

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## ABSTRACT

Excess water in set dental stone decreases its strength. So different methods were used to expel excess water but the compressive strength may be affected by drying technique. The purpose of this study was to evaluate the compressive strength of two types of set dental stone after air, conventional oven and microwave drying techniques.

A total of 60 stone specimens (30 specimens made from Silky Rock stone and 30 Zeta stone) were prepared by the aid of an acrylic split mold according to ADA Specification No. 25. Specimens were divided into six groups of 10 identical specimens for each. Then groups were either dried by air, conventional oven or microwave oven. Using Unconfined Compression Machine, the specimens were loaded by a cross head speed of 1 mm/minute till the specimen being fractured. The load required to fracture the stone specimens was recorded and analyzed using analysis of variance followed by Duncan's Multiple Range Test for the statistical comparisons between drying techniques at a significance level of  $p \leq 0.05$ , and Student's t-test was used to compare between the two stone types.

The results revealed that high significant differences were present between the different drying techniques ( $p < 0.0001$ ) with air dried specimens were significantly stronger than others and microwave dried specimens were significantly stronger than conventional oven dried specimens. Silky Rock (type IV) stone was significantly stronger than Zeta (type III) stone ( $p < 0.001$ ).

From this study, it could be concluded that the highest compressive strength can be obtained by air drying of the stone for 24 hours, while microwave drying technique give better results than conventional oven drying technique with the advantage of time saving over the two other drying techniques.

**Key Words:** Compressive strength, dental stone, microwave drying.

Hasan RH, Mohammad KA. The effects of drying techniques on the compressive strength of gypsum products. *Al-Rafidain Dent J.* 2005; 5(1): 63-68.

**Received:**  
27/10/2004

**Sent to Referees:**  
1/11/2004

**Accepted for Publication:**  
20/2/2005

## INTRODUCTION

Although they are not directly used as dental restorative materials, gypsum products are important adjunctive materials used

in many laboratory procedures.<sup>(1)</sup> The working model (cast) is a replica of oral structures on which an appliance or restoration is made. So it must possess enough st-

length and abrasion resistance as it will be subjected to the stresses of carving and finishing procedures.<sup>(2)</sup> A type III dental stone and high strength dental stones are able to withstand most of the manipulative procedures involved in production of appliances and restorations.<sup>(3)</sup> Gypsum products when mixed with water set to form hard mass, the actual amount of water required for mixing is greater than the amount necessary for the chemical reaction. So the water that remains after the completion of the chemical reaction is called excess water which definitely affect the strength of set product as when specimen has been dried the dry strength may be two or more time the wet strength.<sup>(3,4)</sup>

The one hour after mixing compressive strength is a measure of wet strength, while gypsum may take as long as 7 days to dry. For practical purposes, stone casts would reach sufficient hardness after 24 hours.<sup>(5)</sup> There is no improvement in abrasion resistance between 24 hours and 7 days air dryness.<sup>(6)</sup>

Stone manufacturers advised to wait 24–48 hours before manipulating gypsum casts. However, sometimes it may be inconvenient to wait such a long time, dentist often find it necessary to manipulate the cast as soon as possible after they poured. Unfortunately, these wet casts possess insufficient strength and surface hardness to withstand the manipulative procedures without being fractured or distorted.<sup>(2)</sup>

Conventional hot air oven and microwave oven had been used in an attempt to shorten the drying time. Although drying gypsum products in a microwave oven can save considerable time, however there are little researches on the strength of gypsum material dried in this manner.<sup>(2)</sup> Therefore, it was the objective of this study to evaluate the compressive strength of different dental stones using air, conventional oven and microwave oven drying techniques.

## MATERIALS AND METHODS

In this study, an acrylic split mold (Figure 1) was designed and constructed for the purpose of the preparation of a stone samples with 40 mm height and 20 mm

diameter in accordance to ADA Specification No. 25<sup>(7)</sup> for dental gypsum products.

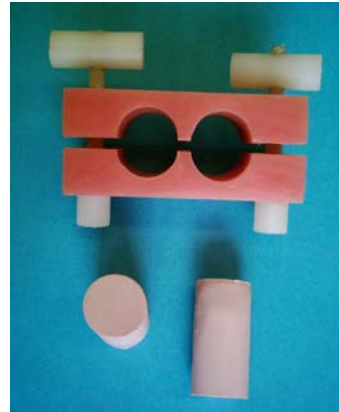


Figure (1): The acrylic split mold with two stone cylindrical samples

Regarding preparation of the acrylic split mold, two metal cylinders (with 40 mm height and 20 mm diameter) were prepared using computerized milling machine. A metal box–shape container with dimensions of 40 mm height, 50 mm width and 80 mm length (without roof and floor) was made. The metal cylinders and the metal box were painted with a thin layer of Vaseline separating material to permit easy separation of the wax pattern. The metal box then fixed on a glass slab and the two metal cylinders were also fixed vertically on the glass slab inside the metal box with a same longitudinal line at the middle of the metal box. Dental wax (TP Regular, Major, Italy) was melted in a thermostatically controlled bath machine (KAVO GmbH, Germany) at 65°C, then poured in the metal box around the metal cylinders until the box completely filled with wax. Then another glass slab was put on the top surface of the box immediately after wax pouring before hardening to ensure smooth and flat surface of the wax pattern.

After hardening of the wax, the wax pattern easily separated from the metal box, and the two metal cylinders also separated from the wax pattern. By using dissecting knife, the wax pattern was bisected longitudinally into two identical parts to produce wax pattern of a split mold. The two “wax” parts of the split mold were flaked, wax eliminated and packed with heat cured acrylic resin

(Major Base 2, Major, Italy) and cured according to manufacturer's instructions. Then two holes were drilled transversely (one at each side of the acrylic split mold) permitting the fixation of the two parts together by the aid of two Teflon (Trademark, Bayer, Germany) made screws and nuts to ensure correct alignment of the mold parts throughout the process of stone pouring.

Two types of dental stone, Silky Rock (Whip mix, Louis Ville, Kentucky, USA) and Zeta (Industria Zingardi, Italy) were evaluated for the effect of drying technique on the compressive strength. The stone types and their powder/liquid ratios as recommended by their manufacturers are listed in Table (1).

Table (1): The tested dental stones and their powder/liquid ratios

| Product    | Type | Powder/Water Ratio gm/ml | Batch No. | Manufacturer                               |
|------------|------|--------------------------|-----------|--|
| Silky Rock | IV   | 100/23                   | 7546      | Whip mix,<br>Louis Ville,<br>Kentucky, USA |
| Zeta       | III  | 100/31                   | GSGIA0701 | Industria Zingardi,<br>Italy               |

The recommended powder was added to the water in a rubber bowl and hand-mixed for 1 minute to a smooth consistency.<sup>(4)</sup> To reduce porosity, the dental stone was placed on dental vibrator (BEGO, Germany) for 30 seconds to expel air bubbles from the slurry. The assembled acrylic mold was placed on glass slab and the mixed stone was poured into the acrylic mold. Vibrator was used during pouring to get rid of air bubble incorporation within the poured stone. Immediately after pouring, another glass slab was placed at the top surface of the mold in order to get flat and parallel ends. After 20 minutes, the glass slabs were removed and the mold was disassembled carefully and the stone cylinders were easily separated from the mold (Figure 1).

A total of 60 cylindrical stone samples were prepared, 30 samples from each stone type, 10 samples were used for each dryness method.

For air dried groups, the samples were left to be dried in air at  $20 \pm 2$  °C for 24 hours before testing. For conventional oven drying, 50 minutes after pouring they were placed in the oven (Memmert S 25, Germany) at 200 °F for 1 hour.<sup>(8)</sup> While for microwave drying method, 50 minutes after pouring the samples were placed in the microwave oven (Panasonic NN-GX 36 WF, Matsushita Electric Industrial Co, Ltd)

for 15 minutes at 80 watts.<sup>(9, 10)</sup> A beaker with 400 ml of water was placed in the microwave oven as a heat sink when samples were microwaved to protect the magnetron of the oven.<sup>(11)</sup>

Testing then was employed by an Unconfined Compression Machine (Inc, Model CN 472, EVANSTON III-USA), with 2000 Kg proving ring at a cross head speed of 1 mm/minute (Figure 2), and maximum reading before the sample being failed or fractured was recorded and divided by 3.14 which is the surface area of the stone cylinder base and top that is subjected to the testing force (load in Kg/surface area in cm<sup>2</sup>), and the resultant value representing the compressive strength of that sample in Kg/cm<sup>2</sup>.

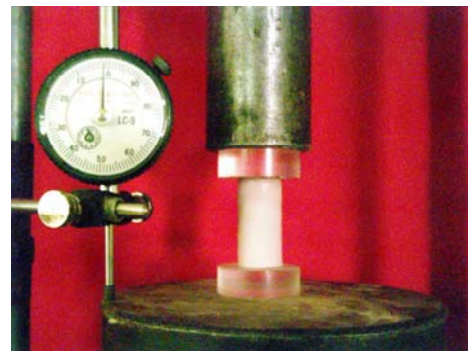


Figure (2): Loading the stone sample by the Unconfined Compression Machine

The data were statistically analyzed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test to compare between drying techniques, and Student's t-test was used to compare between the two stone types.

**RESULTS**

The mean and standard deviation of the load required to produce failure for each tested group were calculated and listed in Table (2).

Table (2): The mean and standard deviation for the compressive strength of the tested groups

| Tested Groups                      | N  | Mean (Kg/cm <sup>2</sup> ) ± SD |
|------------------------------------|----|---------------------------------|
| Air Dried Silky Rock               | 10 | 465 ± 38                        |
| Air Dried Zeta                     | 10 | 396 ± 69                        |
| Conventional Oven Dried Silky Rock | 10 | 195 ± 27                        |
| Conventional Oven Dried Zeta       | 10 | 161 ± 47                        |
| Microwave Oven Dried Silky Rock    | 10 | 364 ± 62                        |
| Microwave Oven Dried Zeta          | 10 | 243 ± 20                        |

N: Number of specimens; SD: Standard deviation.

For the effects of drying techniques, ANOVA indicated that there were high significant differences among groups ( $p < 0.0001$ ). Duncan's Multiple Range Test indicated that air dried stone specimens ( $431 \pm 64$  Kg/cm<sup>2</sup>) was significantly more resistant to compressive loading than other groups. Microwave dried stone specimens ( $303 \pm 77$  Kg/cm<sup>2</sup>) was significantly stronger than conventional oven dried stone sp-

ecimens ( $178 \pm 40$  Kg/cm<sup>2</sup>) as shown in Table (3) and Figure (3).

Student's t-test was used to compare between the two stone types, and indicated that Silky Rock stone specimens ( $341 \pm 122$  Kg/cm<sup>2</sup>) possessed significantly higher compressive strength ( $p < 0.001$ ) than Zeta specimens ( $267 \pm 111$  Kg/cm<sup>2</sup>) as shown in Table (4).

Table (3): Analysis of variance and Duncan's Multiple Range Test for the effect of curing technique on the compressive strength of dental stone

| Source         | df | SS         | MS        | F-value | P-value |
|----------------|----|------------|-----------|---------|---------|
| Between groups | 5  | 443500.139 | 88700.028 | 39.961  | 0.000   |
| Within groups  | 54 | 66589.500  | 2219.650  |         |         |
| Total          | 59 | 510089.639 |           |         |         |

df: Degree of freedom, SS: Sum of squares, MS: Mean square.

| Drying Technique         | N  | Mean (Kg/cm <sup>2</sup> ) ±SD | Duncan's Grouping |
|--------------------------|----|--------------------------------|-------------------|
| Air Drying               | 20 | 431 ± 64                       | A                 |
| Conventional Oven Drying | 20 | 178 ± 40                       | C                 |
| Microwave Drying         | 20 | 303 ± 77                       | B                 |

N: Number of specimens; SD: Standard deviation.

Groups that have similar letters are not significantly different from each other.

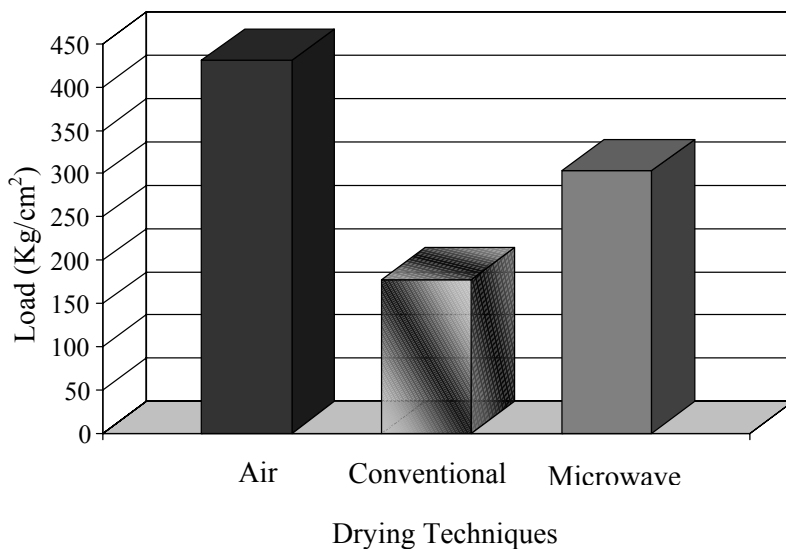


Figure (3): The effect of drying technique on the compressive strength of dental stone  
Columns with the same color are not significantly different

Table (4): Mean, standard deviation and Student’s t-test for compressive strength of Silky Rock and Zeta type stones

| Stone Type | N  | Mean (Kg/cm <sup>2</sup> ) ± SD | t-value | Significance |
|------------|----|---------------------------------|---------|--------------|
| Silky Rock | 30 | 341 ± 122                       | 4.2     | 0.001        |
| Zeta       | 30 | 267 ± 111                       |         |              |

N: Number of specimens; SD: Standard deviation

### DISCUSSION

To be clinically useful, gypsum materials should possess high compressive strength and fracture and abrasion resistance.<sup>(9, 12)</sup> Generally, the compressive strength of gypsum products is related to the water/powder ratio, mixing time, free water content in set product, volume of mixture, chemical composition, relative humidity, room temperature at which the material is stored and elapsed time after the cast is poured.<sup>(13)</sup>

The results of the present study showed that air dried samples were significantly more resistant to compressive loading than those which were dried by microwave technique. These findings were in contrast with other studies that reported microwave dried samples had significantly more compressive strength than those dried by air.<sup>(2,9)</sup> The scientific cause for such differences in results is the variation in elapsed time after the sample was poured, where in the present study compressive strength test was conducted after 24 hours drying at ro-

om temperature this allow significant time to expel the excess water, while in the other studies<sup>(2, 9)</sup> test was conducted after 2 hours where some excess water present and that may reduce the compressive strength.

On other hand, microwave drying technique showed initial benefits due to reduced processing times for 15 minutes at 80 watts. Microwaving is energy conversion and not conduction heating as in a conventional oven.<sup>(12, 13)</sup> Microwave absorbent materials such as dental gypsum convert this energy into endothermic heat with short time. Also, other studies recommended using of lower power level, as using of high power level may lead to decrease in compressive strength.<sup>(9, 10, 12)</sup>

The results of this study showed that using of conventional oven for drying of gypsum product for 1 hour give samples with significantly lower compressive strength than other two techniques. The possible explanation is the temperature inside conventional oven elevated rapidly and not

gradually. This will lead to rapid boiling of the free water and rapid water escapement from dental stone causing holes and cracks inside the stone and decreasing the compressive strength. Also such heat may attack the water of crystallization which would reduce the strength instead of increasing it.<sup>(9, 12)</sup>

The results of this study also showed that using of different drying techniques didn't affect the mechanical properties of dental stone IV, where Silky Rock (type IV dental stone) showed significantly more compressive strength than Zeta (type III dental stone), as Silky Rock contains an  $\alpha$ -hemihydrate of the Densite type, cuboidal shape particles and the reduced surface area produce dental stone with high mechanical properties.<sup>(13)</sup>

### CONCLUSIONS

From the results of this study it could be concluded that when maximum compressive strength is needed, the cast should be left to be dry by air for 24 hours before dealing with it. When time saving is of great importance, microwave oven could be used for drying of cast for 15 minutes and dealing with it instead of waiting for 24 hours to be dried by air. Also, conventional oven couldn't be used for stone drying as it reduces the compressive strength. Finally, Silky Rock (type IV) has more compressive strength than Zeta (type III) using whatever the drying technique is used.

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