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Effect of mixing methods on the physical properties of dental stones[☆]

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ABSTRACT

Objectives: This in vitro comparative study evaluated the effect of different stone mixing methods on material properties of four dental stones. Two ADA type IV stones (Silky-Rock and Snap-Stone), one type V high expansion stone (Die Keen), and one recently introduced type V specialty stone (HandiMix) were chosen for this study.

Methods: Forty cylindrical specimens (25 mm × 12.5 mm) were cast for each of the nine stone sub-groups and bench dried at 23 ± 2 °C for 1 and 24 h. Specimens were then tested in an Instron in tensile and compression modes at crosshead speeds of 0.5 and 1.0 mm/min, respectively. Four rectangular-shaped specimens (30 mm × 15 mm × 15 mm) of each stone type were cast and bench dried for 48 h. Knoop microhardness measurements were obtained from defined areas on each specimen for surface hardness testing using 200 g load and 20 s dwell time. A 12.6 mm^2 area was then delimited in the center of two sides of each specimen and photographed under low power magnification (40×). The average pore number per area was then determined for each specimen for surface porosity testing. The setting time and setting expansion for each stone type was recorded as well.

Results: ANOVA ($P < 0.001$) and Ryan–Einot–Gabriel–Welsh test ($P < 0.05$) showed significant differences between diametral tensile strengths and pore numbers for both stone types and mixing methods.

Conclusion: Within the limitations of this study, the newly introduced mixing method did not appear to have an effect on the physical properties of HandiMix stone.

1. Introduction

Dental casts and die materials, especially for fixed prosthodontic procedures, are required to accurately reproduce the impressions they are made from, providing all the fine details, in addition to being dimensionally stable and resistant to abrasion.[1,2]

Several materials that closely fulfill these requirements have been used to fabricate dies. Among these products are dental stone, epoxy resin, as well as dies electroplated with metals like copper and silver.[3–6] Additionally, a blend of stone and investment material has been proposed to fabricate refractory dies.[7]

Improved dental stones, however, have been by far the most popular in fabricating working casts and removable dies, because of their reasonable cost, ease of manipulation, and ability to produce consistent results, especially high strength/high expansion (ADA type V) stone.[2,8,9] These products are commonly mixed either by hand or mechanically under vacuum. Recently, a new type V stone product, HandiMix

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(Whip Mix Corp. Louisville, KY) was introduced to the market. This material is hand mixed by shaking the pre-weighed powder and liquid for 20 s in a supplied disposable plastic container. The stone is then poured into the impression without the use of additional equipment.

The dimensional accuracy of cast and die materials has been the subject of several in vitro investigations over the past decade, with some conflicting findings. Chaffee et al.[10] reported that improved dental stone provided a similar degree of dimensional accuracy in reproducing a complete arch when compared to epoxy resin. However, other investigators found that epoxy resin exhibited considerable shrinkage compare to gypsum products, and suggested that technique modifications were required to obtain castings that would adapt to tooth preparations if epoxy resin were to be used as die material.[9,11] Heshmati et al.[12] measured the linear expansion of 6 ADA types IV and V improved dental stone materials and reported that all stone products showed higher mean linear expansion values at 120 h compared to 2 h (ADA recommendation).

Other major desirable characteristics of die materials include surface hardness and abrasion resistance. Ghahremannezhad et al.[13] reported that applying one coat of cyanoacrylate adhesive as a die hardener to type IV dental stone increased the surface hardness by 150% and the abrasion resistance by 48%. In addition, the application of surface hardeners was shown to create a less porous gypsum surface.[8] Other investigators however, found that die hardeners reduced the surface hardness of gypsum die stones.[14] Furthermore, no significant difference concerning surface abrasion and wear resistance was found when conventional type IV dental stone was compared to resin-impregnated type IV stone.[15]

The compressive and tensile strengths have been the most common laboratory testing modalities to characterize mechanical and physical properties of dental stone.[16] Jørgensen and Kono[17] showed that vacuum mixing increased the compressive strength of dental stone by 20% owing to reduced gypsum porosity. Some authors reported that the diametral tensile strength of type IV stone increased when allowed to dry in a microwave oven compared to bench top,[18] whereas, others found that the microwave drying method reduced the compressive strength of type IV stone.[19]

The aim of this in vitro study was to evaluate the influence of the various mixing techniques on some physical properties of dental stone, as well as to compare the newly introduced HandiMix stone to three other commercially available dental stones. The null hypothesis was that the physical properties of dental stone would not be affected by the mixing method utilized.

2. Materials and methods

Whip Mix Corporation, Louisville, KY 40209, USA and Heraeus Kulzer, Inc., Armonk, NY 10504, USA supplied the four stone materials used in this study. Material testing and evaluation were done according to the American National Standards Institute/American Dental Association (ANSI/ADA) standards, specification #25 for dental gypsum products.[20] The materials were divided into nine groups according to the method of mixing (Table 1). HandiMix is a new dental stone product that has been recently introduced to the market. This material is hand mixed by shaking the supplied pre-measured powder and liquid in a special disposable plastic container for 20 s. The fast set stone can be separated from the impression after 10 min.

2.1. *Compressive and diametral tensile strength testing*

For each of the nine study groups, 40 stone cylindrical specimens (25.0 mm in length and 12.5 mm in diameter)[16] were fabricated for a total of 360 cylinders. All materials were mixed by the same investigator for standardization purposes, and poured in a special split-metal mold to obtain the desired dimensions. Additionally, HandiMix stone was shake-mixed for 20 s according to the manufacturer's directions.

2.1.1. *Compressive strength*

For each stone group, 20 cylinders were tested in compression in a Universal Testing Machine (Instron 4204, Canton, MA) in open air under 1000 kg (10 kN) load at 1.0 mm/min crosshead speed until fracture. Ten cylinders were tested after 1 h, and 10 after 24 h from the setting time. Compressive strength testing was done on the height of the cylinders with moist filter paper padding 0.5-mm thick placed between the specimens and the loading platens. Compressive strength (C) values were calculated by the formula $C = P/\pi r^2$, where P is the load to failure and r is the specimen radius.[16,18,19]

2.1.2. *Diametral tensile strength*

The same setup for each stone group was used; 20 cylinders were tested in tension in the Instron Universal Testing Machine in open air under 1000 kg (10 kN) load at 0.5 mm/

Table 1 – Materials used in the study

Material	Mixing method	Abbreviation	Batch #	Manufacturer
Die Keen (DK)	Vacuum	DKV	0606151	Heraeus Kulzer, Inc.
	Hand	DKH		
Silky-Rock (SR)	Vacuum	SRV	085080602	Whip Mix Corp.
	Hand	SRH		
Snap-Stone (SS)	Vacuum	SSV	062060503	
	Hand	SSH		
HandiMix (HM)	Vacuum	HMV	P: 21070601 L: 06131 AF	
	Hand	HMH		
	Shake	HMS		